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ifo Beiträge zur Wirtschaftsforschung

Five Essays on International Trade, Factor Flows, and the Gains from Globalization

Inga Heiland



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Preface

This volume was prepared by Inga Heiland while she was working at the Ifo Institute. It was completed in July 2016 and accepted as a doctoral thesis by the Department of Economics at the University of Munich. It comprises five chapters addressing one or more aspects of international trade and factor movements, including trade in goods, trade in value added, international movement of labor and capital, and trade in risk. All chapters aim to contribute to our understanding of the economic gains from globalization in its various forms. Thereby, they touch more or less explicitly on the issues of the determinants of the pattern of trade, factor flows, and production, as well as the role of barriers to the international exchange of goods and factors. From a methodological point of view, all chapters share a strong emphasis on general equilibrium analysis, and those chapters that are accompanied by an empirical analysis rely primarily on structural estimation.

Chapters 1 and 2 are concerned with the interaction of goods and factor markets in determining the pattern of trade and factor movements and in shaping the welfare effects of globalization. Chapter 1 addresses trade in goods and capital flows. It analyzes the role that cross-border trade in goods and assets play in sharing risk among countries, and it describes how the pattern of these flows is jointly determined as an outcome of individual decisions taken by investors maximizing utility and firms maximizing shareholder value. In Chapter 2 the focus lies on the interplay between trade and labor markets. In a purely theoretical analysis, well-established results on the gains from trade derived from models with product differentiation are revisited in a framework that includes skill differentiation in the labor force. Chapters 3, 4, and 5 are concerned with the quantification of the gains from trade liberalization. The analyses build on and extend current work in the fields of the "New Quantitative Trade Theory" (NQTT). Chapter 3 analyzes the effects of trade liberalization in the presence of globally fragmented production chains. Chapter 4 builds on and extends the model framework used in Chapter 3 to quantify the global effects of the Transatlantic Trade and Investment Partnership (TTIP), which is the subject of current negotiations between the United States and the European Union. Chapter 5 aims for a methodological contribution to the NQTT. It discusses the implications of parameter uncertainty for model-based counterfactual analysis with estimated structural parameters.

 Keywords: International Trade, International Investment, Asset Pricing, Structural Gravity, Two-way Migration, Heterogeneous Workers, Trade in Value Added, Production Networks, China's WTO entry, Preferential Trade Agreements, TTIP, Bootstrap

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I am grateful to Wilhelm Kohler for the fruitful collaboration in joint projects. I would also like to thank him for his passionate teaching of international economics at the University of Tuebingen, that I had the opportunity to enjoy in the early stages of my academic life, and which opened up the path to academic research for me. A significant part of my dissertation research evolved out of joint work with Rahel Aichele, whom I would like to thank for the great ideas and effort that went into our joint projects.

During my time at Ifo, I benefited greatly from scholarly advice and personal support of many colleagues, fellow PhD students, and administrative staff. Special thanks go to Sybille Lehwald, Erdal Yalcin, Michele Battisti, Christiane Harms, and Anna Gumpert, although many more would deserve to be mentioned. Moreover, I am thankful for Jan Heiland's advice on tough math and programming problems. Finally, I am inexpressibly grateful for my family's and my partner's unconditional love and support at all times.

Five Essays on International Trade, Factor Flows, and the Gains from Globalization

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vorgelegt von Inga Heiland

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This dissertation consists of a collection of articles on international trade and factor flows. It comprises five chapters addressing one or more aspects of international trade and factor movements, including trade in goods, trade in value added, international movement of labor and capital, and trade in risk. All chapters aim to contribute to our understanding of the economic gains from globalization in its various forms. Thereby, they touch more or less explicitly on the issues of the determinants of the pattern of trade, factor flows, and production, as well as the role of barriers to the international exchange of goods and factors. From a methodological point of view, all chapters share a strong emphasis on general equilibrium analysis, and those chapters that are accompanied by an empirical analysis rely primarily on structural estimation.

Chapters 1 and 2 are concerned with the interaction of goods and factor markets in determining the pattern of trade and factor movements and in shaping the welfare effects of globalization. Chapter 1 addresses trade in goods and capital flows. I analyze the role that cross-border trade in goods and assets play in sharing risk among countries, and I describe how the pattern of these flows is jointly determined as an outcome of individual decisions taken by investors maximizing utility and firms maximizing shareholder value. An empirical analysis confirms the model's hypothesis that trade in goods facilitates global risk sharing.

In Chapter 2 (coauthored by Wilhelm Kohler) the focus lies on the interplay between trade and labor markets. In a purely theoretical analysis, we revisit well established results on the gains from trade derived from models with product differentiation in a framework that includes skill differentiation in the labor force. We show that trade liberalization entails adjustments on the labor market that are detrimental to welfare but can be turned into additional gains if trade liberalization goes hand in hand with the integration of labor markets. This framework also provides a theoretical explanation for the empirically highly relevant incidence of twoway migration among similar countries.

Chapters 3, 4, and 5 are concerned with the quantification of the gains from trade liberalization. The analyses build on and extend current work in the fields of the "New Quantitative Trade Theory" (NQTT). Chapter 3 (coauthored by Rahel Aichele) analyzes the effects of trade liberalization in the presence of globally fragmented production chains. In the theoretical part, we discuss how trade along the value chain multiplies the gains from trade liberalization and distributes trade and welfare effects of regional incidences of tariff liberalization to third countries. We show that the value added flows on the bilateral crosssectoral level follow familiar laws of economic gravity, but we also highlight important differences to the gravity equation for gross trade flows (as measured at customs). In the empirical part, the model framework is applied to study the global impacts of China's entry into the WTO in 2001.

Chapter 4 (coauthored by Gabriel Felbermayr and Rahel Aichele) builds on and extends the model framework used in Chapter 3 to quantify the global effects of the Transatlantic Trade and Investment Partnership (TTIP), which is the subject of current negotiations between the United States and the European Union. We propose a set of methodologies that can be used to simulate the effects of preferential trade agreements on the pattern of trade and production in a comprehensive but tractable quantitative trade model and apply it to the TTIP.

Chapter 5 (coauthored by Gabriel Felbermayr and Rahel Aichele) aims for a methodological contribution to the NQTT. It discusses the implications of parameter uncertainty for model-based counterfactual analysis with estimated structural parameters. We show how a bootstrap can be used to obtain confidence bounds for model predictions, reflecting the degree of uncertainty surrounding the parameter estimates, and to estimate the bias arising from the joint incidence of parameter uncertainty and a non-linear model structure. We apply the methodology to the analysis of the welfare effects of the TTIP.

The chapters of this dissertation represent self-contained articles with their own introductions and and concluding sections. The following paragraphs summarize the articles' key contributions and results.

Chapter 1 is devoted to a general equilibrium analysis of trade in goods and assets and the role of cross-border flows of goods and investment in sharing economic risks among countries. I analyze both theoretically and empirically the potential of capital flows and trade in goods to reduce the volatility of risk-averse individuals' consumption, in a world characterized by country-specific productivity shocks. An influential strand of literature building on the seminal work of Helpman and Razin (1978) and Grossman and Razin (1984) has shown that investment flows suffice to internalize all the gains from sharing the

risk entailed by such productivity shocks if trade flows flexibly adjust to the realization of shocks. Another strand of literature stresses the importance of specificity of investment for firms' international investment decisions, typically assuming risk-neutral decision-making (See, e.g., Das et al., 2007; Ramondo et al., 2013; Dickstein and Morales, 2015). However, empirical evidence suggests that investors care about the risk characteristics of firms' internationalization decisions as regards the covariance of profits with their total wealth, and firms thus take the covariance pattern of returns into account when evaluating risky investments (Rowland and Tesar, 2004; Fillat et al., 2015; Graham and Harvey, 2001). This chapter sheds light on the theoretical and empirical implications of the link between between risk aversion and specificity of production decisions in the context of international trade.

I set up a general equilibrium model that builds on a standard theoretical gravity framework, but additionally features risk-averse investors, country-specific productivity shocks, and time lags between production and sales. By virtue of shareholder-value maximization, firms base their decisions not only on expected returns, but also take into account the diversification benefits offered by markets where profits tend to be high in times when sales conditions on other markets are dire. It follows that in the presence of frictions to trade in the form of time lags between production and sales, the pattern of trade can in part be explained by the covariance structure of country shocks, even if asset markets are perfectly integrated. I show that investment and trade flows are jointly determined as aggregate outcomes of firms' and investors' individually optimal decisions and I derive a gravity equation featuring the covariance of the importer's productivity shocks with marginal utility growth of firms' representative investors as an additional explanatory variable. An empirical analysis of US exports to 175 countries in the years 1992 to 2012 yields strong support for the model's hypothesis that the covariance pattern partly determines the pattern of trade. The empirical analysis also confirms the relevance of the time lag between production and sales, which is key to the theoretical foundation of the hypothesis.

The analysis of the welfare effect of trade and labor market integration in Chapter 2 is motivated by the observation that the gains from trade between structurally similar countries, as implied by Krugman's (1979) classical model, derive from specialization of production on a coarser set of varieties produced domestically. In this framework, countries face a trade-off between specialization that allows production at lower average cost, and diversification of production that enhances competition and caters to consumers' love for variety. Trade is beneficial because it allows countries to improve along *both* dimen-

sions of this trade-off at the same time. However, this rationale of the gains from trade relies on a set of assumptions which imply that having fewer and larger domestic firms has no consequences for welfare other than the benefit of lowering average production cost. We argue that this condition is violated if one acknowledges the heterogeneity of skills among the population. We show that horizontal skill differentiation among the workforce, in the sense that every type of skill is well suited for the production of a certain variety, but less so for others, implies that labor market adjustments to trade-induced specialization can be detrimental to welfare. Fewer and larger domestic firms on the labor market and a constant degree of skill heterogeneity in the population imply that more workers will be employed in the production of varieties for which their skills are suboptimal. Moreover, imperfect transferability of skills across firms provides variety producers with monopsony power, which increases as domestic firms become fewer and larger. Therefore, trade liberalization may be harmful. However, we find that migration can undo the negative welfare consequences of labor market adjustments to trade-induced specialization if trade liberalization goes hand in hand with an integration of labor markets.

The model provides a rationale for the incidence of twoway migration among countries with similar standards of living, which is difficult to rationalize with traditional theories of migration and has sofar attracted surprisingly little attention despite its great empirical relevance. In our model, workers with differentiated skills that do not find a producer who makes full use of their particular type of skill in the home country, have an incentive to search for employment in the foreign country where different varieties are produced. As trade liberalization induces more specialization, migration incentives increase. Our model thus also provides a rationale for the empirical regularity of large positive correlations between bilateral trade and migration flows, which, in contrast to the prections of traditional theories of goods and factor flows, suggests that trade and labor movements are complements rather than substitutes.

Chapters 3, 4, and 5 are devoted to quantifying the effects of trade liberalization. The chapters build on and extend recent work in the field of the "New Quantitative Trade Theory" (NQTT). The NQTT, as comprehensively summarized by Costinot and Rodriguez-Clare (2014), constitutes a methodology for counterfactual analysis of structural changes based on general equilibrium trade models. These models have in common a high degree of parsimony compared to classical computable general equilibrium (CGE) models that have been the workhorses for evaluation of trade policy changes in the past. The parsimony of NQTT models facilitates a concise analytical description of counterfactual changes in model outcomes. The NQTT models also have in common the prediction

that bilateral trade flows follow the gravity equation, a relationship that has proven very successful in explaining the empirical pattern of trade. Hence, despite their parsimony, the NQTT models are successful in matching central moments of the data. Moreover, a tight link between the model and the data is established by virtue of structural estimation, which allows to back out the model's unobserved structural parameters in a way that is consistent with both the model and the data used in the counterfactual analysis. Chapters 3, 4, and 5 aim to contribute both methodologically and topically to this strand of research.

In Chapter 3, we use a NQTT framework to analyze the gains from trade liberalization in the presence of globally fragmented value chains. Vertical specialization of countries in a global value chain makes it difficult to assess the effects of trade liberalization on the global pattern of production. Gross bilateral trade flows no longer reveal a country's or a sector's value added contribution. Yet, it is value added that matters for employment and welfare. Johnson and Noguera (2012a) show that trade values measured at customs vastly overstate the value added that is exchanged between countries and they also provide an empirical methodology based on input-output tables to calculate the value added content of exports. Since then, a great amount of research effort has been expended into understanding the determinants of value added trade flows. Empirical analyses use gravity-type estimation equations to relate value added trade flows to country characteristics and bilateral trade cost (see, e.g., Johnson and Noguera, 2012d). However, in contrast to the gravity model for gross trade flows, there are no structural foundations supporting a log-linear relationship between trade in value added, bilateral trade cost, and the economic size of the importer and exporter. In this paper, we derive a structural equation for value added trade flows from Caliendo and Parro's (2015) model. We show that value added trade on the bilateral cross-sectoral level follows a gravity-like equation, where bilateral trade costs are replaced with a summary measure of the sectoral trade trade costs between all the countries value added travels through on its journey along the value chain. We also develop theoretically-founded measures of production networks based on a country's relative importance as a sourcing or processing location for another country's production.

Based on these structural equations for value added trade and production networks, we conduct a counterfactual analysis of China's entry into the WTO to quantify the effects of this major event of trade liberalization on welfare across the world and on the global pattern of production and trade. To that end, we structurally estimate the model's key parameters, calibrate it to the year 2000 using the World Input-Output Database, and perform a counterfactual analysis by changing China's inward and outward tariffs to the

levels observed in 2007. We find that these tariff changes, which we attribute to China's WTO entry, account for about 45% of the decrease in China's value added exports to exports ratio as observed between 2000 and 2007. This suggests that the WTO entry spurred China's development into one of the world's most important processing location of foreign value added. Furthermore, our results imply that China's WTO accession was the driving force behind the strengthening of the production networks with its neighbors and led to significant welfare gains for China, Australia, and the proximate Asian economies.

Chapter 4 undertakes a quantification of the potential economic effects of the Transatlantic Trade and Investment Partnership (TTIP), a preferential trade agreement that is the subject of current negotiations between the United States and the European Union. Besides eliminating tariffs, the negotiating parties aim to reduce non-tariff barriers to trade (NTBs), such as, for example, differences in regulatory standards, labeling requirements or protectionist sanitary and phytosanitary measures, and to reduce barriers to cross-border flows in services and investment. The TTIP would enhance the integration of two markets which together account for more than 30% of world GDP, and is expected to have a major impact on the global economy.

We use the model by Caliendo and Parro (2015) and the structural equations for value added trade developed in the previous chapter to quantify the potential effects of the TTIP on the global pattern of trade and production, as well as the welfare consequences for the TTIP countries and the rest of the world. The key assumption underlying our counterfactual scenario is that the TTIP will reduce the cost of NTBs to the same extent as existing trade agreements between other countries have reduced the cost of NTBs, on average. Thereby, we distuinguish between deep and shallow trade agreements based on a classification developed by Dür et al. (2014). We use structural estimation to back out the model's unobserved parameters, that is, the dispersion parameters of the sectoral productivity distribution and the elasticity of trade cost with respect to deep and shallow trade agreements.

Our paper builds on the work of Felbermayr et al. (2013) and Felbermayr et al. (2015a), who propose to use estimated effects of preferential trade agreements for the evaluation of prospective trade agreements in contrast to other studies of the TTIP that rely on estimates of bilateral trade cost and conjectured trade cost reduction (Francois et al., 2013). We extend the analysis of Felbermayr et al. (2013) and Felbermayr et al. (2015a) to a multi-industry setting featuring cross-sectoral and international trade in intermediates. Our empirical framework comprises 140 countries or regional aggregates and 38 industries

from the agricultural, manufacturing, and service sectors. We find an increase in real income of 0.4% for the EU, 0.5% for the United States, and -0.02% for the rest of the world. However, there is substantial heterogeneity across the 140 geographical entities that we investigate. Gross value of EU-US trade is predicted to increase by 50%. Moreover, we quantify trade diversion effects on third countries and find that those are less severe for value added trade than for gross trade, highlighting the importance of global value chains in understanding the effects of the TTIP on outsiders and the global economy.

Chapter 5 is devoted to the issue of parameter uncertainty in counterfactual analyses based on models that are calibrated with estimated parameters. With structural estimation of unobserved model parameters constituting one of its building blocks, this issue naturally arises in the NQTT. With few exceptions (Lai and Trefler, 2002; Anderson and Yotov, 2016; and Shapiro, 2015), the issue of parameter uncertainty has been overseen by this literature. Based on well established results from the econometrics literature, we argue that predicted outcomes of models calibrated with estimated parameters are surrounded by uncertainty, deriving from the estimates' stochastic nature. Moreover, the model's endogeneous variables are often highly non-linear functions of the estimated parameters, implying that model predictions based on estimated values of parameters are biased estimates of the model outcomes that one would obtain if the true parameter values were known. We show how a bootstrap can be used to estimate the bias and to obtain measures of uncertainty, that is, confidence bounds for the model's predictions reflecting the degree of uncertainty surrounding the estimated parameters.

To shed some light on the importance of this issue, which will generally depend on the model and the data used in a particular application, we apply the proposed methodology to the counterfactual analysis of the TTIP discussed in Chapter 4. Confidence intervals obtained from 425 bootstrap replication of the model outcomes show that many of the predicted welfare effects are statistically different from zero, among them the predicted welfare gains for all but one of the TTIP countries and the world as whole. However, regarding the effects on other countries, we find that in a number of cases the predictions can, statistically, not be differentiated from zero. We also find that the bias is non-negligible, notwithstanding the high degree of precision of the estimation. Based on bootstrap replications of the model's predictions, we obtain an estimated average bias of 7%. In line with the theory, we find that the bias goes up as the degree of parameter uncertainty increases. Repeating the bootstrap exercise based on a random 50% sample of our original dataset, we obtain an average estimated bias of 11%. We conclude that

accounting for parameter uncertainty is important for both the magnitude and the significance of predictions obtained from simulation studies based on estimated parameters.

Chapter 1

Global Risk Sharing Through Trade in Goods and Assets: Theory and Evidence

1.1 Introduction

Firms engaged in international trade expose their stakeholders to income volatility if profits earned in foreign destination markets are stochastic. At the same time, however, firms' international activity has the potential to diversify the income risk associated with shocks to stakeholders' other sources of income. Trade's potential for consumption risk sharing between countries is well understood; its effectiveness in doing so, however, is rarely confirmed by the data (Backus and Smith, 1993). Goods market frictions limit the attractiveness of trade as a means of equalizing differences in marginal utility of consumption across countries.¹ Likewise, asset market frictions prevent full consumption risk sharing from being achieved by means of international portfolio investment.²

Nevertheless, competitive firms strive to maximize the net present value of their operations conditional on the prevalence of goods and asset market frictions. For firms

¹See Obstfeld and Rogoff (2001) for a comprehensive discussion of the role of goods market frictions in explaining the failure of consumption risk sharing.

²Ample evidence shows that international equity markets continue to be fairly disintegrated to date. See Fama and French (2012) for recent evidence and a comprehensive overview of previous evidence based equity return data. Fitzgerald (2012) finds that conditional on the presence of trade cost, risk sharing is close to complete among developed countries, but significantly impeded by asset market frictions between developed and developing countries. Bekaert et al. (2011) and Callen et al. (2015) reach a similar conclusion.

owned by risk-averse shareholders who dislike consumption volatility this means taking into account that shareholders care not only about the level of expected profits, but also about the distribution of payoffs over good states and bad states. Survey evidence confirms this conjecture. Based on the responses of 392 chief financial officers (CFO) to a survey conducted among U.S. firms in 1999, Graham and Harvey (2001) report that more than 70% always or almost always use discount factors that account for the covariance of returns with movements in investors' total wealth to evaluate the profitability of an investment. Asked specifically about projects in foreign markets, more than 50% of the CFOs responded that they adjust discount rates for country-specific factors when evaluating the profitability of their operations. While the concept of optimal decision-making based on expected payoffs and risk characteristics is prevalent in the literature on firms' optimal choices of production technologies³ and in the literature on international trade and investment under uncertainty⁴, the concept has not, to date, made its way into the literature devoted to firms' exporting decisions under demand uncertainty, which typically assumes risk-neutral behavior of firms.⁵ This paper addresses that oversight.

I show both theoretically and empirically that investors' desire for smooth consumption has important consequences for firms' optimal pattern of exports across destination markets characterized by idiosyncratic and common shocks. Using product-level export data from the United States, I find that export shipments are larger to those markets where expected profits correlate negatively with the income of U.S. investors, conditional on market size and trade cost. I thus provide evidence that exporting firms are actively engaged in global risk sharing by virtue of shareholder-value maximization.

I build a general equilibrium model with multiple countries where firms owned by riskaverse investors make exporting decisions under uncertainty. The key assumption is that firms have to make production decisions for *every* destination market *before* the level of demand is known. There is ample evidence that exporters face significant time lags between production and sales of their goods.⁶ Moreover, a sizable literature documents that investors care about firms' operations in foreign markets and their potential to diversify the risk associated with volatility of aggregate consumption or the aggregate domestic

³See, for example, Cochrane (1991), Cochrane (1996), Jermann (1998), Li et al. (2006), and Belo (2010). ⁴Compare Helpman and Razin (1978), Grossman and Razin (1984), and Helpman (1988).

⁵See, for example, Das et al. (2007), Ramondo et al. (2013), Dickstein and Morales (2015), and Morales et al. (2015).

⁶Djankov et al. (2010) report that export goods spend between 10 to 116 days in transit after leaving the factory gate before reaching the vessel, depending on the country of origin. Hummels and Schaur (2010) document that shipping to the United States by vessel takes another 24 days on average.

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stock market (see, e.g., Rowland and Tesar, 2004; Fillat et al., 2015). However, little is known about how investors' desire for consumption smoothing changes firms' incentives to serve specific markets through exports, and what this means for the pattern of aggregate bilateral trade and the degree of global risk sharing. Here lies the contribution of my paper. I show that introducing risk-averse investors and a time lag between production and sales in an otherwise standard monopolistic competition setup leads to a firm-level gravity equation that includes a novel determinant of bilateral trade flows: the model predicts that, ceteris paribus, firms ship more to countries where demand shocks are more positively correlated with the marginal utility of firms' investors. I provide empirical support for this hypothesis based on a panel of product-level exports from the United States to 175 destination markets.

In the model, the stochastic process of aggregate consumption and in particular the implied volatility of marginal utility, which reflects the amount of aggregate risk borne by a representative agent in equilibrium, are determined as aggregate outcomes of firms' and investors' optimal decisions. Under some additional assumptions regarding the stochastic nature of the underlying shocks, the model facilitates an intuitive decomposition of the equilibrium amount of aggregate volatility into contributions by individual countries, which are determined by the volatility of country-specific shocks and endogenous aggregate bilateral exposures to these shocks through trade and investment. From those country-specific contributions to aggregate risk, I derive a structural expression for the covariances of country shocks with expected marginal utility growth of investors, which are key for investors' and firms' individual optimal decisions. In addition to the direct bilateral exposure of investors to a given destination country through ownership of firms selling to this market, these covariances also reflect indirect exposure through firms' sales to markets with correlated shocks. Building on methodology developed in the asset pricing literature, I use the structure of the model to estimate the covariance pattern of demand shocks with U.S. investors' marginal utility growth for 175 destination markets.

With those estimated covariances at hand, I test the main prediction of the model using a panel of U.S. exports by product and destination. I find strong support for the hypothesis. Looking at variation across time within narrowly defined product-country cells, I find that, conditional on "gravity," changes in the pattern of U.S. exports across destination markets over 20 years can in part be explained by changes in the correlation pattern of destination market specific demand shocks with U.S. investors' marginal utility growth. This implies that exporters respond to investors' desire for consumption smoothing and hence play an active role in global risk sharing. Moreover, I find differential effects across exporting sectors and across modes of transportation, lending support to the model's key assumption – the time lag between production and sales. I find that the correlation pattern has a stronger impact on exports from sectors characterized by greater reliance on upfront investment according to the measure developed by Rajan and Zingales (1998). Moreover, I find stronger effects for shipments by vessel compared to shipments by air. Both findings suggest that time lags are indeed key to understanding the importance of demand volatility for exports and, in particular, the role of the correlation pattern of country shocks in determining the pattern of exports across destination markets.

Those results are consistent with other findings from the survey by Graham and Harvey (2001). In that survey, CFOs were asked to state whether and, if so, what kind of risk factors besides market risk (the overall correlation with the stock market) they use to adjust discount rates. Interest rates, foreign exchange rates, and the business cycle are the most important risk factors mentioned, but inflation and commodity prices were also listed as significant sources of risk. Figure A1.1 in the appendix shows the share of respondents who answered that they always or almost always adjust discount rates or cashflows for the given risk factor. Many of these risk factors are linked to the term structure of investment and returns; interest rate risk, exchange rate risk, inflation, and commodity price risk all indicate that firms have limited ability to timely adjust their operations to current conditions.

1.2 Related Literature

The model developed in this paper builds on the literature that provided structural microfoundations for the gravity equation of international trade (for a comprehensive survey of this literature, see Costinot and Rodriguez-Clare, 2014). I introduce risk-averse investors and shareholder value maximizing firms into this framework to show that demand uncertainty and, in particular, cross-country correlations of demand volatility alter the cross-sectional predictions of standard gravity models.⁷ Moreover, by modeling international investment explicitly, the model rationalizes and endogenizes current account deficits and thereby addresses an issue that severely constrains counterfactual analysis based on static quantitative trade models (see, e.g., Ossa, 2014, 2016).

⁷The model proposed in this paper nests the standard gravity equation as a special case. Trivially, elimination of the time lag implies that export quantities are always optimally adjusted to the current level of demand and hence, cross-sectional predictions follow the standard law of gravity. Likewise, the covariance pattern of country shocks plays no role if investors are risk neutral or if demand growth is deterministic.

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This paper is also related to the literature on international trade and investment under uncertainty. Helpman and Razin (1978) show that the central predictions of neoclassical trade models remain valid under technological uncertainty in the presence of complete contingent claims markets. Grossman and Razin (1984) and Helpman (1988) analyze the pattern of trade and capital flows among countries in the absence of trade frictions. Egger and Falkinger (2015) recently developed a general equilibrium framework with international trade in goods and assets encompassing frictions on both markets. In these models, countries exhibit fluctuations in productivity. Risk-averse agents may buy shares of domestic and foreign firms whose returns are subject to productivity shocks in their respective home country. Grossman and Razin (1984) point out that in this setting, investment tends to flow toward the country where shocks are positively correlated with marginal utility. Once productivity is revealed, production takes place and final goods are exported to remunerate investors. In contrast to this literature where diversification is solely in the hand of investors, I argue that there is a role for internationally active firms to engage in diversification, in addition to profit maximization. The key assumption I make in this regard is market specificity of goods, which implies that firms can alter the riskiness of expected profits in terms of their covariance with investors' marginal utility by producing more or less for markets characterized by correlated demand shocks. If, in contrast, only total output, but not the market-specific quantities have to be determined ex-ante as in the earlier literature, then relative sales across markets will be perfectly adjusted to current conditions and this additional decision margin of firms vanishes.

The foreign direct investment model developed by Ramondo and Rappoport (2010) shows that market specificity of investment opens up the possibility for firms to engage in consumption smoothing even in the presence of perfectly integrated international asset markets. In their model, free trade in assets leads to perfect comovement of consumption with world output. Multinational firms' location choices affect the volatility of global production and their optimal choices balance the diversification effects of locations that are negatively correlated with the rest of the world and gains from economies of scale that are larger in larger markets. My paper complements these findings by showing that a similar rationale applies to firms' market-specific export decisions under various degrees of financial market integration.⁸

⁸My paper also differs with regard to the increasing returns to scale assumption. Even though there are increasing returns at the firm level, I assume that aggregate country-level output exhibits decreasing returns to scale, which is another natural force limiting the possibility of risk diversification through trade and investment. Decreasing returns in the aggregate imply that more investment in a market that offers great diversification benefits thanks to negatively correlated shocks with the rest of the world decreases the expected return to that investment. Optimal investment choices balance these two opposing forces.

Empirical evidence supports the relevancy of market specificity of investment through which firms' international activities expose shareholders to country-specific volatility. Fillat et al. (2015) and Fillat and Garetto (2015) find that investors demand compensation in the form of excess returns for holding shares of internationally active firms and provide evidence that those excess returns are systematically related to the correlation of demand shocks in destination markets with the consumption growth of investors in the firms' home country. In the model developed by these authors, demand volatility in foreign markets exposes shareholders to additional risk because firms may be willing to endure losses for some time if they have sunk costs to enter these markets. Once sunk costs have been paid, firms maximize per-period profits for whatever demand level obtains. Hence, the fact that firms' investors perceive some markets as riskier than others influences the market entry decision, but does not impact the level of sales. I abstract from entry cost and instead consider the implications of longer time lags between production and foreign sales, which do have an impact on the intensive margin of firms' optimal exports. My paper is similar to these authors' work in that I also develop a structural model linking firm values to country shocks and to the distribution of marginal utility growth. However, Fillat and Garetto (2015) and Fillat et al. (2015) analyze asset returns conditional on firms choices, whereas my focus lies on the optimal choices themselves. Moreover, thanks to the simpler dynamic structure, I am able to close the model and determine the distribution of investors' marginal utility growth in general equilibrium.

The paper is thus also related to the literature on firm investment under uncertainty, specifically the strand that models the supply and demand side for equity in general equilibrium by linking both firms' investment and investors' consumption to volatile economic fundamentals such as productivity shocks. This literature began with testing and rejecting the asset pricing implications of a standard real business cycle models (see Jermann, 1998). Models augmented with various types of friction, such as capital adjustment cost (Jermann, 1998), financial constraints (Gomes et al., 2003), and inflexible labor (Boldrin et al., 2001), have proven more successful in matching macroeconomic dynamics and replicating the cross-section of asset returns. In this paper, I show that market specificity of investment in conjunction with a time lag between production and sales caused by longer shipping times for international trade have the potential to play a role similar to adjustment cost. As described above, my export data set, which comprises shipments by mode of transportation, allows me to test the relevance of this particular type of friction.

The extant literature shows that demand volatility in conjunction with time lags due to shipping impacts various decision margins of exporters and importers, including order size and the timing of international transactions (Alessandria et al., 2010), as well as the choice of an optimal transportation mode (Aizenman, 2004; Hummels and Schaur, 2010). In this literature, agents are risk neutral and demand volatility is costly because it can lead to suboptimal levels of supply or incur expenses for hedging technologies such as fast but expensive air shipments, costly inventory holdings, or high-frequency shipping. I contribute to this literature by showing that risk aversion on the part of firms' investors changes the perceived costliness of destination-market-specific volatility depending on the correlation with marginal utility growth and, therefore, changes the willingness to bear a particular market's specific risk. Even though the model ignores the possibility of hedging risk by means of inventory holdings or fast transport, it implies that optimal market-specific hedging choices will be affected by investors' perception of costliness.⁹

1.3 Theory

Consider a world consisting of I countries inhabited by individuals who derive utility from consumption of a final good and earn income from the ownership of firms producing differentiated intermediate goods. Intermediate goods are sold to domestic and foreign final goods producers whose output is subject to a country-specific stochastic technology.

1.3.1 Utility, Consumption, and Investment

The expected utility that an infinitely-lived representative risk-averse agent $i \in \iota$ derives from lifetime consumption $\{C_{i,t+s}\}_{s=0}^{\infty}$ is given by

$$U_{i,t} = \mathcal{E}_t \sum_{s=0}^{\infty} \rho^s u_i(C_{i,t+s}) \quad \text{with} \quad u'_i(\cdot) > 0, \ u''_i(\cdot) < 0, \tag{1.1}$$

where ρ is his time preference rate. The agent is endowed with wealth $W_{i,t}$ which he consumes or invests into $a_{ij,t}$ shares of firms $j \in \mathcal{J}_{i,t}$ that sell at price $v_{j,t}$ and into $a_{i,t}^f$ units of a risk-free asset. All prices are denoted in units of the aggregate consumption good. Wealth thus observes

$$W_{i,t} = A_{i,t} + C_{i,t}$$
 where $A_{i,t} = \sum_{j \in \mathcal{J}_{i,t}} a_{ij,t} v_{j,t} + a_{i,t}^f$. (1.2)

⁹Differential perception of the costliness of volatility depending on the covariance with aggregate risk is prevalent in the literature on optimal inventory choices with regard to domestic demand volatility (see, for example, Khan and Thomas, 2007).

Every period the agent receives interest $r_{i,t}^f$ on his investment in the risk-free asset and a dividend per share that corresponds to a fraction δ_j of firm j's profit $\pi_{j,t}$. Without loss of generality, I set $\delta_j = 1$. Moreover, the agent makes net investments $da_{ij,t} = a_{ij,t} - a_{ij,t-1} \leq 0$ in risky assets (firm shares) and the safe asset $(da_{i,t}^f)$, so that his per-period budget constraint reads

$$C_{i,t} = \sum_{j \in \mathcal{J}_{i,t-1}} a_{ij,t-1} \pi_{j,t} + a_{i,t-1}^f r_{i,t}^f - \sum_{j \in \mathcal{J}_{i,t}} \mathrm{d}a_{ij,t} v_{i,t} - \mathrm{d}a_{i,t}^f.$$
(1.3)

The agent's wealth thus evolves over time according to

$$W_{i,t+1} = \sum_{j \in \mathcal{J}_{i,t}} a_{ij,t} v_{j,t} + a_{i,t}^f + \sum_{j \in \mathcal{J}_{i,t}} a_{ij,t} \left(\mathrm{d}v_{j,t+1} + \pi_{j,t+1} \right) + a_{i,t}^f r_{i,t+1}^f$$
$$= R_{i,t+1}^W \left(W_{i,t} - C_{i,t} \right) \quad \text{where} \quad R_{i,t+1}^W = \sum_{j \in \mathcal{J}_{i,t}} \frac{a_{ij,t} v_{j,t}}{A_{i,t}} R_{j,t+1} + \frac{a_{i,t}^f}{A_{i,t}} R_{i,t+1}^f. \quad (1.4)$$

 $R_{i,t+1}^W$ denotes the gross return to the wealth portfolio $A_{i,t}$, $R_{i,t+1}^f = 1 + r_{i,t+1}^f$ is the exogenously given gross interest rate earned by the risk-free asset. Gross returns to risky assets, $R_{j,t+1} = \frac{\pi_{j,t+1}+v_{j,t+1}}{v_{j,t}}$, will be determined by firms' choices. The investor chooses optimal investment levels by maximizing utility in Equation (1.1) with respect to $a_{ij,t}, a_{i,t}^f$ and subject to Equations (1.2), (1.3), (1.4), and the no-Ponzi-game condition $0 = \lim_{s\to\infty} \rho^s u'_i(C_{i,t+s})A_{i,t+s}$. His first-order conditions yield an Euler equation for the risk-free asset,

$$1 = \mathcal{E}_t \left[\rho \frac{u_i'(C_{i,t+1})}{u_i'(C_{i,t})} \right] R_{i,t}^f \quad \forall \ t,$$

$$(1.5)$$

and Euler equations for the risky assets,

$$v_{j,t} = \mathcal{E}_t \left[\rho \frac{u'_i(C_{i,t+1})}{u'_i(C_{i,t})} (\pi_{j,t+1} + v_{j,t+1}) \right] \quad \forall \ j,t.$$
(1.6)

The Euler equations describe the consumption-investment tradeoff: investment (disinvestment) occurs while the price paid today is smaller (larger) than the marginal return tomorrow, where the return tomorrow is scaled by the time preference rate and expected marginal utility growth. This scaling factor is commonly referred to as the stochastic discount factor (SDF).

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The Euler equations also describe the tradeoff between investing in different types of assets. Chaining together Equation (1.6) and using Equation (1.5) yields

$$v_{j,t} = \mathcal{E}_t \sum_{s=1}^{\infty} \rho^s \frac{u_i'(C_{i,t+s})}{u_i'(C_{i,t})} \pi_{j,t+s} = \sum_{s=1}^{\infty} \frac{\mathcal{E}_t \left[\pi_{j,t+s}\right]}{R_{i,t+s}^f} + \sum_{s=1}^{\infty} \operatorname{Cov}_t \left[\rho^s \frac{u_i'(C_{i,t+s})}{u_i'(C_{i,t})}, \pi_{j,t+s} \right].$$
(1.7)

The right-hand side of Equation (1.7) shows that an investor's willingness to pay for a share of firm j, which promises a risky dividend stream $[\pi_{i,t+s}]_{s=1}^{\infty}$, is determined not only by the expected value (discounted with the risk-free interest rate), but also by the payoff's correlation with

$$m_{i,t+s} := \rho^s \frac{u'_i(C_{i,t+s})}{u'_i(C_{i,t})},\tag{1.8}$$

the investor's SDF. The SDF is an inverse measure of the investor's well-being: in good times, when expected consumption growth is high, the SDF is small since an additional unit of expected consumption tomorrow is less valuable. In contrast, the SDF is large in bad times, when expected consumption is small and marginal utility is high. Equation (1.6) states that stocks that pay high dividends in times when expected marginal utility is high are more valuable to an investor.¹⁰ The investor buys risky assets ($da_{ij,t} > 0$) while his willingness to pay exceeds the price $v_{j,t}$. He thus increases expected consumption tomorrow at the expense of consumption today so that expected growth in marginal utility falls. Equation (1.5) thus commands that he partly disinvest the risk-free asset. Moreover, as the share of asset j in the investor's total portfolio, $\frac{a_{ij,t}v_{j,t}}{A_{i,t}}$, increases, asset j becomes more correlated with the return on total wealth and thus less attractive as a means of consumption smoothing. Hence, the investor's willingness to pay for additional units of this asset decreases. The Euler equations thus relate investors' willingness to pay for an asset to the asset's price *in equilibrium*.

The assumption of a representative investor is innocuous in an economy where individuals have identical beliefs about the probabilities with which uncertain events occur, the financial market is complete, and individuals' preferences are of the von Neumann-Morgenstern type as described in Equation (1.1) (see Constantinides, 1982). Completeness of financial markets means that trading and creating state contingent assets is unrestricted and costless and hence idiosyncratic risks are insurable. Constantinides (1982) shows that under those conditions, equilibrium outcomes in an economy characterized by

¹⁰Note that this is an immediate implication of investors' risk aversion. With risk neutrality (u'' = 0), the discount factor would be constant and thus perfectly uncorrelated with any dividend stream.

optimal choices of investors exhibiting heterogeneous per-period utility functions and heterogeneous levels of wealth are identical to the case where a "composite" investor owning the sum of all inviduals' wealth makes optimal decisions. Moreover, he shows that the composite investor's preferences inherit the von Neumann-Morgenstern property and the concavity of individuals' utility functions.

The above setup of the financial market then encompasses three cases of financial market integration. Let $\mathcal{I}_i \subseteq \mathcal{I}$ with $i = 1, ..., \iota$ denote mutually exclusive and collectively exhaustive sets of countries among which asset trade is unrestricted. Then $\iota = I$ denotes the case where all countries are in financial autarky, so that there is one representative investor for every single country in \mathcal{I} and the set of available assets $\mathcal{J}_{i,t}$ is restricted to the set of domestic firms. The case of $I > \iota > 1$ describes partially integrated international asset markets, where investor *i* is representative for every country in \mathcal{I}_i and $\mathcal{J}_{i,t}$ comprises the firms from all countries in \mathcal{I}_i . Finally, $\iota = 1$ denotes the case of a fully integrated international financial market, where investor *i* is representative for all countries and has unrestricted access to shares of all firms.

Note that the creation and trade of other "financial" assets within a complete market, that is, creation and trade of assets like derivatives, options, or futures, which are in zero net supply, has no bearing on the representative investor's optimal consumption or investment decisions.¹¹ This does not mean that none of those assets are traded; in fact, they are essential for eliminating idiosyncratic risk in the first place and facilitating a description of the equilibrium by means of a representative investor. However, since by definition they must be in zero net supply, they cannot play a role in mitigating aggregate risk and thus their presence does not have any impact on the tradeoff between risky assets and the risk-free investment, nor do they have any bearing on the consumption-investment tradeoff.

The Euler equations describe the demand side of the asset market. The risk-free asset is assumed to be in unlimited supply with an exogenous return $R_{i,t}^f$. In contrast, the supply of primary assets and their stochastic properties will be endogenously determined by firms' entry and production decisions, which are described in the following section.

¹¹I follow Dybvig and Ingersoll (1982)'s terminology in differentiating "financial" or "derivative" assets from "primary" assets, where the former are defined by being in zero net supply and therefore, in contrast to the latter which are in positive net supply, have no impact on *aggregate* wealth of the economy. Firm shares are the prototype of primary assets. More generally, primary assets can be characterized by the set of assets which form the aggregate asset wealth portfolio.
1.3.2 Firm Behavior

The production process involves two stages: Each country produces differentiated tradable varieties and a final investment and consumption good that uses domestic and imported differentiated varieties as inputs. The final good is freely tradable and serves as numéraire. It is either consumed or used as an input in the production of differentiated varieties. Final good producers in country h bundle $\bar{q}_{jh,t}$ units of domestic and imported varieties $j \in \mathcal{N}_t$ into the composite good $Y_{h,t}$ based on the production function

$$Y_{h,t} = \psi_{h,t} \bar{Q}_{h,t}^{\eta} \quad \text{with} \quad \bar{Q}_{h,t} = \left(\sum_{j \in \mathcal{N}_t} \left(\bar{q}_{jh,t}\right)^{\frac{\varepsilon-1}{\varepsilon}}\right)^{\frac{\varepsilon}{\varepsilon-1}}$$
(1.9)

with $\varepsilon > 1$ and $0 < \eta < 1$. Moreover, I assume that $\eta \varepsilon / (\varepsilon - 1) < 1$, which implies that the elasticity of output with respect to the number of varieties is smaller one and the marginal productivity of the first variety is infinite. $\psi_{h,t}$ describes country h's state of technology at time t. I assume that at each point in time, country-specific productivities $\psi_{h,t}$ are drawn from a multivariate distribution with non-negative support and finite expected values.¹² The distribution is known to all agents of the model.

Inverse demand for any individual variety of the differentiated good follows as

$$p_{jh,t}(\bar{q}_{jh,t}) = \eta \left(\frac{\bar{q}_{jh,t}}{\overline{Q}_{h,t}}\right)^{-\frac{1}{\varepsilon}} \frac{Y_{h,t}}{\overline{Q}_{h,t}}$$

where $p_{jh,t}$ is the price of variety j in country h. In the differentiated goods sector, firms produce varieties using c_j units of the composite good per unit of output and, when shipping goods to country h, they face iceberg-type trade costs $\tau_{jh} \ge 1$. Moreover, each period, firms pay a fixed cost α_j .¹³ I assume that firms within each country are homogeneous with respect to cost, but every firm produces a distinct variety. Since I will be considering a representative firm for a given country, I subsume the home country index in the firm index j. The number of firms and varieties from country j is $N_{j,t}$.

Demand for a firm's variety in any destination market h is volatile because it depends on the destination country's stochastic state of productivity $\psi_{h,t}$. I assume that variety producers have to decide on the optimal output quantity for a given market *before* the

¹²As discussed in more detail below, some further assumptions on the distribution will be needed for parts of the general equilibrium analysis.

¹³Production and trade cost may well vary over time. However, this has no bearing on the qualitative predictions of the model and therefore I omit time indices on these variables for simplicity's sake.

productivity of the destination country is known because production and shipping take time. Hence, at time t they choose the quantity $q_{jh,t} = \bar{q}_{jh,t+1}$ to be sold in t + 1 and they base this decision on the expected level of demand.¹⁴ Consequently, the amount of the composite good at time t is also determined a period in advance and follows as $\bar{Q}_{h,t+1} = Q_{h,t} = \left(\sum_{j \in \mathcal{I}} N_{j,t} (q_{jh,t})^{\frac{\varepsilon-1}{\varepsilon}}\right)^{\frac{\varepsilon}{\varepsilon-1}}$.

With quantities determined, the price that variety producers expect depends on the realization of the stochastic productivity level in the destination country:

$$E_{t}[p_{jh,t+1}] = \eta \left(\frac{q_{jh,t}}{Q_{h,t}}\right)^{-\frac{1}{\varepsilon}} Q_{h,t}^{\eta-1} E_{t}[\psi_{h,t+1}] = \eta \left(\frac{\tilde{q}_{jh,t}}{Q_{h,t}}\right)^{-\frac{1}{\varepsilon}} \frac{E_{t}[Y_{h,t+1}]}{Q_{h,t}}$$
(1.10)

At time t, firm j thus expects to make the following operating profit in market h at time t + 1:

$$E_t [\pi_{jh,t+1}] = E_t [p_{jh,t+1}(q_{jh,t}) \cdot q_{jh,t} - c_j \tau_{jh} q_{jh,t+1}]$$
(1.11)

Note that current revenue depends on the quantity produced at time t, while current cost depend on the quantity produced in t + 1. Total profits are $\pi_{j,t+1} = \sum_{h \in \mathcal{I}} \pi_{jh,t+1} - \alpha_j$.

Firm j maximizes its net present value, acknowledging that its investors' discount factor is stochastic and potentially correlated with the profit it expects to make in different markets. As discussed above, firm j may obtain financing from investors in multiple countries, depending on the degree of financial market integration. Lets assume, without loss of generality, that the firm's home country j is part of the set of countries \mathcal{I}_i whose asset markets are fully integrated. Then, the relevant discount factor for firm j is $m_{t+s}^j = m_{i,t+s}$. The firm takes the distribution of the SDF as given; hence, its optimization problem reads

$$\max_{[q_{jh,t+s} \ge 0]_{s=0}^{\infty} \ \forall h} \ V_{j,t} = \mathcal{E}_t \left[\sum_{s=0}^{\infty} m_{t+s}^j \cdot \pi_{j,t+s} \right].$$

¹⁴I have thus implicitly assumed that firms cannot reallocate quantities across markets once the uncertainty about demand has been resolved, and that they do not hold inventory in destination countries.

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Since quantities can always be adjusted one period ahead of sales, the optimal choice of $q_{jh,t}$ at any time t can be simplified to a two-period problem, that is,

$$\max_{q_{jh,t}\geq 0 \ \forall h} \mathbf{E}_{t} \left[m_{t+1}^{j} \cdot \sum_{h\in\mathcal{I}} p_{jh,t+1}(q_{jh,t}) \cdot q_{jh,t} \right] - \sum_{h\in\mathcal{I}} c_{j}\tau_{jh}q_{jh,t} - \alpha_{j}$$
$$= \sum_{h\in\mathcal{I}} \eta \left(\frac{q_{jh,t}}{Q_{h,t}} \right)^{\frac{\varepsilon-1}{\varepsilon}} \left(\mathbf{E}_{t} \left[Y_{h,t+1} \right] \mathbf{E}_{t} \left[m_{t+1}^{j} \right] + \operatorname{Cov}_{t} \left[m_{t+1}^{j}, Y_{h,t+1} \right] \right) - \sum_{h\in\mathcal{I}} c_{j}\tau_{jh}q_{jh,t} - \alpha_{j}$$

The first-order condition yields an optimal quantity for any market h that is produced at time t and to be sold in t + 1 equal to

$$q_{jh,t}^* = \frac{\theta(1+\lambda_{h,t}^j)^{\varepsilon} \left(R_{j,t+1}^f c_j \tau_{jh}\right)^{-\varepsilon}}{\sum_{j \in \mathcal{I}} N_{j,t} (1+\lambda_{h,t}^j)^{\varepsilon-1} \left(R_{j,t+1}^f c_j \tau_{jh}\right)^{1-\varepsilon}} \cdot \mathcal{E}_t \left[Y_{h,t+1}\right], \qquad (1.12)$$

where I have defined $\theta := \frac{\eta(\varepsilon-1)}{\varepsilon} < 1$ and

$$\lambda_{h,t}^j := R_{j,t+1}^f \operatorname{Cov}_t \left[m_{t+1}^j, \frac{Y_{h,t+1}}{\operatorname{E}_t \left[Y_{h,t+1} \right]} \right].$$

To arrive at Equation (1.12), I used $Q_{h,t}^{\frac{\varepsilon-1}{\varepsilon}} = \sum_{j \in \mathcal{I}} N_{j,t}(q_{jh,t}^*)^{\frac{\varepsilon-1}{\varepsilon}}$ and Equation (1.5) to substitute for the expected value of the SDF. I call $\lambda_{h,t}^j$ the "risk premium" of market h. It is negative for markets that are *risky* in the sense that demand shocks on these markets are negatively correlated with the SDF, and positive otherwise. Equation (1.9) implies that demand growth comoves one to one with the country-specific productivity shocks $E_t [\psi_{h,t+1}] / \psi_{h,t+1}$.

Equation (1.12) states that firms ship larger quantities to markets with lower trade cost and higher expected demand. They ship less in times of high real interest rates, that is, when current consumption is highly valued over consumption tomorrow, because production cost and trade cost accrue in t, while revenue is obtained in t + 1. Moreover, firms ship more to those markets where demand growth is positively correlated with their investors' SDF, since investors value revenues more if, ceteris paribus, they tend to be high in bad times and low in good times. This is the central prediction of the model, which I believe is new to the trade literature, and will be subjected to empirical testing in Section 1.4. First, however, I relate the model's predictions to the standard gravity framework and close the model to show how the risk premia are determined in general equilibrium and how they can be estimated. I also show that they will be zero only under special circumstances, namely, if the exogenous distribution of productivity shocks and financial market integration permit complete elimination of *aggregate* risk, and if investors, trading off risk against returns, endogenously choose to do so.

Once the state of the destination country's productivity is revealed in t + 1, the firm's revenue in market h obtains as

$$p_{jh,t+1}(q_{jh,t}^*)q_{jh,t}^* = \phi_{jh,t}Y_{h,t+1}, \qquad (1.13)$$

where

$$\phi_{jh,t} = \left(\frac{q_{jh,t}^*}{Q_{jh,t}}\right)^{\frac{\varepsilon-1}{\varepsilon}} = \frac{\left(1+\lambda_{h,t}^j\right)^{\varepsilon-1} \left(R_{j,t+1}^f c_j \tau_{jh}\right)^{1-\varepsilon}}{\sum_{j \in \mathcal{I}} N_{j,t} (1+\lambda_{h,t}^j)^{\varepsilon-1} \left(R_{j,t+1}^f c_j \tau_{jh}\right)^{1-\varepsilon}}$$

denotes firm j's trade share in market h, that is, the share of country h's real expenditure devoted to firm j. Equation (1.13) is a firm-level gravity equation with bilateral trade cost augmented by a risk-adjusted interest rate. Note that Equation (1.13) nests the gravity equation of derived from the model of Krugman (1980) with homogenous firms and monopolistic competion as a special case.¹⁵ In fact, there are a number of special cases under which sales predicted by the model follow the standard law of gravity. Suppose, first, that the time lag between production and sales is eliminated. Then, demand volatility becomes irrelevant as firms can always optimally adjust quantities to the current demand level $(E_t[Y_{h,t}] = Y_{h,t})$. Next, suppose that investors are risk neutral, so that marginal utility is constant. Then, the SDF does not vary over time and hence has a zero covariance with demand shocks. In this case, Equation (1.13) will differ from the standard gravity equation only due to the presence of the time lag, which introduces the risk-free rate as an additional cost parameter. The same relationship obtains if demand growth is deterministic. Moreover, full integration of international financial markets will equalize SDFs across countries, so that the covariance terms (and the risk-free rates) are identical across source countries and hence cancel each other out in the trade share equation. Note, however, that in this last case, the covariance will still influence optimal quantities as described in Equation (1.12). Firms still ship larger quantities to countries with positive λ s and investors value these firms more, but since all their competitors from other countries behave accordingly, trade shares are independent of λ . Finally, covariances could be set to zero *endogenously*, a possible but unlikely case, as I will discuss in more detail below.

¹⁵See, for example, Head and Mayer (2014) for a description of this model.

Firm j's maximum net present value is given by

$$V_{j,t}^{*} = \sum_{h \in \mathcal{I}} \left(\mathbb{E}_{t} \left[m_{t+1}^{j} \cdot p_{jh,t+1}(q_{jh,t}^{*}) q_{jh,t}^{*} \right] - c_{j} \tau_{jh} q_{jh,t}^{*} \right) - \alpha_{j}$$
(1.14)
$$= \sum_{h \in \mathcal{I}} (1 - \theta) \frac{1 + \lambda_{h,t}^{j}}{R_{j,t+1}^{f}} \phi_{jh,t} \mathbb{E}_{t} \left[Y_{h,t+1} \right] - \alpha_{j},$$

the sum of expected sales, adjusted by an inverse markup factor $0 < (1 - \theta) < 1$ and discounted with a market-specific risk-adjusted interest rate, minus fixed cost.

1.3.3 Model Closure

1.3.3.1 Firm Entry and Asset Market Clearing

Firm entry governs the supply of assets from every country. I assume that there are no barriers to entry; hence, firms enter as long as their net present value is non-negative. In view of Equation (1.14), this implies that in equilibrium

$$V_{j,t}^* = 0 \qquad \Leftrightarrow \qquad \mathbf{E}_t \left[m_{t+1}^j \cdot \sum_{h \in \mathcal{I}} p_{jh,t+1}(q_{jh,t}^*) q_{jh,t}^* \right] = \sum_{h \in \mathcal{I}} c_j \tau_{jh} q_{jh,t}^* + \alpha_j. \tag{1.15}$$

Entry lowers the price of incumbents' varieties and thus their profits due to the concavity of the final goods production function in the composite good.¹⁶ Moreover, entry of additional firms from country j implies that the share of assets of this particular type in the investor's portfolio increases and the asset becomes more risky in the sense that its payoff correlates more with the investor's total wealth. Hence, $V_{j,t}^*$ is driven down to zero as new firms enter. Equation (1.15) determines the number of firms and thus the supply of assets from every country. Asset market clearing implies

$$N_{j,t} = a_{ij,t} \qquad \forall \ j \in \mathcal{I}_i, \tag{1.16}$$

that is, the number of variety producers in country j is equal to the representative investor i's demand for shares of this particular type.¹⁷ Remember that depending on the degree

¹⁶There is a countervailing positive effect of firm entry on incumbents' profits arising from the love of variety inherent to the CES production function of the composite good, which is inversely related to ε , the elasticity of substitution. The assumption that $\eta \varepsilon / (\varepsilon - 1) < 1$ assures that concavity dominates love for variety.

¹⁷Remember that I have normalized the number of shares per firm to unity.

of financial market integration, the representative investor's demand equals the composite demand of all individuals from country j or from (a subset of) all countries.

Combining the entry condition (1.15) with the Euler equation (1.6) that governs asset demand and substituting $\sum_{h\in\mathcal{I}} p_{jh,t+1}(q_{jh,t}^*) \cdot q_{jh,t}^* = \pi_{j,t+1} + \sum_{h\in\mathcal{I}} c_j \tau_{jh} q_{jh,t+1}^* + \alpha_j$ implies that the equilibrium asset price equals the cost of setting up a new firm, that is,

$$v_{j,t} = \sum_{h \in \mathcal{I}} c_j \tau_{jh} q_{jh,t}^* + \alpha_j.$$

$$(1.17)$$

With asset prices and profits determined, the returns to holding firm shares can be described in terms of country-specific demand growth, which, by Equation (1.9), correlates perfectly with the productivity shocks. Using Equations (1.13), I obtain

$$R_{j,t+1} = \frac{\pi_{j,t+1} + v_{j,t+1}}{v_{j,t}} = \sum_{h \in \mathcal{I}} \frac{\phi_{jh,t} \mathbf{E}_t \left[Y_{h,t+1} \right]}{v_{j,t}} \left(\frac{Y_{h,t+1}}{\mathbf{E}_t \left[Y_{h,t+1} \right]} \right)$$
(1.18)

as the gross return of a share of firm j. Returns are linear combinations of demand growth in the destination markets, where markets are weighted by the share of expected sales in the total discounted value of the firm.

1.3.3.2 Equilibrium

Let N_t , ψ_{t+1} , $q_{j,t}$ denote $(I \times 1)$ vectors collecting, respectively, the number of firms, the productivity levels, and firm j's optimal quantity in each country h = 1, ..., I. Then $q_t = [q'_{1,t}, ..., q'_{i,t}, ..., q'_{I,t}]$ is a $(I \times I)$ matrix of all firms' sales across all markets. Moreover, let $a_{i,t}$ denote the $(I_i \times 1)$ vector of investor i's optimally chosen number of shares of all representative firms $j \in \mathcal{I}_i$, where I_i is the number of countries in \mathcal{I}_i . $\tilde{\pi}^i_{t+1}$ and v^i_t denote $(I_i \times 1)$ vectors of these firms' profits and share prices, respectively. I use a tilde to indicate random variables defined by a conditional density function. For example, $\tilde{\psi}_{t+1}$ describes the joint distribution of the productivity levels $f(\psi_{t+1}|\Psi_t)$ conditional on the history of realized productivity shocks. Then, the set of equilibrium conditions determining the endogenous variables q_t , N_t , $\{a_{i,t}\}_{i=1}^{\iota}$, $\{v^i_t\}_{i=1}^{\iota}$, $\{C_{i,t}\}_{i=1}^{\iota}$, and, for all $s = 1, ..., \infty$, \tilde{q}_{t+s} , \tilde{N}_{t+s} , $\{\tilde{\pi}^i_{t+s}\}_{i=1}^{\iota}$, $\{\tilde{v}^i_{t+s}\}_{i=1}^{\iota}$, $\{\tilde{m}_{i,t+s}\}_{i=1}^{\iota}$, $\{\tilde{C}_{i,t+s}\}_{i=1}^{\iota}$ is given by

Investors' first-order conditions (1.5) and (1.6):

$$a_{i,t}^f \left[\widetilde{m}_{i,t+1}; R_{i,t+1}^f \right]$$
 and $a_{ij,t} \left[v_{j,t}, \widetilde{\pi}_{j,t+1}, \widetilde{m}_{i,t+1} \right] \quad \forall j \in \mathcal{I}_i \text{ and } i = 1, ..., \iota$

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Firms' first-order conditions (1.12): $\boldsymbol{q}_{j,t} \begin{bmatrix} \boldsymbol{q}_t, \boldsymbol{N}_t, \widetilde{m}_{i,t+1}; \widetilde{\boldsymbol{\psi}}_{t+1} \end{bmatrix} \quad \forall \ j \in \mathcal{I}_i \text{ and } i = 1, ..., \iota$ Profits (1.11): $\widetilde{\pi}_{j,t+1} \begin{bmatrix} \boldsymbol{q}_t, \boldsymbol{N}_t; \widetilde{\boldsymbol{\psi}}_{t+1} \end{bmatrix} \quad \forall \ j \in \mathcal{I}_i \text{ and } i = 1, ..., \iota$ Free entry condition (1.15): $N_{j,t} \begin{bmatrix} \boldsymbol{q}_t, \boldsymbol{N}_t, \widetilde{m}_{i,t+1}; \widetilde{\boldsymbol{\psi}}_{t+1} \end{bmatrix} \quad \forall \ j \in \mathcal{I}_i \text{ and } i = 1, ..., \iota$ Asset market clearing (1.16): $a_{ij,t} \begin{bmatrix} N_{j,t} \end{bmatrix} \quad \forall \ j \in \mathcal{I}_i \text{ and } i = 1, ..., \iota$ Stochastic discount factor (1.8): $\widetilde{m}_{i,t+1} \begin{bmatrix} C_{i,t}, \widetilde{C}_{i,t+1} \end{bmatrix} \quad \forall \ i = 1, ..., \iota$

Budget constraint (1.3):

$$\widetilde{m}_{i,t+1} \left[C_{i,t}, \widetilde{C}_{i,t+1} \right] \qquad \forall i = C_{i,t} \left[a_{i,t}^f, \boldsymbol{a}_{i,t}, \boldsymbol{v}_t^i; W_{i,t} \right] \quad \text{and}$$

$$\widetilde{C}_{i,t+1}\left[a_{i,t}^{f}, \boldsymbol{a}_{i,t}, \widetilde{\boldsymbol{\pi}}_{t+1}^{i}, \widetilde{a}_{i,t+1}^{f}, \widetilde{\boldsymbol{a}}_{i,t+1}, \widetilde{\boldsymbol{v}}_{t+1}^{i}; R_{i,t+1}^{f}\right] \qquad \forall \ i = 1, ..., \iota$$

and the no-Ponzi-game condition $0 = \lim_{s \to \infty} m_{i,t+s} A_{i,t+s} \forall i = 1, ..., \iota$.¹⁸

This describes the equilibrium from the point of view of the representative investors for the ι subsets of countries. If financial markets are partially or fully integrated ($\iota > 1$), the equilibrium values for investment and consumption describe aggregates of all countries in \mathcal{I}_i . Hence, consumption or investment on the national level, as well as bilateral financial flows, are not determined at this point. To pin down those values in the case of (partially) integrated international financial markets, further assumptions on the distribution of wealth and the utility functions are needed. Note that up to this point and also in what follows, no restrictions are placed on the distribution of wealth across countries or even across individuals. The only assumptions about preferences made so far state that all individuals' utility functions are of the von Neumann-Morgenstern-type and exhibit risk aversion. In Appendix A1.2, I show how countries' current accounts can be derived once country-level consumption and bilateral investment flows are determined.¹⁹

¹⁸I include a subset of the exogenous or predetermined variables, separated by a semicolon, whereever this seems conducive to conveying the intuition behind the conditions. Also, remember that I use superscript j on the variables m, R^f , and λ to denote the SDF, the risk-free rate, and the risk premia relevant to firm j and subscript i to denote the SDF, the risk-free rate, and the risk premia of investors from country i. For all $j \in \mathcal{I}_i, m_{t+1}^j = m_{i,t+1}, \lambda_{h,t}^j = \lambda_{ih,t} \forall h \in \mathcal{I}$, and $R_{j,t+1}^f = R_{i,t+1}^f$.

¹⁹Country-level (or even individual-level) consumption and bilateral investment flows can, for example, easily be determined under the assumption that individuals' preference exhibit identical degrees of constant relative risk aversion, that is, all individuals per-period utility functions observe $u(c_{i,t}) = c_{i,t}^{(1-\gamma)}/(1-\gamma)$ for $\gamma > 1$ or $u(c_{i,t}) = \ln c_{i,t}$. Then, every individual in an integrated financial market will own a fraction of the same wealth portfolio, which is the portfolio chosen by the representative agent. The fraction owned by an individual corresponds to his share of wealth in total wealth. Analogously, individual consumption is proportional to consumption of the representative investor, depending, again, only on the individual's share in total wealth (see Rubinstein, 1974 and Grossman and Razin, 1984).

1.3.3.3 The Stochastic Discount Factor and Country Risk Premia

This section shows how the distribution of the SDF derives from the distribution of country-specific productivity shocks in order to understand how the country risk premia $\lambda_{ih,t} = R_{i,t+1}^f \operatorname{Cov}_t \left[\tilde{m}_{i,t+1}, \tilde{Y}_{h,t+1} \right]$ are determined and how they develop over time. Optimal consumption and investment plans in conjunction with the stochastic properties of firms' profits pin down the distribution of future consumption and link the SDF to the country-specific shocks. To make this link explicit, I impose an additional assumption on the stochastic nature of the productivity levels. Specifically, I assume that the productivity levels are indepently and identically distributed over time and follow a multivariate lognormal distribution. This assumption facilitates describing the SDF in terms of current consumption and next-period wealth, with the latter being directly affected by the country-specific productivity shocks through the profits of firms in the investor's portfolio.

Using the budget constraint (1.3) together with Equations (1.2) and (1.4), equilibrium consumption of the representative investor *i* can be expressed in terms of asset wealth and the return to the wealth portfolio. Substituting optimal consumption plans for $C_{i,t}$ and $\widetilde{C}_{i,t+1}$ in $\widetilde{m}_{i,t+1}$ yields $\widetilde{m}_{i,t+1} = f_i(A_{i,t-1}, R^W_{i,t}, A_{i,t}, \widetilde{R}^W_{i,t+1}, \widetilde{A}_{i,t+1})$. Moreover, $\widetilde{A}_{i,t+1}$ can be replaced by the sequence of optimal future investments, which depend on initial wealth and the evolution of asset prices and returns, to pin down the SDF as

$$m_{i,t+1} = f_i \left(A_{i,t-1}, R_{i,t}^W, A_{i,t}, \widetilde{R}_{i,t+1}^W, \{ \widetilde{\boldsymbol{v}}_{t+s}^i \}_{s=1}^\infty, \{ \widetilde{\boldsymbol{\pi}}_{t+s}^i \}_{s=1}^\infty, \{ R_{i,t+s}^f \}_{s=1}^\infty \right),$$
(1.19)

a function of current wealth and investment and exogenous parameters (from the investor's point of view) only. See Appendix A1.1 for details of the derivation.

Generally, the precise relationship $f_i(\cdot)$ depends crucially on two fundamentals; the nature of the stochastic processes guiding the distribution of returns and the functional form of $u_i(\cdot)$.²⁰ Fama (1970) showed that the multiperiod consumption choice problem can be reduced to a two-period problem of choosing between today's consumption and

It follows that for all countries k, j in I_i , country-level consumption $C_{k,t}$ and bilateral investment $a_{kj,t}$ are proportional to the representative investor *i*'s consumption C_i and investment into the firms from all countries in $\mathcal{I}_i, a_{ij,t}$, with the factor of proportionality equal to $W_{k,t}/W_{i,t}$ where $W_{i,t} = \sum_{k \in \mathcal{I}_i} W_{k,t}$.

²⁰If the shocks are independent over time, fluctuations in returns do not indicate changes in investment opportunities and do no affect total discounted future wealth of the infinitely lived agent. In contrast, if returns are non-stationary, changes in returns do imply changes in investors' total wealth and changes in the set of investment opportunities and, therefore, may affect long-run consumption plans. How quickly investors return to the their steady long-run consumption level after a temporary shock crucially depends on the elasticity of intertemporal substitution, a feature inherent to $u(\cdot)$. If shocks are permanent, $u(\cdot)$ determines whether income effects of higher expected returns in the future on current consumption dominate substitution effects from changes in the incentive to invest.

tomorrow's wealth if investment returns are independently and identically distributed over time, that is, if the set of investment opportunities is independent of the current state or past states of the economy. This implies, that $f_i(\cdot)$ can be written as $g_{i,t}(\widetilde{R}^W_{i,t+1})$, a function of the return to wealth in t + 1 and variables determined in the previous period, with the latter being subsumed in the i, t index of the function. Moreover, as the pioneers of the Capital Asset Pricing Model (CAPM) (Sharpe, 1964; Lintner, n.d.; and Black, 1972) have shown, $g_{i,t}(\cdot)$ is *linear* in $\widetilde{R}^W_{i,t+1}$ if returns are normally distributed, *independently* of the functional form of $u_i(\cdot)$.

Let us assume that productivity levels are lognormally distributed with constant mean and variance, that is, $\forall t$

$$\widetilde{\boldsymbol{\psi}}_t \sim Lognormal\left(\boldsymbol{\mu}, \boldsymbol{\Sigma}\right).$$
 (1.20)

Then, productivity shocks follow an approximate normal distribution $\tilde{\hat{\psi}}_{t} \underset{apprx.}{\sim} N\left(\boldsymbol{\mu}^{\hat{\psi}}, \boldsymbol{\Sigma}^{\hat{\psi}}\right)$, where $\tilde{\hat{\psi}}_{t} = \left[\tilde{\hat{\psi}}_{1,t}, ..., \tilde{\hat{\psi}}_{h,t}, ..., \tilde{\hat{\psi}}_{I,t}\right]'$ with typical element $\tilde{\hat{\psi}}_{h,t} = \frac{\psi_{h,t} - E_{t-1}[\psi_{h,t}]}{E_{t-1}[\psi_{h,t}]}$. The approximation works best in the neighborhood of zero. Rewriting returns in Equation (1.18) using Equation (1.9) as

$$\widetilde{R}_{j,t+1} = \sum_{h \in \mathcal{I}} \frac{\phi_{jh,t} Q_{h,t}^{\eta} \mu_h}{v_{j,t}} \cdot \widetilde{\widehat{\psi}}_{h,t+1}$$

shows that returns are linear combinations of productivity shocks. Hence, they inherit the approximate normal distribution. Moreover, from the investor's point of view at time t, future returns follow i.i.d. distributions as well if he does not expect changes in $\phi_{jh}, Q_h(\boldsymbol{q}, \boldsymbol{N})$, and v_j in any future period t+s to be systematically related to realizations of $\tilde{\boldsymbol{\psi}}^{21}$ Under those assumptions, the results of Fama (1970) can be applied to obtain a linear discount factor model:

$$\widetilde{m}_{i,t+1} = \zeta_{i,t} + \gamma_{i,t} \widetilde{R}_{i,t+1}^W \quad \text{where} \quad \gamma_{i,t} < 0.$$
(1.21)

For details of the derivation, which in parts follows Cochrane (2005), Chapter 9, see Appendix A1.1.

²¹This requires a certain degree of myopia on the part of investors. Specifically, it requires assuming that investors do not take into account general equilibrium adjustments in the number of firms and their market-specific profits following a specific realization of global productivity levels at any future date.

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The linear model for the SDF facilitates deriving an explicit expression for $\lambda'_{i,t} = [\lambda_{i1,t}, ..., \lambda_{ih,t}, ..., \lambda_{i\mathcal{I},t}]$, the covariances of the SDF with the country-specific productivity shocks. To ease notation, I henceforth drop the tilde symbol for random variables. Using Equation (1.18) together with the expression for $R^W_{i,t+1}$ in Equation (1.4), the SDF can be written as a linear function of asset returns:

$$m_{i,t+1} = \zeta_{i,t} + \gamma_{i,t} \sum_{j \in \mathcal{J}_{i,t}} \frac{a_{ij,t}}{A_{i,t}} \sum_{h} \phi_{jh,t} \mathcal{E}_t \left[Y_{h,t+1} \right] \left(\frac{Y_{h,t+1}}{\mathcal{E}_t \left[Y_{h,t+1} \right]} \right)$$
(1.22)

Equation (1.22) implies that *partial* covariances of $m_{i,t+1}$ with demand growth in any country h are given by the coefficients from a linear regression of the form $m_{i,t+1} = b_{i0,t} + \mathbf{b}'_{i,t} \hat{\mathbf{Y}}_{t+1}$ with $\mathbf{b}'_{i,t} = [b_{i1,t}, ..., b_{ih,t}, ..., b_{iH,t}]$ and $\hat{\mathbf{Y}}'_t = [\hat{Y}_{1,t}, ..., \hat{Y}_{h,t}, ..., \hat{Y}_{\mathcal{I},t}]$, where

$$b_{ih,t} = \gamma_{i,t} \sum_{j \in \mathcal{J}_{i,t}} \frac{a_{ij,t}}{A_{i,t}} \phi_{jh,t} \mathcal{E}_t \left[Y_{h,t+1} \right].$$
(1.23)

Equation (1.23) shows that the partial correlation of the SDF with country h's demand growth is a weighted sum of exports by all firms in the investor's portfolio, where each firm is weighted by its portfolio share. Note that the theory implies $\gamma_{i,t} < 0$; hence, a larger exposure to demand growth in h through higher exports implies a stronger *negative* partial correlation with the SDF. What matters for investors' perception of riskiness, however, is not the partial correlation, but the overall correlation, which takes into account that firms also sell to other countries exhibiting demand shocks that may be correlated with the shocks in country h. The covariances of country-specific shocks with country i's SDF (scaled with the risk-free rate) are thus given by

$$\boldsymbol{\lambda}_{i,t} = R_{i,t+1}^{f} \operatorname{Cov}_{t} \left[m_{i,t+1}, \hat{\boldsymbol{Y}}_{t+1} \right] = R_{i,t+1}^{f} \operatorname{Cov}_{t} \left[\hat{\boldsymbol{Y}}_{t+1}, \hat{\boldsymbol{Y}'}_{t+1} \right] \boldsymbol{b}_{i,t}, \quad (1.24)$$

with hth element equal to

$$\lambda_{ih,t} = R_{i,t+1}^{f} \text{Cov}_t \left[m_{i,t+1}, \hat{Y}_{h,t+1} \right] = R_{i,t+1}^{f} \left(\sigma_t^{\hat{Y}_h} \right)^2 b_{ih,t} + R_{i,t+1}^{f} \sum_{k \neq h} \sigma_t^{\hat{Y}_h, \hat{Y}_k} b_{ik,t}.$$
(1.25)

Note that the bs are themselves functions of the λ s so that Equation (1.25) is an implicit expression for $\lambda_{ih,t}$.

Using the linear SDF from Equation (1.22) to rewrite the Euler equation (1.6) as

$$\mathbf{E}_{t}\left[R_{j,t+1}\right] - R_{i,t+1}^{f} = -\boldsymbol{\lambda}_{i,t}^{\prime}\boldsymbol{\beta}_{j,t} \tag{1.26}$$

shows that the λ s can be interpreted as monetary risk premia.²² Equation (1.26) decomposes the return that j's share earns in excess of the risk-free rate on average, which is the compensation investors demand for its riskiness, into a risk price and a risk quantity associated with the firm's activity in every market. The quantity component, $\beta_{jh,t}$, measures firm j's exposure to demand volatility in market h. More precisely, $\beta_{jh,t}$ is the elasticity of the firm's value with respect to demand growth in market h. According to Equation (1.18), it equals the share of expected sales in market h in the total present value of the firm, that is, $\beta_{jh,t} = \frac{\phi_{jh,t} E_t[Y_{h,t+1}]}{v_{j,t}}$. The λ s measure how much compensation in terms of average return in excess of the risk-free rate investors demand per unit of exposure $\beta_{jh,t}$ to volatility in market h.

1.3.4 Equilibrium Risk Premia and the Risk-Return Tradeoff

The risk premia obtaining in equilibrium are outcomes of investors' risk-return tradeoff. This section explains the intuition behind this tradeoff and, more specifically, it shows that the risk premia will generally be nonzero, even with perfectly integrated international asset markets. In complete financial markets investors can freely trade and create assets. However, the creation of primary assets is subject to the stochastic properties of the investment opportunities, and the creation of other financial assets is subject to the restriction that they be in zero net supply in equilibrium. The latter implies that financial assets can be used to eliminate investors' idiosyncratic risk, but have no role in mitigating aggregate risk, since zero net supply means that somebody's gain from holding such an asset must be somebody else's loss.

The amount of aggregate risk present in equilibrium, defined as volatility of the SDF, is thus purely an outcome of investment choices. Aggregate risk is absent if and only if consumption does not vary over time. Equation (1.22) shows that the volatility of the SDF derives from the volatility of the country-specific shocks, where the individual countries' contributions depend on firms' export choices $\phi_{jh,t} E_t[Y_{h,t+1}]$ and investors' portfolio choices $a_{ij,t}$. It is apparent that the potential for eliminating consumption risk through portfolio management is constrained by the correlation pattern of country shocks. Unless some shocks are perfectly negatively correlated, the only way to set the variance of the SDF to zero is zero investment in risky assets. This means that no firm is active and investors put all their savings into the risk-free asset. All λ s will then be zero. For this

 $^{^{22}}$ See Appendix A1.3 for details of the derivation.

to be an equilibrium outcome, however, the value of creating a new firm must be zero. Rewriting Equation (1.14) in terms of exogenous variables and λ only yields

$$V_{j,t}^{*} = \frac{1-\theta}{\theta^{\frac{\eta}{\eta-1}}} \sum_{h\in\mathcal{I}} \left(\frac{1+\lambda_{h,t}^{j}}{R_{j,t+1}^{f}}\right)^{\varepsilon} \frac{(c_{j}\tau_{jh})^{-\varepsilon} \mathbf{E}_{t} \left[\psi_{h,t+1}\right]^{\frac{\eta}{1-\eta}}}{\left(\sum_{j\in\mathcal{I}} N_{j} (c_{j}\tau_{jh}R_{j,t+1}^{f})^{1-\varepsilon} (1+\lambda_{h,t}^{j})^{\varepsilon-1}\right)^{\frac{\varepsilon-\eta\varepsilon-1}{(\varepsilon-1)(\eta-1)}}} - \alpha_{j}.$$
(1.27)

Since $\varepsilon - \eta \varepsilon - 1 < 0$, the value of creating a new firm goes to infinity as the number of firms approaches zero. This owes to the fact that marginal productivity of the first variety is infinite, by the assumption that $\frac{\eta \varepsilon}{\varepsilon - 1} < 1$, and it holds for $\lambda \leq 0$. Hence, avoiding any exposure to aggregate risk by not investing into firms at all cannot be an equilibrium outcome.

Now suppose that the covariance structure of country shocks permits hedging aggregate risk because at least one country's shocks are perfectly negatively correlated with the rest. Investors can exploit the hedging opportunity by buying firms from the country with negatively correlated shocks. Or, more generally, by buying firms that sell a lot to this market. This is precisely what the Euler equation commands: the willingness to pay is larger for assets that correlate positively with the SDF. However, only under special conditions will it be optimal to exploit the hedging opportunity to its full extent, that is, to completely eliminate aggregate risk. The reason lies again with the decreasing returns to scale inherent in the production function. Financing more firms that ship a lot to a certain destination market that correlates negatively with the SDF means that the amount of the composite good produced in this country increases. This implies a decrease in the marginal productivity of the composite good and a decrease in firms' expected market-specific profits. Equation (1.27) shows that, ceteris paribus, the value of an individual firm falls in the number of firms selling to a given market. Hence, investors are faced with a classical risk-return tradeoff where the optimal choice is generally not to fully eliminate aggregate risk.

A two-country example makes this point very clear. Suppose there are only two countries i and h, which are identical with regard to production cost for varieties, trade cost, and the risk-free rate. That is, suppose $\mathcal{I} = (i, h)$, $c_i = c_h = c$, $\alpha_i = \alpha_j = \alpha$, $\tau_{ih} = \tau_{hi} = \tau$, $\tau_{ii} = \tau_{hh} = 1$. Moreover, suppose that the variance of productivity shocks is identical in both countries, $\sigma^{\hat{\psi}_h} = \sigma^{\hat{\psi}} = \sigma^{\hat{Y}}$, and that shocks are perfectly negatively correlated, $\rho^{\hat{Y}_i,\hat{Y}_h} = \frac{\sigma^{\hat{Y}_i,\hat{Y}_h}}{\sigma^{\hat{Y}_i}\sigma^{\hat{Y}_h}} = -1$. The two countries may differ in their initial level of asset wealth $A_{i,t} \leq A_{h,t}$ and in the mean of the productivity level. Further suppose, without loss of generality, that $E_t [\psi_{h,t+1}] \geq E_t [\psi_{i,t+1}]$. Finally, assume, for simplicity, that asset mar-

kets are fully integrated and preferences exhibit constant relative risk aversion. Complete elimination of aggregate risk would then imply that the country risk premia as described in Equation (1.25) jointly obey

$$\lambda_{k,\ell} = R_{k,t+1}^{f} \operatorname{Cov}_{t} \left[m_{k,t+1}, \hat{Y}_{\ell,t+1} \right] = 0 \quad \forall \ k,\ell = i,h$$

$$\Leftrightarrow \quad \operatorname{E}_{t} \left[Y_{\ell,t+1} \right] \left(a_{k\ell} \phi_{\ell\ell,t} + a_{kk} \phi_{k\ell,t} \right) = -\rho^{\hat{Y}_{k},\hat{Y}_{\ell}} \cdot \operatorname{E}_{t} \left[Y_{k,t+1} \right] \left(a_{kk} \phi_{kk,t} + a_{k\ell} \phi_{\ell k,t} \right) \quad \forall \ k,\ell = i,h$$

$$\Leftrightarrow \quad \operatorname{E}_{t} \left[Y_{h,t+1} \right] = \operatorname{E}_{t} \left[Y_{i,t+1} \right]. \tag{1.28}$$

The third step follows from the fact that with fully integrated international asset markets and constant and equal degrees of relative risk aversion, investors in both countries will own a share of the same international market portfolio. That is, $a_{ii,t} = \varphi N_{i,t}$, $a_{hi,t} = \varphi N_{i,t}$ $(1-\varphi)N_{i,t}, a_{ih,t} = \varphi N_{h,t}, a_{hh,t} = (1-\varphi)N_{h,t}, \text{ where } \varphi/(1-\varphi) = A_{h,t}/A_{i,t}.$ Equation (1.28) states that zero risk premia obtain if expected final goods production between the two countries is equalized. Note that Equation (1.28) together with $E_t[\psi_{i,t+1}] \leq E_t[\psi_{h,t+1}]$ implies $Q_{i,t} \ge Q_{h,t}$, that is, the output of the composite good is larger in the less productive market. This already suggests that an allocation yielding $\lambda_{ih} = 0$ is not efficient. To make this argument formally, I show in Appendix A1.4 that to obtain equal expected output in both countries, the number of firms in the less productive country i must be larger and, hence, firms from country i face a more competitive environment. This is reflected in smaller equilibrium net present values of firms from country i compared to firms from country h, which is inconsistent with the free entry condition mandating that net present values be equal and zero in both countries. It follows that $\lambda_{k\ell} = 0 \ \forall \ k, \ell = i, h$ can be an equilibrium consistent with optimal choices of firms and investors only in the knife-edge case where $E_t [\psi_{h,t+1}] = E_t [\psi_{i,t+1}].$

Generally, firms make larger profits by selling more to more productive and less crowded markets. The amount of aggregate risk taken on by investors in equilibrium balances the incentive to finance firms that make higher profits with the desire for smooth consumption. Perfect consumption insurance and zero risk premia are feasible but suboptimal if investors put all their wealth into the risk-free asset. Alternatively, perfect consumption insurance and positive investment in firms is possible when, for every country, there is at least one other country exhibiting perfectly negatively correlated shocks. But even then, zero aggregate risk will be an equilibrium outcome only in special cases, such as the one just outlined.

1.4 Empirics

1.4.1 Estimating λ

There are three challenges to estimating $\lambda_{ih,t}$. First, the SDF is not observed; hence, direct linear estimation as suggested by Equation (1.21) is not feasible. Second, the theory (see Subsection 1.3.3.3) suggests that the coefficients $\zeta_{i,t}$, $\gamma_{i,t}$ vary over time as investors make changes to their consumption plans depending on the current level of wealth. Third, as implied by Equation (1.22), bilateral exposures $b_{ih,t}$ change when investors change their portfolio and firms adjust their sales structure. I borrow methodology from the empirical asset pricing literature to address the first and second issue by means of GMM estimation of an unconditional version of investors' first-order conditions in conjunction with the linear model for the SDF. I address the third issue by estimating the λ s for rolling time windows.

The Euler equations (1.6) and (1.5) imply that $m_{i,t+1}$ prices every asset $j \in \mathcal{J}_{i,t}$. Hence, I obtain a moment condition of the form

$$1 = \mathcal{E}_t [m_{i,t+1} R_{j,t+1}] \qquad \text{where} \qquad m_{i,t+1} = \zeta_{i,t} + \gamma_{i,t} R^W_{i,t+1} \tag{1.29}$$

that holds for every asset at each point in time, and one additional condition that identifies the mean of the SDF as the inverse of the risk-free rate:

$$\frac{1}{R_{i,t+1}^f} = \mathcal{E}_t \left[m_{i,t+1} \right]. \tag{1.30}$$

The moment conditions are functions of the parameters $\zeta_{i,t}$, $\gamma_{i,t}$ and data, namely, the return on the wealth portfolio. By the law of iterated expectations and under the assumption that $\zeta_{i,t}$ and $\gamma_{i,t}$ are uncorrelated with the return to the wealth portfolio, taking expectations over time, $1 = E[E_t[m_{i,t+1}R_{i,t+1}]]$, yields unconditional moments

$$1 = \mathbb{E}\left[\left(\zeta_i + \gamma_i R_{i,t}^W\right) R_{j,t+1}\right] \quad \forall j \in \mathcal{J}_{i,t} \quad \text{and} \quad 1 = \mathbb{E}\left[\left(\zeta_i + \gamma_i R_{i,t}^W\right) R_{i,t+1}^f\right] \quad (1.31)$$

where $\zeta_i = E[\zeta_{i,t}]$ and $\gamma_i = E[\gamma_{i,t}]$. I estimate Equation (1.31) with GMM using data on $R_{i,t}^W$ and data on individual asset returns $R_{j,t}$. With the estimated parameters, I predict a time series of the SDF and then compute $\lambda_{ih,t} = R_{i,t+1}^f \operatorname{Cov}_t \left[m_{i,t+1}, \hat{Y}_{h,t+1} \right]$ for rolling time windows of length T, that is, I compute $R_{i,t}^f = T^{-1} \sum_{s=0}^T R_{i,t-s}^f$ and $\operatorname{Cov}_t \left[m_{i,t+1}, \hat{Y}_{h,t+1} \right] = T^{-1} \sum_{s=0}^T \left[m_{i,t-s} \cdot \hat{Y}_{h,t-s} \right] - T^{-2} \sum_{s=0}^T m_{i,t-s} \cdot \sum_{s=0}^T \hat{Y}_{i,t-s}.$

Return data	# Obs.	Mean	Std. Dev.	Min	Max
Time	450			1977M1	2014M6
r^f	450	0.41	0.29	0	1.35
r^W	450	1.02	4.49	-22.64	12.89
\overline{R}^e	49	.73	.17	.37	1.24
Import growt	h data				
Time	360			1983M1	2012M12
$\mu^{\hat{Y}}$	180	0.04	0.05	0.01	0.45
$\sigma^{\hat{Y}}$	180	0.27	0.35	0.06	2.61

 Table 1.1: Summary statistic of return and import growth data

Returns in %. \overline{R}^e is the average excess return (gross return minus risk-free rate) of industry portfolios over time. $\mu^{\hat{Y}} (\sigma^{\hat{Y}})$ denotes the mean (standard deviation) of country-specific demand shocks over time.

1.4.2 Estimating λ s for the U.S. Financial Market

I estimate risk premia with respect to 175 countries for the U.S. financial market, since my empirical analysis of the impact of risk premia on exports will be based on U.S. exports. Hence, I assume that the SDF of investors trading on the U.S. financial market is the relevant SDF for U.S. firms. As discussed above, this is consistent with the cases where investors from (a subset of) all countries (including the United States) trade freely on a supranational asset market as well as with financial autarky. The export data span the years 1992 to 2012 and I estimate a $\lambda_{h,t}^{US}$ for every market in every year based on data reaching back 10 years into the past. That is, I estimate the covariance of demand shocks and the mean of the risk-free rate based on the 10 most recent years.

1.4.2.1 Data

For monthly asset returns I use 49 value-weighted industry portfolios provided by Kenneth R. French through his Data Library.²³ The portfolios are constructed based on all stocks traded on NYSE, AMEX, and NASDAQ. Theoretically, every asset and every portfolio of assets available to U.S. investors could be used to estimate Equation (1.31). Figure A1.2 in the Appendix plots the distribution of excess returns to the industry portfolios. A robustness check with regard to this choice of test assets will be provided. I follow the asset pricing literature by approximating R_t^W , the return on the wealth portfolio, with

 $^{^{23}} http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data\ library.html$

Time period:	1977M1 - 2014M6	1977M1 - 1989M6	1989M7 - 2001M12	2002M1 - 2014M6
ζ_{US}	1	.99	1	1
[t-stat.]	[133]	[90.4]	[80.2]	[80.2]
$oldsymbol{\gamma}_{IIS}$	-3.37	-2.92	-3.81	-3.61
[t-stat.]	[-2.54]	[-1.50]	[-1.86]	[-1.24]
# Moment Conditions	50	50	50	50
# Observations	450	150	150	150
# Parameters	2	2	2	2
Test of joint signific.: χ_e^2	49280	35166	12818	17206
$P(\chi_2^2 > \chi_c^2)$	0	0	0	0
J-Test: J -Stat	97	397.8	161.5	196.8
$\mathbf{P}(\chi^2_{48} > J)$	0	0	0	0

Table 1.2: Parameter estimates of the linear SDF model

Results from first-stage GMM.

the return to the value-weighted market portfolio including all stocks traded on NYSE, AMEX, and NASDAQ. Monthly data on the market portfolio and the risk-free rate are also from Kenneth R. French's Data Library.

I use total monthly imports by country obtained from the IMF's Direction of Trade Database to measure demand growth. Growth is measured with respect to the previous month and rates are adjusted for constant monthly factors. Table 1.1 summarizes the data used to estimate the risk premia. The data appendix A1.5 gives details more details.

1.4.2.2 Results

Table 1.2 summarizes the results from GMM estimation of Equation (1.31). Column (1) shows parameter estimates based on the full sample period, which are strongly significant. As suggested by the theory, γ is negative; hence, the return to market portfolio is negatively related to the SDF. Columns (2) through (4) repeat the estimation for consecutive subperiods of the sample, each covering 12.5 years. In view of the assumption that the coefficients $\zeta_{i,t}$, $\gamma_{i,t}$ are uncorrelated with returns, which underlies the unconditional moments (1.31), it is reassuring that the estimates barely change over time.

I use the estimates in Column (1) to predict a time series of the SDF in accordance with Equation (1.21) and then compute covariances with import growth scaled with the average risk-free rate as in Equation (1.25) for each point in time, always going back 120 months into the past. Figure 1.1 presents an overview of the results. The left panel plots correlation coefficients based on 10-year windows of monthly import growth data and the predicted time series of the SDF; the right panel shows the distribution of estimated λ s. Both panels show that the median values, as well as the whole distribution, have been

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Figure 1.1: Estimated correlation coefficients and risk premia with U.S. investors' SDF

The figure shows correlation coefficients (left panel) and covariances scaled by the average risk-free rate (right panel) of country-specific demand shocks with the SDF of U.S. investors. Grey bars denote the range of the distribution between the 10th and 90th percentile.

shifting downward over time. In view of Equation (1.25), this may be interpreted as the United States becoming more integrated with the rest of the world and taking advantage of the diversification benefits available in integrated international goods and asset markets. The difference between the two panels is due to heterogeneity in the volatility of country shocks, which affects the absolute size of the λ s but not the correlation coefficient. From the right panel it is apparent that volatility in general has been decreasing. The figure also shows correlation patterns for two exemplary countries, Canada and China. Both panels reveal a strong downward trend for Canada, indicating that Canada and the United States have steadily become more integrated. In contrast, China's risk premium has been increasing and was among the highest in 2012, suggesting that trade with China still offers substantial diversification benefits.

Figure A1.3 in the Appendix shows how other countries' risk premia have been developing over time. Generally, I find patterns similar to Canada's for Mexico, Brazil, the EU countries, Australia and New Zealand. I find trends resembling China's, for example, also for Indonesia. Russia's risk premium exhibits barely any change. Table A1.6 in the Appendix lists the risk premia for all countries in selected years.

1.4.3 Testing the Relevance of Risk Premia in the Gravity Model

1.4.3.1 Empirical Model and Data

With the estimated risk premia in hand, I can now test the main prediction of the model, which states that firms take into account the riskiness of markets for their investors when deciding how much to ship to a given market, as implied by Equation (1.12):

$$q_{jh,t}^* = \frac{\theta(1+\lambda_{h,t}^j)^{\varepsilon} \left(R_{j,t+1}^f c_{j,t} \tau_{jh,t}\right)^{-\varepsilon}}{\sum_{j \in \mathcal{I}} N_{j,t} (1+\lambda_{h,t}^j)^{\varepsilon-1} \left(R_{j,t+1}^f c_{j,t} \tau_{jh,t}\right)^{1-\varepsilon}} \cdot \mathcal{E}_t \left[Y_{h,t+1}\right]$$

Note that I add an index t to the cost parameters to acknowledge that they are potentially time varying as well. I use finely disaggregated product-level exports from the United States to 175 destination countries to test whether exports are, ceteris paribus, higher to countries exhibiting larger covariances with the SDF of U.S. investors.²⁴ The data are from the U.S. Census Bureau's Foreign Trade Division and cover the universe of U.S. exports. I use three equally spaced time periods between 1992 and 2012 to allow structural changes in risk premia over time to come into effect. I consider more years of data in a robustness analysis. My main estimation equation is a log-linear version of Equation (1.12),

$$\ln q_{jh,t} = \varepsilon \ln(1+\lambda_{h,t}^j) - \varepsilon \ln \tau_{jh,t} - \varepsilon \ln \left(R_{j,t+1}^f c_{j,t}\right) + \ln \theta + \ln \operatorname{E}_t\left[Y_h\right] + \ln \Pi_{jh,t}, \quad (1.32)$$

where $\Pi_{jh,t} = \sum_{j \in \mathcal{I}} N_{j,t} (1 + \lambda_{h,t}^j)^{\varepsilon-1} \left(R_{j,t+1}^f c_{j,t} \tau_{jh,t} \right)^{1-\varepsilon}$. In the empirical model, j now indicates a product and h is a destination market. My dependent variable is the quantity (in kilograms) of product j shipped to country h in year t. I use an algorithm developed by Pierce and Schott (2012) to concord a total of 12,364 HS 10-digit product categories from the original dataset over time. This yields 7,056 product groups that are robust with respect to changes in the classification and the creation or elimination of product categories. Export quantities and values are aggregated to the level of these synthetic product codes. I use shipments by air or vessel only, which make up more than 90% of value shipped for about 98% of all observations; robustness checks with regard to this choice will be provided. Table A1.7 summarizes all variables used in the gravity

 $^{^{24}}$ I observe 180 destination countries in the dataset, but only for 175 of them data on all relevant variables is available.

estimations and contains details regarding data sources and variable definitions. The data appendix A1.5 provides further details.

On the right-hand side of Equation (1.32) I use logs of real GDP and real per capita GDP to proxy for expected demand in the destination country.²⁵ I use product-time fixed effects $d_{j,t}$ throughout the estimations, which absorb everything that is inherent to the product at a given point in time, but does not vary across destination markets, such as production cost, quality, or the world level of demand. These product-time fixed effects also absorb the risk-free rate. Moreover, I include product-country fixed effects d_{jh} to capture market-product-specific characteristics that do not vary over time, such as part of the trade costs and the time-constant component of country h's degree of market competition, $\Pi_{ih,t}$, also known as multilateral resistance. For the time-varying part of the trade cost, I use a binary trade agreement indicator and estimates of freight cost for shipments by vessel and air. Since I do not directly observe freight cost for U.S. exports, I use data on U.S. imports by product and country of origin, also from the U.S. Census Bureau's Foreign Trade Division, to calculate median ad valorem shipping cost by partner country and time, assuming that bilateral freight costs of imports are a reasonable proxy for bilateral freight costs of exports. Since the availability of tariff data is limited, I include them only in a robustness analysis. The empirical model used to test the model's central prediction is thus

$$\ln q_{j^{US}h,t} = \beta_1 \ln(1 + \lambda_{h,t}^{US}) + \beta_2 FreightCost_{h,t} + \beta_3 RTA_{h,t} + \beta_4 \ln GDP_{h,t} + \beta_5 \ln CGDP_{h,t} + d_{jh} + d_{j,t} + u_{jh,t}.$$
(1.33)

A potential omitted variables concern involves the fact the multilateral resistance terms $\Pi_{jh,t}$ may vary across time and products and are thus not fully captured by productdestination and product-time fixed effects. Hence, consistent estimation of the coefficients in Equation (1.33) with OLS relies on the assumption that the time-varying component of $\Pi_{jh,t}$, that ends up in the error term, is uncorrelated with the regressors. The disaggregation of the data by transportation mode, which I describe below, allows addressing this issue.

²⁵Given that in the presence of time lags firms base export quantities on the *expected* level of demand, this choice is not innocuous. But it is hard to come by a better proxy. Besides the fact that exporters' expectation are unobserved, the exact point in time at which the expectation is formed is also unknown. Note that t here denotes the point in time when the goods pass U.S. customs. If production of the good took a significant amount of time, the firm might have formed the relevant expectation much earlier. Some relief is provided by the fact that I look at total shipments within a year. If expectations are rational, then the sum of expected demand over subperiods of time should converge to the total realized level of demand. I conduct a robustness test using GDP and GDP per capita from the previous year.

First, however, I consider heterogeneity of the effect of λ across sectors to assess the validity of the model's key assumption, which is that the correlation pattern of demand shocks matters because of a time lag between production and sales. If firms could immediately adjust quantities to the current demand level, they would still exhibit volatile profits and thus expose their investors to risk, yet current sales would be perfectly explained by the current level of demand and the λ s should not matter. I use Rajan and Zingales's (1998) measure of external finance dependence to differentiate sectors based on their need for upfront investment, which is measured by the average share of capital expenditure that cannot be financed by the cash flow from the same project. Presuming that a need for upfront investment implies that there is a relevant time lag between production and sales, I test whether exports of products from sectors that are more dependent on upfront investment are more strongly affected by the correlation pattern of country shocks by means of an interaction term $\ln(1 + \lambda_{h,t}^{US}) \times ExtFinDep_{s^j,t}$. s^j denotes the sector defined by the NAICS six-digit code to which product j belongs.²⁶

Next, I consider heterogeneity across transportation modes. Products shipped by vessel and by air to the same market at the same point in time provide me with a nice opportunity to test for the relevance of a time lag caused by shipping. Arguably, air shipments are less or not at all exposed to demand volatility once the good has reached the U.S. border. To test this presumption, I estimate Equation (1.33) separately for shipments by air and shipments by vessel. As an alternative estimation strategy, I pool shipments by both transportation modes and assess a differential impact of λ by means of an interaction term with a zero-one indicator for air shipment. Hence, I estimate

$$\ln q_{j^{US}h,t}^{m} = \beta_{1} \ln(1 + \lambda_{h,t}^{US}) + \beta_{11} \ln(1 + \lambda_{h,t}^{US}) \times Air_{jh,t}^{m} + \beta_{2} FreightCost_{h,t} + \beta_{3} RTA_{h,t} + \beta_{4} \ln GDP_{h,t} + \beta_{5} \ln CGDP_{h,t} + d_{jmh} + d_{jm,t} + u_{jmh,t}$$
(1.34)

where $m \in (Air, Ves)$, to test whether risk premia have a differential effect on shipments by air relative to shipments by vessel. The disaggregation by transportation mode also allows me to estimate this interaction term with a specification where product-destinationtime fixed effects take care of time-varying multilateral resistance terms:

$$\ln q_{j^{US}h,t}^m = \beta_{11} \ln(1 + \lambda_{h,t}^{US}) \times Air_{jh,t}^m + d_{jmh} + d_{jm,t} + d_{jh,t} + u_{jmh,t}$$
(1.35)

²⁶There are a few products where the assignment to NAICS six-digit sectors is no longer unique after aggregating HS10 digits to time consistent product groups as described above. I use weighted averages of the ExtFinDep measure in those cases.

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The sign of the direct effect λ on shipments by air is a priori ambiguous. Consider the extreme case where the only cause of a time lag is transit time by vessel so that production and delivery by air is possible instantly.²⁷ Shipments by vessel, however, have the advantage of being cheaper. In line with the logic laid out by Aizenman (2004) and Hummels and Schaur (2010), firms will ship some positive quantity by vessel and whenever demand shocks are positive and large, they will exercise the option of shipping some more by expensive air transport. Under these conditions, air shipments are fully explained by the current level of demand and the quantity previously shipped by vessel. If vessel shipments are larger to markets offering diversification benefits in terms of positive λ 's, then the option value of serving those markets by air is smaller. Hence, we would expect to see a negative impact of λ on shipments by air. Arguably, the case of instant delivery is extreme. Time lags caused by production and shipping to the airport, as well as customs procedures, are likely also relevant for shipments by air and hence imply some degree of exposure to market-specific demand volatility. Which effect dominates is an empirical question.

1.4.3.2 Results

Column (1) of Table 1.3 shows parameter estimates from the baseline specification (1.33). Estimations are based on three years of data, equally spaced between 1992 and 2012, and rely on time variation over time within product-country cells only. Unobserved product-time-specific heterogeneity is controlled for by additional fixed effects. Throughout all estimations I calculate standard errors that are robust to two-way clusters within products and countries, as advocated by Cameron et al. (2011).

I find that the risk premia have a significantly positive effect on export quantities. I standardized $\ln(1+\lambda)$ to make coefficients comparable across specifications. The standard deviation of $\ln(1 + \lambda)$ is .005; hence, the non-standardized coefficient corresponding to .033 in Column (1) is 6.6. This implies that a 1% increase in $1+\lambda$ increases trade by 6.6%. In view of Figure 1.1, this means that the change of .3% in Canada's risk premium from the level in 1992 to the level of 2012 has led to a decrease in trade of about 2%. Changing China's risk premium in 2012 to the level of Canada's in 2012 would result in a trade effect of similar magnitude. Note, however, that this is a partial equilibrium argument, since the λ s are themselves decreasing functions of the amount of trade between the United States and a given destination market. Hence, the general equilibrium effect is likely to

²⁷Alternatively, one might consider a case where production does take time but quantities do not need to be customized to a specific market.

be smaller in absolute terms. The structural interpretation of the estimate is helpful in gauging the plausibility of its magnitude. The theoretical gravity equation implies that the elasticity of export quantities with respect to the risk premia is equal to ε , where $\varepsilon - 1$ is the elasticity of trade values with respect to trade cost. A implied trade cost elasticity of 5.6 places this estimate well inside the range typically found in the literature.²⁸

In Column (2) I interact the risk premia with Rajan and Zingales's sectoral measure of external financial dependence. I find a positive and significant effect of the interaction, implying that exposure to demand volatility is more important for sectors that have to make considerable investments upfront. This lends support to the model's assumption of a time lag. A similar conclusion can be derived from the analysis of differential effects across modes of transportation. In Columns (3) and (4) I present the results from estimating Equation (1.33) separately for shipments by vessel and by air, respectively. As discussed above, shipments by vessel are expected to be more affected by the correlation pattern of demand shocks than shipments by air, with the effect on the latter being ambiguous a priori. I find that shipments by vessel are indeed more positively and significantly affected. The estimated effect on shipments by air is also positive, but smaller and not significant. Columns (5) - (7) show the results from estimating Equations (1.34) and (1.35) based on the same data set, pooling shipments by air and vessel.²⁹ Column (5) shows that the direct effect of λ is slightly smaller in the estimation based on disaggregated data, which allows controlling for product-destination and product-time fixed effects interacted with the mode of transportation. The negative and significant interaction terms in Columns (6) and (7) show that the differential effect of λ on shipments by air relative to shipments by vessel, as indicated by Columns (3) and (4), is robust to controlling for unobserved heterogeneity on a more disaggregated level. It is reassuring that the inclusion of productdestination-time fixed effects to capture, among other things, time variation in multilateral resistance terms does not affect the estimate of the interaction term. To summarize, I find a positive and significant effect of risk premia on export quantities, suggesting that firms do adjust relative sales across markets in accordance with investors' desire for smooth consumption. The differential effects across sectors and modes of transportation imply that demand volatility constitutes a risk because of a time lag between production and sales, thus lending support to the model's key assumption.

²⁸See, for example, Caliendo and Parro (2015). Note, however, that the estimated magnitude is sensitive to the choice of data frequency used to calculate the covariances (see Subsection 1.4.1) and should hence be interpreted with care.

²⁹Hence, the number of observations is twice as large as in Columns (1), (3), and (4) where I use either total shipments by product and destination or shipments by vessel, respectively, by air, only.

Dep. Var.:	$\ln q_{jh,t}$	$\ln q_{jh,t}$	$\ln q^{Ves}_{jh,t}$	$\ln q_{jh,t}^{Air}$	$\ln q^m_{jh,t}$	$\ln q^m_{jh,t}$	$\ln q_{jh,t}^m$
$\ln GDP$	$0.374 \\ (0.268)$	$\begin{array}{c} 0.308 \\ (0.266) \end{array}$	$\begin{array}{c} 0.240 \\ (0.221) \end{array}$	0.431^{**} (0.198)	0.337^{*} (0.204)	0.337^{*} (0.204)	
$\ln CGDP$	$\begin{array}{c} 0.122 \\ (0.280) \end{array}$	$\begin{array}{c} 0.103 \\ (0.285) \end{array}$	$\begin{array}{c} 0.100 \\ (0.238) \end{array}$	$\begin{array}{c} 0.024 \\ (0.227) \end{array}$	$\begin{array}{c} 0.062 \\ (0.227) \end{array}$	$\begin{array}{c} 0.062 \\ (0.227) \end{array}$	
RTA	0.332^{***} (0.096)	0.349^{***} (0.100)	0.424^{***} (0.114)	$\begin{array}{c} 0.130 \\ (0.081) \end{array}$	0.276^{***} (0.073)	0.276^{***} (0.073)	
$\ln(1+\lambda)$	0.033^{**} (0.015)	$\begin{array}{c} 0.033^{**} \\ (0.017) \end{array}$	0.029^{**} (0.013)	$\begin{array}{c} 0.013 \\ (0.011) \end{array}$	0.021^{*} (0.011)	0.031^{**} (0.013)	
FreightCost	-0.788 (0.963)	-0.495 (0.898)	-0.074 (0.237)	-0.435 (0.367)	-0.276 (0.289)	-0.270 (0.285)	-0.389^{**} (0.194)
\times Air						-0.019^{**} (0.010)	-0.019^{*} (0.010)
$\times ExtFinDep$		0.0003^{*} (0.000)					
Fixed effects	$prd \times yr$ $prd \times cty$	$prd \times yr$ $prd \times cty$	$prd \times yr$ $prd \times cty$	$prd \times yr$ $prd \times cty$	prd×yr×air prd×cty×air	prd×yr×air prd×cty×air	$prd \times yr \times air$ $prd \times cty \times air$ $prd \times cty \times yr$
$\frac{\text{Observations}}{\text{Adjusted }R^2}$	3,360,036 0.645	3,094,634 0.649	3,360,036 0.599	3,360,036 0.629	$6,720,072 \\ 0.612$	6,720,072 0.612	6,720,072 0.228
S.e. (in parentheses) robust to two	-way clusters or	n product and e	country level. S	ignificance levels: *	p < 0.1, ** p < 0.0	5, *** $p < 0.01$.

Table 1.3: Gravity estimations with risk premia

Robustness test:	Tar	iffs	5 yrs $(\Delta = 5)$	21 yrs $(\Delta = 1)$	Export	value	25 FF pfs	FF four factors
Dep. Var.:	$\ln q_{jh,t}$	$\ln q_{jh,t}$	$\ln q_{jh,t}$	$\ln q_{jh,t}$	$\ln s_{jh,t}$	$\ln s_{h,t}$	$\ln q_{jh,t}$	$\ln q_{jh,t}$
$\ln \ GDP$	0.856^{**} (0.388)	0.881^{**} (0.390)	0.454^{*} (0.264)	$0.405 \\ (0.266)$	$0.441 \\ (0.356)$	$\begin{array}{c} 1.009^{***} \\ (0.258) \end{array}$	$\begin{array}{c} 0.373 \\ (0.268) \end{array}$	$0.395 \\ (0.268)$
$\ln CGDP$	$\begin{array}{c} 0.149 \\ (0.398) \end{array}$	$\begin{array}{c} 0.189\\ (0.398) \end{array}$	0.049 (0.275)	-0.043 (0.278)	$\begin{array}{c} 0.217 \\ (0.370) \end{array}$	-0.442^{*} (0.263)	$\begin{array}{c} 0.122 \\ (0.280) \end{array}$	$\begin{array}{c} 0.120 \\ (0.277) \end{array}$
RTA	$\begin{array}{c} 0.191 \\ (0.122) \end{array}$	$\begin{array}{c} 0.211^{*} \\ (0.125) \end{array}$	0.216^{***} (0.077)	0.150^{**} (0.073)	0.446^{**} (0.116)	-0.025 (0.078)	0.332^{***} (0.096)	0.326^{***} (0.096)
FreightCost	-1.912 (2.096)	-1.831 (2.116)	-0.617 (0.607)	-0.877^{*} (0.461)	-1.057 (1.317)	-1.604^{*} (0.883)	-0.788 (0.963)	-0.771 (0.961)
$\ln(1+\lambda)$	$\begin{array}{c} 0.080^{*} \\ (0.045) \end{array}$	0.079^{*} (0.045)	0.025^{*} (0.013)	0.016^{**} (0.008)	0.047^{**} (0.021)	$\begin{array}{c} 0.037^{*} \\ (0.020) \end{array}$	0.033^{**} (0.015)	0.043^{***} (0.016)
ln(1+t)	-0.886^{***} (0.317)							
Fixed effects	$prd \times yr$ $prd \times cty$	$prd \times yr$ $prd \times cty$	$prd \times yr$ $prd \times cty$	$prd \times yr$ $prd \times cty$	$prd \times yr$ $prd \times cty$	yr cty	$prd \times yr$ $prd \times cty$	$prd \times yr$ $prd \times cty$
Observations Adjusted R^2	$1,725,578\\0.616$	$1,725,578\\0.616$	5,718,219 0.669	$\begin{array}{c} 24,418,154 \\ 0.693 \end{array}$	3,360,036 0.667	$3,586 \\ 0.955$	3,360,036 0.645	3,360,036 0.645
S.e. (in	parentheses) rc	bust to two-wa	y clusters on produc	t and country level. S	ignificance level	s: * $p < 0.1$,	** $p < 0.05, ***$	p < 0.01.

 Table 1.4: Gravity estimations with risk premia: Robustness

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Robustness test:	$\operatorname{Air}/\operatorname{Ves}$ only	ex. CAN&MEX	p.kg.freight cost	lagged GDP
Dep. Var.:	$\ln q_{jh,t}$	$\ln q_{jh,t}$	$\ln q_{jh,t}$	$\ln q_{jh,t}$
ln <i>GDP</i>	$\begin{array}{c} 0.360 \\ (0.264) \end{array}$	$\begin{array}{c} 0.367 \\ (0.267) \end{array}$	$\begin{array}{c} 0.400 \\ (0.265) \end{array}$	
ln CGDP	$\begin{array}{c} 0.117 \\ (0.277) \end{array}$	$0.118 \\ (0.279)$	$0.104 \\ (0.283)$	
ln <i>L.GDP</i>				$\begin{array}{c} 0.289 \\ (0.286) \end{array}$
ln <i>L.CGDP</i>				$\begin{array}{c} 0.044 \\ (0.299) \end{array}$
RTA	$\begin{array}{c} 0.323^{***} \\ (0.101) \end{array}$	$\begin{array}{c} 0.321^{***} \\ (0.101) \end{array}$	$\begin{array}{c} 0.329^{***} \ (0.097) \end{array}$	$\begin{array}{c} 0.332^{***} \\ (0.098) \end{array}$
FreightCost	-0.623 (0.905)	-0.692 (0.933)		-0.913 (0.976)
FreightCost p.kg.			$\begin{array}{c} 0.00764 \\ (0.23) \end{array}$	
$\ln(1+\lambda)$	$\begin{array}{c} 0.033^{**} \\ (0.015) \end{array}$	0.033^{**} (0.015)	$\begin{array}{c} 0.034^{**} \ (0.015) \end{array}$	0.028^{**} (0.014)
Fixed effects	$prd \times yr$ $prd \times cty$	$prd \times yr$ $prd \times cty$	$prd \times yr$ $prd \times cty$	$prd \times yr$ $prd \times cty$
Observations Adjusted R^2	$3,\!288,\!307$ 0.639	$3,318,872 \\ 0.645$	$3,360,036 \\ 0.645$	$3,332,73\overline{4}$ 0.646

Table 1.5: Gravity estimations with risk premia: Robustness, continued

S.e. (in parentheses) robust to two-way clusters on product and country level. Significance levels: * p < 0.1, ** p < 0.05, *** p < 0.01.

1.4.3.3 Robustness

I conduct various tests to analyze the robustness of my results with regard to changes in the exact specification of Equation (1.33). Results are collected in Tables 1.4 and 1.5 in the Appendix. First, I include tariffs as additional trade cost variables. Tariff data are available on the HS six-digit level; for some products on higher levels of aggregation. Time and country coverage is very patchy, even after filling in missing values with lags or leads or weighted averages on higher levels of aggregation.³⁰ Hence, I lose a significant share of

 $^{^{30}\}mathrm{I}$ detail the procedures used to fill in missings in Appendix A1.5.

observations. Column (2) of Table 1.4 shows that the effect of λ in this smaller sample is still positive and significant, but also larger. Including tariffs (Column 1) barely affects the coefficient estimate for λ . Next, I re-estimate Equation (1.33) using more of the available years of data: five equally spaced time windows between 1992 and 2012 in Column (3) and all 21 years in Column (4). The effect of λ remains positive and significant. Interestingly, it decreases in magnitude as time windows become narrower. This is consistent with the presumption that the effect of changes in the covariance pattern on exports takes some time to phase in.

In Column (5) I use export values on the product-year-destination level as the dependent variable. I find a positive and significant effect of the risk premia as well. Note that in view of Equation (1.13), this suggests that financial markets are not fully integrated across countries; otherwise, trade shares would be independent of λ . I also estimate a gravity equation on the country level, aggregating values over all products, and I find again a positive and significant effect of the risk premia on exports (Column 6).

I also perform robustness checks with regard to choices made in the estimation of the risk premia. I use Fama and French's 25 benchmark assets as an alternative set of test assets to obtain estimates of γ^{US} , ζ^{US} . These portfolios are constructed based on all stocks traded on NYSE, AMEX, and NASDAQ, which are sorted two-ways by size in terms of equity and by value (ratio of book equity to market equity). This method of portfolio construction, described in detail in Fama and French (1993), has become the benchmark for measuring the performance of models in the empirical asset pricing literature. Moreover, I use the four factor model proposed by Fama and French (2015) as an alternative to the CAPM to obtain a predicted time series of the SDF. The four factor model uses three mean return spreads of diversified portfolios sorted by size (R^{SMB}), by profitability (R^{RMW}), and by investment levels (R^{CMA}) in addition to the return on the market portfolio to describe the SDF as

$$m_{i,t+1} = \zeta_{i,t} + \gamma_{i,t} R_{i,t}^W + \gamma_{i,t}^{SMB} R_{i,t}^{SMB} + \gamma_{i,t}^{RMW} R_{i,t}^{RMW} + \gamma_{i,t}^{SMB} R_{i,t}^{CMA}.$$
 (1.36)

This model is very successful in explaining the cross-section of mean asset returns, but it does not have a theoretical foundation. Table A1.8 presents the parameter estimates using the alternative test assets or the alternative SDF model, obtained from GMM estimation as decribed in Subsection 1.4.1. Changing the test assets has only a small impact on the CAPM estimates. Similarly, adding the additional explanatory factors as prescribed by Equation (1.36) to the linear model of the SDF slightly increases the estimate of $\gamma_{i,t}$ but does not affect its significance. The other factors are not individually significant. I

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use those alternative parameter estimates to predict time series of the SDF and obtain alternative sets of country risk premia. Columns (7) and (8) of Table 1.4 show that the results from the gravity estimation are robust to those variations.

Table 1.5 contains some additional robustness tests. Column (1) shows estimates based on a sample from which I dropped observations for which the share of shipments (in terms of value) by a transportation mode other than air or vessel exceeds 10%. This is the case for about 2% of all observations. In Column (2) I dropped Canada and Mexico, since ground transportation is a relevant alternative shipping mode for contiguous countries. Shipments by vessel and air might reflect extraordinary circumstances. In Column (3) I use freight cost per kilogram instead of ad valorem freight cost and in Column (4) I use lagged values of GDP and per capita GDP as proxies for the expected level of demand. None of these changes to the baseline specification much affects the magnitude or significance of the coefficient estimate for λ .

1.5 Conclusion

Trade's potential for global risk sharing has long been understood, but supportive empirical evidence is rare. Following Backus and Smith (1993), a large literature has shown that the aggregate implications of effective global risk sharing are not borne out by the data. Financial market data show that asset markets continue to be fairly disintegrated (Fama and French, 2012). Nevertheless, competitive firms strive to maximize shareholder value conditional on the level of frictions inhibiting trade of goods and assets on global markets. With risk-averse investors who desire high returns but also smooth consumption over time, this implies optimization of a risk-return tradeoff for every project involving aggregate risk.

In this paper I propose a general equilibrium model of trade in goods and investment in assets that incorporates this logic. I show that irrespective of the degree of financial market integration, shareholder value maximization incentivizes to firms to take into account whether volatility inherent to profits from exporting helps investors diversify the risk of volatile consumption when choosing optimal quantities. The model predicts that firms ship more to markets where profits tend to be high in times when investors' other sources of income do not pay off very well. Aggregation of individual firms' and investors' optimal choices in turn determines the amount of aggregate risk that is taken on by the agents of the model in equilibrium, as well as the extent to which country-specific productivity shocks that determine exporting firms' profits contribute in a positive or negative way to the consumption smoothing of investors from other countries. Using data on returns to firm shares traded on the U.S. financial market, I estimate correlations of country-specific shocks with marginal utility growth of U.S. investors for the years 1992 to 2012. The correlations indicate that over the course of three decades, the United States has become increasingly integrated with the rest of the world, with a consequent decrease in diversification benefits from trade. In a separate analysis based on product-destination market export data for the United States, I show that the differential change in the correlation pattern across countries is consistent with long-term changes in the pattern of trade across destination markets within narrowly defined product categories.

I conclude from this analysis that risk diversification through trade matters at the level of the individual firm and has shaped trade patterns during the past three decades.

Appendix A.1

A1.1 Model Details

Investors' optimization problem. The investor's optimization problem is

$$\max_{\{\boldsymbol{a}_{i,t+s}, a_{i,t+s}^{f}\}_{s=0}^{\infty}} E_{t} \sum_{s=0}^{\infty} \rho^{s} u_{i}(C_{i,t+s})$$

s.t. $C_{i,t+s} = W_{i,t+s} - A_{i,t+s}$
 $W_{i,t+s} = R_{t+s}^{W} A_{t+s-1} = \boldsymbol{a}_{i,t+s-1}^{\prime} \boldsymbol{\pi}_{t+s}^{i} + a_{i,t+s-1}^{f} R_{t+s}^{f}$
 $A_{i,t+s} = \boldsymbol{a}_{i,t+s}^{\prime} \boldsymbol{v}_{t+s}^{i} + a_{i,t+s}^{f}$
 $0 = \lim_{s \to \infty} \rho^{s} u_{i}^{\prime}(C_{i,t+s}) A_{i,t+s}$

Inserting constraints (1)-(3) yields

$$\max_{\{\boldsymbol{a}_{i,t+s}, a_{i,t+s}^{f}\}_{s=0}^{\infty}} \operatorname{E}_{t} \sum_{s=0}^{\infty} \rho^{s} u_{i} \left(\boldsymbol{a}_{i,t+s-1}^{\prime} \boldsymbol{\pi}_{t+s}^{i} + a_{i,t+s-1}^{f} R_{i,t+s}^{f} - \boldsymbol{a}_{i,t+s}^{\prime} \boldsymbol{v}_{t+s}^{i} - a_{i,t+s}^{f} \right) \quad (A1.1)$$

s.t. $0 = \lim_{s \to \infty} \rho^{s} u_{i}^{\prime} (C_{i,t+s}) A_{i,t+s}$

The investor's FOCs with respect to investment (1.5) and (1.6) are readily derived from this expression.

Derivation of Equation (1.19). To derive Equation (1.19), I first restate the relevant equilibrium conditions for easier reference.

- Investors' first-order conditions (1.5) and (1.6):

$$a_{i,t}^f \left[\widetilde{m}_{i,t+1}, R_{i,t+1}^f \right]$$
 and $a_{ij,t} \left[v_{j,t}, \widetilde{\pi}_{j,t+1}, \widetilde{m}_{i,t+1} \right] \quad \forall j \in \mathcal{I}_i \text{ and } i = 1, ..., \iota$

- Stochastic discount factor (1.8): $\widetilde{m}_{i,t+1}\left[C_{i,t},\widetilde{C}_{i,t+1}\right] \qquad \forall i = 1,...,\iota$ - Budget constraint (1.3): $C_{i,t}\left[a_{i,t}^{f}, \boldsymbol{a}_{i,t}, \boldsymbol{v}_{i}^{i}; W_{i,t}\right]$ and

$$\widetilde{C}_{i,t+1} \begin{bmatrix} a_{i,t}^f, \boldsymbol{a}_{i,t}, \widetilde{\boldsymbol{\pi}}_{t+1}^i, \widetilde{a}_{i,t+1}^f, \widetilde{\boldsymbol{a}}_{i,t+1}, \widetilde{\boldsymbol{v}}_{t+1}^i, R_{i,t+1}^f \end{bmatrix} \qquad \forall \ i = 1, ..., \iota$$

Substituting $C_{i,t}, C_{i,t+1}$ in $m_{i,t+1}$ from the budget constraint yields

$$\widetilde{m}_{i,t+1}\left[a_{i,t}^{f}, \boldsymbol{a}_{i,t}, \boldsymbol{v}_{t}^{i}, \widetilde{\boldsymbol{v}}_{t+1}^{i}, \widetilde{\boldsymbol{\pi}}_{t+1}^{i}, \widetilde{a}_{i,t+1}^{f}, \widetilde{\boldsymbol{a}}_{i,t+1}, W_{i,t}, R_{i,t+1}^{f}\right]$$

and substituting $\widetilde{m}_{i,t+1}$ in the Euler equations then gives

$$\begin{aligned} & a_{i,t}^{f} \left[\boldsymbol{a}_{i,t}, \boldsymbol{v}_{t}^{i}, \widetilde{\boldsymbol{v}}_{t+1}^{i}, \widetilde{\boldsymbol{\pi}}_{t+1}^{i}, \widetilde{\boldsymbol{a}}_{i,t+1}^{f}, \widetilde{\boldsymbol{a}}_{i,t+1}, W_{i,t}, R_{i,t+1}^{f} \right] & \text{and} \\ & a_{ij,t} \left[a_{i,t}^{f}, \boldsymbol{a}_{i,t}, \boldsymbol{v}_{t}^{i}, \widetilde{\boldsymbol{v}}_{t+1}^{i}, \widetilde{\boldsymbol{\pi}}_{t+1}^{i}, \widetilde{\boldsymbol{a}}_{i,t+1}^{f}, \widetilde{\boldsymbol{a}}_{i,t+1}, W_{i,t}, R_{i,t+1}^{f} \right] & \forall \ j \in \mathcal{I}_{i} \end{aligned}$$

This system of $I_i + 1$ equations can be used to eliminate $a_{i,t}^f, \mathbf{a}_{i,t}$ on the "right-hand side," so that

$$\begin{aligned} & a_{i,t}^{f} \left[\boldsymbol{v}_{t}^{i}, \widetilde{\boldsymbol{v}}_{t+1}^{i}, \widetilde{\boldsymbol{\pi}}_{t+1}^{i}, \widetilde{\boldsymbol{a}}_{i,t+1}^{f}, \widetilde{\boldsymbol{a}}_{i,t+1}, W_{i,t}, R_{i,t+1}^{f} \right] & \text{and} \\ & a_{ij,t} \left[\boldsymbol{v}_{t}^{i}, \widetilde{\boldsymbol{v}}_{t+1}^{i}, \widetilde{\boldsymbol{\pi}}_{t+1}^{i}, \widetilde{\boldsymbol{a}}_{i,t+1}^{f}, \widetilde{\boldsymbol{a}}_{i,t+1}, W_{i,t}, R_{i,t+1}^{f} \right] & \forall \ j \in \mathcal{I}_{i}. \end{aligned}$$

Updating $a_{i,t}^f, \boldsymbol{a}_{i,t}$ one period then gives

$$\widetilde{a}_{i,t+1}^{f} \left[\widetilde{\boldsymbol{v}}_{t+1}^{i}, \widetilde{\boldsymbol{v}}_{t+2}^{i}, \widetilde{\boldsymbol{\pi}}_{t+2}^{i}, \widetilde{a}_{i,t+2}^{f}, \widetilde{\boldsymbol{a}}_{i,t+2}, \widetilde{W}_{i,t+1}, R_{i,t+2}^{f} \right] \quad \text{and} \\ \widetilde{a}_{ij,t+1} \left[\widetilde{\boldsymbol{v}}_{t+1}^{i}, \widetilde{\boldsymbol{v}}_{t+2}^{i}, \widetilde{\boldsymbol{\pi}}_{t+2}^{i}, \widetilde{a}_{i,t+2}^{f}, \widetilde{\boldsymbol{a}}_{i,t+2}, \widetilde{W}_{i,t+1}, R_{i,t+2}^{f} \right] \quad \forall \ j \in \mathcal{I}_{i}$$

Replacing $\widetilde{W}_{i,t+1}$ with $a_{i,t}^f, \boldsymbol{a}_{i,t}, \widetilde{\boldsymbol{\pi}}_{t+1}^i, R_{i,t+1}^f$ and using again the system of $I_i + 1$ equations to eliminate $a_{i,t}^f, \boldsymbol{a}_{i,t}$, I obtain

$$\widetilde{a}_{i,t+1}^{f} \left[\widetilde{\boldsymbol{v}}_{t+2}^{i}, \widetilde{\boldsymbol{\pi}}_{t+2}^{i}, \widetilde{a}_{i,t+2}^{f}, \widetilde{\boldsymbol{a}}_{i,t+2}, \widetilde{\boldsymbol{\pi}}_{t+1}^{i}, R_{i,t+1}^{f}, R_{i,t+2}^{f} \right] \quad \text{and}$$
(A1.2)
$$\widetilde{a}_{ij,t+1} \left[\widetilde{\boldsymbol{v}}_{t+2}^{i}, \widetilde{\boldsymbol{\pi}}_{t+2}^{i}, \widetilde{\boldsymbol{a}}_{i,t+2}^{f}, \widetilde{\boldsymbol{a}}_{i,t+2}, \widetilde{\boldsymbol{\pi}}_{t+1}^{i}, R_{i,t+1}^{f}, R_{i,t+2}^{f} \right] \quad \forall \ j \in \mathcal{I}_{i}.$$

Inserting $a_{i,t}^f, \boldsymbol{a}_{i,t}, \widetilde{a}_{i,t+1}^f, \widetilde{\boldsymbol{a}}_{i,t+1}$ (before substituting for $\widetilde{W}_{i,t+1}$) into $\widetilde{m}_{i,t+1}$ then yields

$$\widetilde{m}_{i,t+1}\left[\widetilde{\boldsymbol{v}}_{t+1}^{i}, \widetilde{\boldsymbol{v}}_{t+2}^{i}, \widetilde{\boldsymbol{\pi}}_{t+1}^{i}, \widetilde{\boldsymbol{\pi}}_{t+2}^{i}, \widetilde{a}_{i,t+2}^{f}, \widetilde{\boldsymbol{a}}_{i,t+2}, W_{i,t}, \widetilde{W}_{i,t+1}, R_{i,t+1}^{f}, R_{i,t+2}^{f}\right]$$

Now, repeated substitution of $\tilde{a}_{i,t+1}^f, \tilde{a}_{i,t+1}$ as in Equation (A1.2) updated to period t + s for $s = 2, ..., \infty$ in $\tilde{m}_{i,t+1}$ gives

$$\widetilde{m}_{i,t+1}\left[W_{i,t},\widetilde{W}_{i,t+1},\{\widetilde{\boldsymbol{v}}_{t+s}^i\}_{s=1}^\infty,\{\widetilde{\boldsymbol{\pi}}_{t+s}^i\}_{s=1}^\infty,\{R_{i,t+s}^f\}_{s=1}^\infty\right]$$

which is equivalent to Equation (1.19) in the main text.

Derivation of Equation (1.21). Writing out in full the expection in Equation (A1.1) at time t, I obtain

$$\max_{\{a_{i,t+s},a_{i,t+s}^{f}\}_{s=0}^{\infty}} \sum_{s=0}^{\infty} \rho^{s} \int_{\psi_{t+s}} u\left(a_{i,t+s-1}'\pi_{t+s}^{i}(\Psi_{t+s}) + a_{i,t+s-1}^{f}R_{i,t+s}^{f}\right) (A1.3)$$

$$-a_{i,t+s}'\psi_{t+s}^{i}(\Psi_{t+s}) - a_{i,t+s}^{f}\right) dF(\psi_{t+s}|\Psi_{t+s-1})$$

s.t. $0 = \lim_{s \to \infty} \rho^{s} u_{i}'(C_{i,t+s})A_{i,t+s}$

where Ψ_{t+s} denotes the full history of realized productivity levels up to t+s. Note that at this point, no assumptions have been imposed on the distribution $dF(\Psi_{t+s}|\Psi_{t+s-1})$ other than finiteness of expected values and non-negative support. As Fama (1970) showed, the problem is greatly simplified if the random variables follow independent and identical distribution over time. The i.i.d. assumption implicit in Equation (1.20) implies that $F(\Psi_{t+s}|\Psi_{t+s-1}) = F(\Psi)$. Moreover, the assumption that the investor takes as given the number of firms and the prices of the currently available set of assets (including the riskfree rate) implies that $\{\pi_{t+s}(\Psi)\}_{s=1}^{\infty} = \pi_t(\Psi), \{\Psi_{t+s}^i(\Psi)\}_{s=1}^{\infty} = \Psi_t^i$, and $R_{t+s}^f = R_t^f \forall s =$ $1, ..., \infty$, that is, profits associated with a given realization of Ψ and asset prices are expected not to change over time.³¹ Then, given the current state of the economy t, the investor's optimization problem at any future date t + s is identical to the problem faced at time t except for the level of wealth $W_{i,t+s}$ he is starting with. Let $G(W_t)$ denote the maximum value of the optimization problem (A1.3) as a function of the initial level of wealth. Then, (A1.3) may be written as

$$\max_{\{\boldsymbol{a}_{i,t+s}\}_{s=0}^{\infty}} u_i(W_{i,t} - \boldsymbol{a}'_{i,t}\boldsymbol{v}_t - a^f_{i,t+1}) + \rho G(W_{i,t+1})$$

s.t. $0 = \lim_{s \to \infty} \rho^s u'_i(C_{i,t+s}) A_{i,t+s}$

and the first order conditions obtain as

$$1 = \mathcal{E}_t \left[\rho \frac{G'(W_{i,t+1})}{u'_i(C_{i,t})} \right] R^f_{i,t+1} \quad \text{and} \quad v_{j,t} = \mathcal{E}_t \left[\rho \frac{G'(W_{i,t+1})}{u'_i(C_{i,t})} (\pi_{j,t+1} + v_{j,t+1}) \right] \quad \forall \ j,t.$$

Hence, the SDF observes

$$m_{i,t+1} = \rho \frac{G'(W_{i,t+1})}{u'_i(C_{i,t})} = \rho \frac{G'\left(R^W_{i,t+1}(W_{i,t} - C_{i,t})\right)}{u'_i(C_{i,t})} = g_{i,t}(R^W_{i,t+1}).$$

Under the lognormal assumption on productivity levels (Equation (1.20)), returns to firm shares as described in Equation (1.18) and the return to the wealth portfolio (Equa-

³¹Equation (A1.3) implies that $\tilde{\psi}$ is the only source of uncertainty. However, including uncertainty about changes in exogenous variables as well does not affect the investor's choice problem if shocks are i.i.d. and independent of Ψ .

tion (1.4)) are approximately normally distributed. Using Stein's Lemma, I obtain an approximate linear relationship between the SDF and the return to the wealth portfolio. The following derivation closely follows Cochrane (2005), Chapter 9.

Stein's Lemma: If f, R are bivariate normal (BVN), g(f) is differentiable and $E[|g'(f)|] < \infty$, then Cov[g(f), R] = E[g'(f)]Cov[f, R].

Now, assume $\mathbb{E}_t \left[\left| g_{i,t}'(R_{i,t+1}^W) \right| \right] < \infty$. Then, $R_{i,t+1}^W$ and $R_{j,t+1} \sim BVN \quad \forall j \in \mathcal{I}_i$, $m_{i,t+1} = g_{i,t}(R_{i,t+1}^W)$, the investor's first-order conditions

$$1 = \mathcal{E}_t[m_{i,t+1}R_{j,t+1}] \quad \Leftrightarrow \quad 1 = \mathcal{E}_t[m_{i,t+1}]\mathcal{E}_t[R_{j,t+1}] + \mathcal{Cov}_t[m_{i,t+1}, R_{j,t+1}], \qquad (A1.4)$$

and Stein's lemma imply that

$$1 = \mathcal{E}_t[g_{i,t}(R_{i,t+1}^W)]\mathcal{E}_t[R_{j,t+1}] + \mathcal{E}_t[g_{i,t}'(R_{i,t+1}^W)]\mathcal{C}ov_t[R_{i,t+1}^W, R_{j,t+1}].$$

Hence, a SDF of the form $m_{i,t+1} = \mathcal{E}_t[g_{i,t}(R^W_{i,t+1})] + \mathcal{E}_t[g'_{i,t}(R^W_{i,t+1})](R^W_{i,t+1} - \mathcal{E}_t[R^W_{i,t+1}])$ exists that is linear in $R^W_{i,t+1}$ and satisfies Equation (A1.4) for all $j \in \mathcal{I}_i$.

A1.2 Current Account and Balance of Payments

The current account of country $k \in \mathcal{I}_i$ defined as net exports plus net earnings from foreign investment obtains as the sum of final goods net exports $Y_{k,t} + a_{k,t-1}^f R_{k,t}^f - (C_{k,t} + \sum_{j \in \mathcal{I}_i} a_{kj,t}v_{j,t} + a_{k,t}^f + N_{k,t}v_{k,t})$ (final goods output including savings minus domestic absorption), net domestic intermediate exports $N_{k,t-1} \sum_{h \in \mathcal{I}} \phi_{kh,t-1}Y_{h,t} - Y_{k,t}$ (exports by variety producers minus intermediate imports by final goods producers) and profits owned from investment in foreign assets $\sum_{j \in \mathcal{I}_i} a_{kj,t-1}\pi_{j,t}$ minus profits owned by foreign investors in the home country $N_{k,t-1}\pi_{k,t}$.³² The current account is then

$$CA_{k,t} = Y_{k,t} + a_{k,t-1}^{f} R_{k,t}^{f} - \left(C_{k,t} + \sum_{j \in \mathcal{I}_{i}} a_{kj,t} v_{j,t} + a_{k,t}^{f} + N_{k,t} v_{k,t} \right) + N_{k,t-1} \sum_{h \in \mathcal{I}} \phi_{kh,t-1} Y_{h,t} - Y_{k,t} + \sum_{j \in \mathcal{I}_{i}} a_{kj,t-1} \pi_{j,t} - N_{k,t-1} \pi_{k,t} = -\sum_{j \in \mathcal{I}_{i}} da_{kj,t} v_{j,t} + dN_{k} v_{k,t}$$

³²I include domestic sales and domestic earnings in inflows and outflows to save on notation. They net each other out in all positions.

and equal to net foreign investment, that is, equal to the capital account. Hence, the international payment system is balanced.

A1.3 Expected Return-Beta Representation

The structural equation of the SDF (1.22) falls into the class of *linear factor models*, which are commonly used in the asset pricing literature to analyse asset returns by means of their correlations with *factors*, typically portfolio returns or macro variables. In my case the factors are country-specific productivity shocks. As shown in Cochrane (1996), every linear factor model has an equivalent *expected return-beta* representation which implies that the λ s can be interpreted as monetary *factor risk premia* or *factor prices*.

The Euler equation for risky assets (1.6) implies that, in equilibrium, the return to every asset $j \in \mathcal{I}_i$ observes

$$1 = \mathcal{E}_t [m_{i,t+1} R_{j,t+1}] \qquad \text{where} \qquad m_{i,t+1} = b_{i0,t} + \boldsymbol{b}'_{i,t} \hat{\boldsymbol{Y}}_{t+1}.$$

Following Cochrane (2005) Chapter 6, I can rewrite this as

$$E_{t}[R_{j,t+1}] - R_{i,t+1}^{f} = -R_{i,t+1}^{f} \boldsymbol{b}_{i,t}^{\prime} \operatorname{Cov}_{t} \left[\hat{\boldsymbol{Y}}_{t+1}, R_{j,t+1} \right]$$

$$= -R_{i,t+1}^{f} \boldsymbol{b}_{i,t}^{\prime} \operatorname{Cov}_{t} \left[\hat{\boldsymbol{Y}}_{t+1}, \hat{\boldsymbol{Y}}_{t+1}^{\prime} \right] \operatorname{Cov}_{t} \left[\hat{\boldsymbol{Y}}_{t+1}, \hat{\boldsymbol{Y}}_{t+1}^{\prime} \right]^{-1} \operatorname{Cov}_{t} \left[\hat{\boldsymbol{Y}}_{t+1}, R_{j,t+1} \right]$$
(A1.5)

Define $\boldsymbol{\beta}_{j,t} := \operatorname{Cov}_t \left[\hat{\boldsymbol{Y}}_{t+1}, \hat{\boldsymbol{Y}}'_{t+1} \right]^{-1} \operatorname{Cov}_t \left[\hat{\boldsymbol{Y}}_{t+1}, R_{j,t+1} \right]$ as the vector of coefficients resulting from a multivariate time-series regression of firm *j*'s return on the factors. Then, Equation (1.24) implies that (A1.5) can be written as

$$\mathbf{E}_t \left[R_{j,t+1} \right] - R_{i,t+1}^f = -\boldsymbol{\lambda}_{i,t}^{\prime} \boldsymbol{\beta}_{j,t}.$$

A1.4 A Special Case of $\lambda = 0$

To show that $\lambda_t = 0$ and $E_t [\psi_{h,t+1}] \ge E_t [\psi_{i,t+1}]$ imply that the number of firms in country i is weakly larger, I consider the amount of composite good production consistent with firms' optimal quantity decisions as given in Equation (1.12) evaluated at $\lambda_t = 0$:

$$Q_{i,t} = \left(\sum_{j=i,h} N_j(q_{j,i}^*)^{\frac{\varepsilon-1}{\varepsilon}}\right)^{\frac{\varepsilon}{\varepsilon-1}} = \theta \mathcal{E}_t\left[Y_{i,t+1}\right] \left(N_i c^{1-\varepsilon} + N_h (c\tau)^{1-\varepsilon}\right)^{\frac{\varepsilon}{\varepsilon-1}}$$

Since $E_t[Y_{h,t+1}] = E_t[Y_{i,t+1}], Q_{i,t} \ge Q_{h,t}$ implies $N_i c^{1-\varepsilon} + N_h (c\tau)^{1-\varepsilon} \ge N_i (c\tau)^{1-\varepsilon} + N_j c^{1-\varepsilon}$. This holds true if $N_i \ge N_h$ and it means that market *i* is more competitive since it features a larger number of domestic firms that do not incur trade costs to access the market compared to country h where the number of foreign firms is larger than the number of domestic firms. Comparing optimum firm values as given in (1.14) evaluated at $\lambda_t = 0$, shows that

$$V_{h,t}^{*} - V_{i,t}^{*} = \frac{\mathbf{E}_{t} \left[Y_{h,t+1} \right]}{R_{t+1}^{f}} \left(\psi_{hh,t} + \psi_{hi,t} - \psi_{ii,t} - \psi_{ih,t} \right)$$
$$= \frac{\mathbf{E}_{t} \left[Y_{h,t+1} \right]}{R_{t+1}^{f}} (1 - \tau^{1-\varepsilon}) \left(\frac{1}{N_{i}\tau^{1-\varepsilon} + N_{j}} - \frac{1}{N_{i} + N_{j}\tau^{1-\varepsilon}} \right) \ge 0.$$
(A1.6)

Hence, the only case where the free entry condition is not violated is the knife-edge case $E_t [\psi_{h,t+1}] = E_t [\psi_{i,t+1}].$

A1.5 Data Appendix

Import growth. I use total monthly imports by country obtained from the IMF's *Direction of Trade Database* to measure demand growth. Imports are converted to constant U.S. dollars using the Bureau of Labor Statistics' monthly consumer price index. Growth is measured with respect to the previous month and rates are adjusted for constant monthly factors. The earliest observation used to estimate the covariance matrix of import growth across countries is January 1983. To obtain continuus import series for countries evolving from the break-up of larger states or country aggregates defined by the IMF, I use a proportionality assumption to split imports reported for country groups. In particular, I use each country's share in the total group's import in the year succeding the break up to split imports among country group members in all years before the break up. This concerns member countries of the former USSR, Serbia and Montenegro, the Socialist Federal Republic of Yugoslavia, Belgium and Luxembourg, former Czechoslovakia, and the South African Common Customs Area. Moreover, I aggregate China and Taiwan, Westbank and Gaza, as well as Serbia and Kosovo in order to accommodate the reporting levels of other data used in the analysis.

Tariffs. Source: WITS database. I use effectively applied tariffs including ad valorem equivalents of specific tariffs and quotas. Tariffs are provided mostly on HS six-digit level. I use trade weighted averages on the four-digit and two-digit levels to fill missing. Thereby, I obtain tariffs for 27% of all export observations. Filling missings with up to three lags or leads yields non-missing tariffs for another 15% of the sample. There are a few products where the assignment to HS six-digit sectors is no longer unique after aggregating HS ten-digits to time consistent product groups as described above. I use weighted averages of tariffs in those cases where weights correspond to the number of products in potentially different HS 6 groups.

Freight costs. Source: U.S. Census FTD import data provided by Peter Schott through his website at *http://faculty.som.yale.edu/peterschott/sub_international.htm*. I compute

median freight cost per unit value or per kg for total shipments and by mode of transportation on the country-year level.





Source: Figure 4 in Graham and Harvey (2001)


Figure A1.2: Mean excess return of 49 value-weighted portfolios

Mean excess return over risk-free rate (U.S.t-bill rate) calculated over monthly observations between January 1977 and July 2014.



Figure A1.3: Risk premia estimates for selected countries

Country	ISO	$\lambda_{h,1992}^{US}$	$\lambda_{h,2002}^{US}$	$\lambda_{h,2012}^{US}$
Afghanistan	AFG	-0.0063	-0.0020	-0.0007
Angola	ĀGO	-0.0019	-0.0051	0.0014
Albania	ALB	0.0048	-0.0018	-0.0001
Netherlands Antilles	ANT	0.0031	-0.0020	-0.0044
United Arab Emirates	ARE	-0.0006	-0.0000	-0.0007
Argentina	ARG	0.0012	-0.0011	-0.0010
Armenia	ARM	-0.0043	-0.0064	-0.0033
Australia	AUS	0.0016	-0.0010	-0.0028
Austria	AUT	0.0007	0.0001	-0.0010
Azerbaijan Dumun di	AZE	0.0007	0.0015	-0.0031
Bolgium	DDI BFI	0.0020 0.0017	-0.0004	0.0007
Benin	BEN	0.0017	0.0005	-0.0010
Burkina Faso	BFA	0.0020	-0.0013	-0.0022
Bangladesh	BGD	0.0046	-0.0010	-0.0002
Bulgaria	BGR	-0.0026	-0.0003	-0.0003
Bahrain	$_{\rm BHR}$	-0.0019	0.0024	-0.0018
Bahamas, The	$_{\rm BHS}$	0.0007	-0.0104	0.0022
Bosnia and Herzegovina	BIH	0.0015	0.0010	-0.0004
Belarus	BLR	-0.0006	-0.0010	-0.0024
Belize Damma da	BLZ	0.0018	-0.0001	-0.0022
Bermuda Bolivio	BMU	-0.0051	0.0107	0.0006
Brazil	BRA	0.0024	0.0003	-0.0014
Barbados	BRB	-0.00025	0.0007	-0.0014
Brunei Darussalam	BRN	-0.0047	-0.0004	-0.0020
Central African Republic	CAF	0.0028	0.0022	-0.0157
Canada	ĊAN	0.0017	-0.0014	-0.0013
Switzerland	CHE	0.0015	-0.0007	0.0001
Chile	CHL	-0.0012	0.0004	-0.0014
China	CHN	-0.0006	0.0003	0.0014
Cote d'Ivoire	CIV	0.0009	0.0005	0.0041
Cameroon Congo Bon	CMR	-0.0014	0.0009	-0.0011
Colombia	COU	0.0031	-0.0050	0.0047 0.0007
Comoros	COM	-0.0003	-0.0021 0.0022	0.0055
Cabo Verde	CPV	0.0025	-0.0153	-0.0040
Costa Rica	ČŔĬ	0.0022	-0.0004	-0.0016
Cuba	CUB	-0.0012	0.0001	-0.0006
Cyprus	CYP	0.0002	-0.0009	-0.0012
Czech Republic	CZE	-0.0014	-0.0003	0.0000
Germany	DEU	0.0010	-0.0003	-0.0008
Djibouti	DJI	0.0000	0.0004	-0.0014
Dominica	DMA	0.0009	-0.0043	-0.0002
Dominican Bepublic	DOM	-0.0008	-0.0007	-0.0007
Algeria	DZA	0.0001	0.0011	-0.0021
Ecuador	ECU	-0.0020	-0.0004	0.0005
Egypt, Arab Rep.	ĒĞŸ	0.0022	0.0031	0.0004
Spain	ESP	0.0021	0.0010	-0.0005
Estonia	\mathbf{EST}	-0.0012	-0.0002	-0.0015
Ethiopia	ETH	0.0111	-0.0016	0.0008
Finland	FIN	0.0024	0.0007	-0.0009
Fiji Evenen	FJI FDA	0.0000	0.0014	-0.0030
France Essence Islands	FRA	0.0020 0.0012	-0.0008	-0.0009
Cabon	CAB	-0.0013	-0.0025	-0.0013
United Kingdom	GBB	0.00022	-0.0010	-0.0002
Georgia	GEO	-0.0008	-0.0037	-0.0005
Ghana	ĞĦĂ	-0.0016	0.0017	-0.0004
Guinea	GIN	0.0027	0.0012	-0.0011
Gambia, The	GMB	0.0045	0.0035	-0.0002
Guinea-Bissau	GNB	-0.0006	-0.0139	0.0089
Equatorial Guinea	GNQ	-0.0100	0.0037	-0.0056
Greece	GRC	0.0028	0.0011	-0.0002
Grenada	GKD	0.0026	-0.0053	-0.0001
Greemala	GRL CTM	-0.0022	-0.0007	-0.0000
Guvana	GIN	_0 0012	0.0024	0.0007
Hong Kong SAR, China	ЙКĠ	-0.0004	0.0003	0.0003

Table A1.6: Estimated country risk premia for selected years

Country	ISO	$\lambda_{h,1992}^{US}$	$\lambda_{h,2002}^{US}$	$\lambda_{h,2012}^{US}$
Honduras	HND	0.0012	-0.0021	-0.0007
Croatia	HRV	0.0017	0.0014	0.0002
Haiti	HTI	0.0105	0.0010	-0.0004
Hungary	HUN	-0.0045	-0.0009	0.0014
Indonesia	IDN	-0.0025	0.0000	-0.0003
India		0.0033	-0.0009	-0.0032
Irenald Iren Islamia Bon		0.0028 0.0007	-0.0009	-0.0014
Iraa	IRO	-0.0007	-0.0021	0.0007
Iceland	ISL	0.0048	0.0020	-0.0013
Israel	ISR	0.0019	0.0004	-0.0016
Italy	ITA	-0.0011	-0.0020	-0.0009
Jamaica	JAM	0.0013	-0.0009	-0.0022
Jordan	JOR	0.0043	-0.0002	0.0003
Japan Kagalahatan	JPN VAZ	0.0010	-0.0009	-0.0007
Kazaklistali Konya	KEN	-0.0015	-0.0009	-0.0017
Kvrgyz Republic	KGZ	-0.0388	-0.0032	-0.0003
Cambodia	KHM	-0.0006	0.0048	0.0021
St. Kitts and Nevis	KNA	-0.0154	-0.0003	-0.0092
Korea, Rep.	KOR	0.0006	-0.0006	-0.0005
Kuwait	KWT LAO	-0.0033	0.0001	-0.0015
Lao PDK Labance	LAU	0.0015	-0.0027	-0.0010
Lebanon	LBN	-0.0030	-0.0002 0.0021	-0.0017
Libva	LBY	-0.0004	0.0021	-0.0013
St. Lucia	LCA	-0.0027	0.0031	0.0254
Sri Lanka	LKA	0.0012	0.0029	-0.0005
Lithuania	LTU	0.0024	0.0016	-0.0019
Luxembourg	LUX	0.0011	-0.0029	-0.0036
Latvia Magaa SAD China	LVA MAC	-0.0031	-0.0009	-0.0009
Marao SAR, Olina Morocco	MAC	-0.0008	0.0025	-0.0010
Moldova	MDA	0.0013	-0.0000	-0.0013
Madagascar	MDG	0.0088	0.0028	-0.0003
Maldives	MDV	-0.0044	-0.0016	-0.0009
Mexico	MEX	0.0012	-0.0003	0.0001
Macedonia, FYR	MKD	0.0013	-0.0029	0.0001
Malta	MLT	0.0021 0.0035	-0.0017	-0.0000
Myanmar	MMR	0.0109	-0.0011	0.0003
Montenegro	MNE	0.0028	-0.0004	-0.0023
Mongolia	MNG	-0.0006	-0.0046	-0.0017
Mozambique	MOZ	-0.0029	0.0028	-0.0000
Mauritania	MRT	-0.0042	-0.0038	-0.0021
Malawi	MWI	-0.0024	-0.0000	-0.0007
Malavsia	MYS	0.0001	-0.0002	-0.0010
New Caledonia	NCL	0.0013	-0.0022	0.0005
Niger	NER	-0.0029	0.0055	0.0010
Nigeria	NGA	0.0023	-0.0002	-0.0011
Nicaragua	NIC	0.0025	-0.0012	0.0001
Norway	NOR	-0.0001	-0.0005	-0.0010
Nepal	NPL	-0.0001	0.0000 0.0037	-0.0021
New Zealand	NZL	-0.0002	-0.0015	-0.0028
Oman	OMN	0.0002	0.0013	0.0014
Pakistan	PAK	-0.0012	-0.0019	-0.0021
Panama	PAN	0.0015	0.0009	0.0013
reru Philippinos	РЕК РНІ	-0.0005 _0.0001	0.0004 0.0009	-0.0012
Papua New Guinea	PNG	0.0025	-0.0037	-0.0012
Poland	POL	-0.0038	-0.0001	-0.0005
Portugal	\mathbf{PRT}	0.0025	-0.0024	0.0000
Paraguay	PRY	-0.0100	-0.0013	-0.0002
Qatar	QAT DOM	0.0019	0.0004	0.0012
nomama Bussian Federation	RUS	-0.0020	-0.0007	-0.0007
Rwanda	RWA	-0.0010	0.0006	-0.0017
Saudi Arabia	SAU	0.0014	0.0004	-0.0006

Country	ISO	$\lambda_{h,1992}^{US}$	$\lambda_{h,2002}^{US}$	$\lambda_{h,2012}^{US}$
Sudan	SDN	0.0034	-0.0013	0.0018
Senegal	SEN	0.0009	0.0007	-0.0038
Singapore	SGP	0.0002	-0.0008	0.0001
Solomon Islands	ŠĽB	-0.0001	0.0006	0.0022
Sierra Leone	SLE	0.0023	0.0090	0.0001
El Salvador	\widetilde{SLV}	0.0009	-0.0014	0.0016
Somalia	SOM	0.0030	-0.0024	-0.0007
Serbia	SRB	0.0022	-0.0004	-0.0006
Sao Tome and Principe	STP	0.0068	0.0405	0.0026
Suriname	SUR	-0.0025	-0.0005	0.0003
Slovak Republic	SVK	-0.0016	0.0012	0.0002
Slovenia	SVN	0.0009	0.0000	0.0002
Sweden	SWE	0.0008	-0.0048	-0.0013
Seychelles	SYC	-0.0322	-0.0046	0.0056
Syrian Arab Republic	SYR	0.0047	-0.0021	-0.0010
Chad	TCD	0.0027	0.0047	0.0026
Togo	TGO	-0.0001	-0.0060	0.0046
Thailand	THA	0.0006	-0.0031	-0.0002
Tajikistan	TJK	0.0003	-0.0029	-0.0021
Turkmenistan	TKM	-0.0001	0.0034	0.0006
Tonga	TON	0.0041	-0.0010	-0.0066
Trinidad and Tobago	TTO	-0.0026	0.0038	-0.0024
Tunisia	TUN	0.0013	-0.0013	-0.0011
Turkey	TUR	0.0012	-0.0007	-0.0015
Tanzania	TZA	0.0024	0.0010	-0.0000
Uganda	UGA	0.0013	-0.0013	-0.0016
Ukraine	UKR	-0.0003	-0.0027	0.0003
Uruguay	URY	0.0028	-0.0041	-0.0013
United States	USA	0.0010	0.0006	-0.0010
Uzbekistan	UZB	0.0019	-0.0041	-0.0017
St. Vincent and the Grenadines	VCT	-0.0057	-0.0062	-0.0053
Venezuela, RB	VEN	0.0013	-0.0026	-0.0028
Vietnam		-0.0037	-0.0012	-0.0014
vanuatu		-0.0158	-0.0144	-0.0514
Samoa Vana and Dan	WSM	0.0030	0.0170	0.0047
South Africa		0.0002 0.0017	0.0022	-0.0013
Congo Dom Don		0.0017	-0.0011	-0.0004
Zambia	ZAR ZMB	-0.0012	-0.0027	-0.0018
Zamola Zimbahwa		-0.0010	-0.0000	-0.0059
Zimbabwe		0.0054	0.0054	-0.0052

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xport data	Description	# Obs.	# Groups	Mean	Std. Dev.	Min	Max	Source, notes
te ntity ears	in kg.	3,681,276 3,681,276 3,681,276 3,681,276	က်	650, 132 339, 153	26,504,289 $30,258,985$	$\begin{array}{c} 0\\ 0\\ 1992 \end{array}$	$1.56e+10 \\ 2.75e+10 \\ 2012$	US Census, FTD; cp. Pierce and Schott (2012a)
larkets roducts	time consistent HS10 digits or derived codes	3,681,276 $3,681,276$	$180 \\ 7061$					cp. Pierce and Schott (2012b)
kets p. product ducts p. market mtity p. market share	with positive sales with positive sales excl. zeros, in kg.	$\begin{array}{c} 811,408\\ 811,408\\ 811,408\\ 811,408\\ 811,408\\ 811,408\end{array}$		${61 \atop 3,150 \atop 1,538,702 \atop .38 \end{cases}$	$^{32}_{2,148,113}$	$\begin{smallmatrix}&1\\&2\\5,924\\0\end{smallmatrix}$	$^{179}_{5,831}_{9,802,089}$	
orts by vessel kets p. product mtity p. market	with positive sales excl. zeros, in kg.	3,681,276 $579,516$		$\begin{array}{c} 28 \\ 2,143,041 \end{array}$	$^{24}_{3,768,501}$	$\begin{smallmatrix}&0\\14,781\end{smallmatrix}$	$166 \\ 55113832$	
orts by air kets p. product mtity p. market	with positive sales excl. zeros, in kg.	509,459 509,459		$^{52}_{12,932}$	$\begin{array}{c} 33\\12,576\end{array}$	$1 \\ 205$	$^{178}_{50,000}$	
ntry data								
o DP int Cost ff or data	by country, ad valorem × year by country × year, ad valorem by country × year, ad valorem by HS 6 × country × year, ad valorem	3,681,276 3,536,232 3,536,232 3,681,276 3,646,760 3,646,760 3,605,332 1,954,321 1,954,321	$\begin{array}{c} 533\\ 512\\ 512\\ 533\\ 523\\ 522\\ 91,415\\ 91,415\end{array}$	$\begin{array}{c} -0.0004\\ 1.83e+11\\ 9.746\\ 0.05\\ 0.07\\ 0.08\\ 0.07\\ 0.07\\ 0.07\\ 0.07\\ 0.07\\ 0.07\end{array}$	$\begin{array}{c} 0.0050\\ 5.40e{+}11\\ 14,703\\ 0.21\\ 0.04\\ 0.06\\ 0.06\\ 0.07\end{array}$	-0.0514 1.08e+8 114 0.00 0.00 0.00 0.00 0.00 0.00	$\begin{array}{c} 0.0405\\ 4.71e{+}12\\ 79,782\\ 1.00\\ 1.00\\ 0.59\\ 0.57\\ 0.99\\ 30.00\end{array}$	WDI, PWT WDI, PWT WTA RTA database US Census, FTD (import data) US Census, FTD (import data) US Census, FTD (import data) WITS
FinDep	by NAICS 6 digit <i>times</i> year	3, 296, 991	1,437	-0.12	5.58	-93.16	33.51	Compustat; cp. Raian and Zingales (1998)

Table A1.7: Summary statistics of variables used in the gravity estimations

60 Global Risk Sharing Through Trade in Goods and Assets: Theory and Evidence

Model: Test assets:	$\begin{array}{c} \text{CAPM} \\ \text{25 FF pfs.} \end{array}$	FF four factor model 49 industry portfolios
$oldsymbol{\zeta}_{US}$	1 [119]	$ \begin{bmatrix} 1 \\ [76.7] \end{bmatrix} $
$oldsymbol{\gamma}_{US}$	-3.77 [-2.7]	-4.22 [-2.3]
γ_{US}^{smb}	L J	3.21 [1.13]
$oldsymbol{\gamma}_{US}^{rmw}$		-7.92 [-1.24]
γ_{US}^{cma}		[4.57] [.74]
# Moment Conditions	26	50
# Observations	450	450
# Parameters	2	5
Test of joint signific.: χ_e^2	131	1853
$P(\chi_2^2 > \chi_e^2)$	0	0
J-Test: J -Stat	131	67
$P(\chi^2_{M-k} > J)$	0	.02

Table A1.8: Parameter estimates of linear SDF models

Results from first-stage GMM. Time period: 1977M1–2014M6. t-statistics in brackets. Column (1) uses Fama and French (1993)'s 25 Benchmark portfolios (and the risk-free rate) as test assets. Column (2) based on Fama and French (2015)'s four factor model and 49 value-weighted industry portfolios. k denotes # parameters and M # of moment conditions.

Heterogeneous Workers, Trade, and Migration^{*}

2.1 Introduction

Workers are a heterogeneous lot. They have different innate abilities and choose different types and levels of skill formation. The outcome is both vertical and horizontal skill differentiation among workers. Economic well-being depends on good matches between workers' skills and their employment in different activities or firms. Obviously, the quality of these matches is determined by labor market institutions. Less obviously, it also depends on whether economies are connected to each other by trade and migration. In this paper, we analyze how horizontal skill heterogeneity among workers impacts on the welfare and inequality effects of trade and migration.

We develop a general equilibrium model of trade and migration where workers differ in terms of their specific skills. By skills, we mean an individual's relative ability to perform different types of tasks. By specificity, we mean that a certain pattern of such task-related abilities will be particularly useful for a certain product (or industry), and less so for others. Thus, for any given product there is a unique ideal pattern of taskrelated abilities, which we simply call the *ideal skill type*. The more a worker's specific abilities deviate from this ideal skill type, the lower her productivity when employed by a firm producing this product. We focus on horizontal skill heterogeneity in assuming that all workers have the same absolute level of skills, but feature different relative abilities,

^{*}This chapter is coauthored by Wilhelm Kohler. An earlier version was published as CESifo Working Paper No. 4387, 2013. The chapter extends, generalizes, and formalizes ideas developed in my Master's thesis (submitted under the same title in 2011).

i.e., different skill types. Moreover, we assume that both, the absolute level of skills and the degree of heterogeneity in skill types across workers is given exogenously, whether innately or from past educational investment.

We highlight two problems deriving from such worker heterogeneity. First, if the number of different skill types is large and if production involves a fixed cost, then the economy faces a *matching* problem. There will not be enough entry of firms for each worker to find for which her idiosyncratic skill type proves to be an ideal match. Part of the work force will thus be employed in non-ideal matches, and the average quality of matches becomes an endogenous variable. And secondly, firms in such an economy will have *monopsony power* on the labor market. The reason is that for any expansion of employment a firm must hire workers with skills that are ever less suitable to its own product, and ever more suitable to the products of other firms. Attracting such workers requires offering a higher wage. Thus, firms face upward-sloping labor supplies and will therefore set wages below the marginal value product of labor.

In this paper, we show that these two problems, matching and monopsony power on the labor market, have profound implications for the normative effects of both, international trade and migration. To do so, we develop a model that combines horizontal skill-heterogeneity with the standard ingredients of monopolistic competition models of trade first identified by Krugman (1979): the variety effect, the pro-competitive effect, and the scale effect of international trade. However, in assuming symmetric firms, we deliberately rule out the selection-based productivity effect of trade emphasized by Melitz (2003). Instead, we highlight a productivity effect deriving from the average quality of matches between product characteristics and worker skills. Standard models of monopolistic competition emphasize a positive externality of firm entry due to love of variety, and a negative externality due to "business steeling" from incumbent firms. Our model highlights two additional distortions that derive from skill-specificity on the labor market: a positive externality of firm entry on the average quality of firm-worker-matches, and firms' monopsony power on the labor market.

We employ a circular representation of continuous skill heterogeneity as in Amiti and Pissarides (2005).¹ Our analysis of demand and welfare is based on a translog expenditure

¹Our model may also be seen in the tradition of spatial competition models, such as the circular city model developed by Vickrey (1964), Vickrey et al. (1999) and Salop (1979) or models of product differentiation in the spirit of Lancaster (1966). For similar trade applications, see Helpman (1981), Grossman and Helpman (2005) Eckel (2009a,b).

function, which implies love of variety and endogenous markups.² Labor is the only input in production, and all firms share the same technology, featuring a fixed cost and a constant marginal cost in terms of efficiency units of labor. Profit maximization and free entry of firms determine the equilibrium number of firms as well as the positions of these firms along the skill circle. In our model, firms' decision making involves two stages. Stage one involves the entry decision, combined with choosing firm-specific positions on the skill circle, and in stage two firms engage in Bertrand competition by jointly setting goods prices and wage rates per efficiency unit of labor. Workers maximize their earnings by sorting themselves into employment in different firms, based on firm-specific wage offers and skill-requirements. We assume an infinite number of potential entrants with zero outside options, whence entry is governed by a zero profit condition.

We assume that firms have knowledge of the distribution of workers over the skill circle as well as the degree of skill heterogeneity but do not know the individual worker's specific skills. In turn, workers have full knowledge about their skill types and the productivity effect of their skill distance to all firms once these have positioned themselves on the skill circle. When considering entry or exit, firms take as given the observed average quality of matches between worker skills and product requirements, thus ignoring the positive (negative) effect of entry (exit) on the average quality of worker-firm-matches.³

We use this model to analyze the effects of international trade as well as international migration on aggregate welfare as well as on wage inequality. Trade is analyzed assuming segmented national markets, and it comes in the two forms recently emphasized by Mrázová and Neary (2014). The first is the extensive margin where the number of countries trading with each other is increased above 1, which is autarky. The second is the intensive margin where a reduction in the level of trade costs leads to more trade between a given number of countries. Migration may take place in the form of cross-border hiring of workers, or in the form of workers moving to a foreign country in order to work for a foreign firm.

Trade has novel effects relative to existing literature. First, trade-induced firm exit causes a loss in efficiency through a lower average matching quality in the labor market. And secondly, firm exit reduces competition in the labor market, leading to higher

²For the purpose of this paper, the terms product variety and product (or industry) may be used interchangeably. In some cases, our view of skill-specificity may fit product differentiation within an industry, so that the ideal skill relates to a certain product variety. In other cases, skill specificity may occur on a more aggregate level, which implies that ideal skills relate to a product or an industry. Thus, the notion of love of variety as implied by our translog expenditure function must flexibly be interpreted as related to product varieties or to products.

³Such an externality is also present in Helsley and Strange (1990).

markups between wages and the marginal productivity of workers. However, comparing free trade with autarky (extensive margin) we prove that with translog preferences the conventional pro-competitive and variety effects dominate these adverse effects on the labor market. Thus, the gains from trade theorem survives. But the intensive margin involves a non-monotonicity: When moving from a prohibitive level of real trade costs (autarky) to zero trade costs (free trade) aggregate welfare is rising (falling) for high (low) initial levels of trade costs, provided that the number of countries is not too large. Both types of trade liberalization lead to an increase in wage inequality.

Novel results also arise for migration. With borders open for migration, some workers in each country find foreign firms that are better suited to their skills, and firms in each country find foreign workers that are better suited for their products. There will thus be an incentive for two-way migration. Moreover, this type of migration is unambiguously gainful, because it increases the average quality of matches while at the same time lowering wage markups in all countries. We show that the gains from lower wage markups even arise if migration costs are prohibitively high, since the mere potential of migration affects a firm's perceived labor supply elasticity. Moreover, we prove that any trade-cummigration equilibrium always delivers higher aggregate welfare than an equilibrium with free trade alone. In contrast to piecemeal integration of goods markets, piecemeal integration of labor markets is unambiguously welfare increasing for all countries. And finally, in contrast to trade liberalization, the effect of migration on wage inequality is ambiguous.

Our paper contributes to several strands of literature. The first is the literature on whether trade and migration are substitutes or complements. Trade models highlighting endowment-based comparative advantage imply that they are substitutes, but if trade is driven by other forces they may be complements, as first emphasized by Markusen (1983). Empirical evidence strongly favors the view that trade and migration are "nonsubstitutes"; see Felbermayr et al. (2015b). Our model identifies a novel cause of strong complementarity between trade and migration. We identify an incentive for migration which is present absent trade but increases with trade, and we demonstrate that this type of migration has effects opposite to those of trade.

A second strand of literature that we contribute to are the attempts to explain two-way migration between similar countries. Figure 2.1 demonstrates the empirical significance of this type of migration. It plots residuals from a gravity-type estimation of bilateral stocks (in logs) of emigrants and immigrants for all OECD-country pairs.⁴ Points clustering

⁴The gravity equation is more difficult to rationalize for migration than for trade, but it is often used in the literature to explain cross-country patterns of migration, see. e.g. Ortega and Peri (2013), Mayda



Figure 2.1: Bilateral stocks of immigrants and emigrants, OECD-DIOC 2000

along the 45°-line reveal a marked two-way pattern of international migration among similar countries.⁵ This pattern of migration is difficult to explain. Schmitt and Soubeyran (2006) present a model predicting two-way migration of individuals within occupations. But in their model individuals with the same level of skills would never move in both directions, and even within occupations migration is observed only between countries that differ in their sill endowment. In Fan and Stark (2011), individuals suffer from social stigma arising from employment in an occupation of low social status, and humiliation from this stigma is felt to be less severe when working as a "foreigner" in the immigration country. This installs a two-way incentive for migration even between identical countries. Kreickemeier and Wrona (2016) highlight vertical skill heterogeneity with a technology that requires formation of teams and features complementarity between skill levels of

^{(2010),} Beine et al. (2011). The data used in Figure 1 are from the *Database on Immigrants in OECD* countries (*DIOC*) provided by the OECD.

⁵As a summary for the importance of two-way migration, Docquier and Marfouk (2006) report that 33.7% of the stock of skilled migrants residing in OECD countries stem from other high-income countries; see their Table 5.3. It is interesting to note that two-way migration was an important phenomenon also in the 19th century. It features prominently among the "Laws of Migration" that Ravenstein (1885) derives from a detailed account of 19th century migration flows between manufacturing districts in the UK. He calls it "counter-currents of migration," and he insists that it is driven by "business considerations." Our model may be interpreted as a theoretical account of such "business considerations."

team members. If individual skill levels cannot be observed by firms and if migration is costly, then migration may serve as a signal for an above average level of skills. Because individuals in all countries gain from sending this signal, there will be two-way migration between identical countries. As in our model, migration alleviates a labor market imperfection, but it is driven by vertical skill differentiation, whereas we focus on horizontal skill differentiation. This allows us to investigate the link between migration and modern trade models featuring horizontal product differentiation.

As regards trade, our paper relates to a voluminous modern literature on gains from trade in the spirit of Krugman (1979) and Melitz (2003).⁶ Our contribution is to add horizontal skill heterogeneity among workers to an otherwise standard model of trade based on horizontal product differentiation, and to use this model to discuss the welfare and inequality effects of trade as well as migration, emphasizing novel effects deriving from endogenous wage markups as well as endogenous quality of worker-firm matching. To achieve these contributions, we simplify in assuming away firm-heterogeneity in productivity analyzed by Melitz (2003). We assume a translog expenditure function, which is nested in Arkolakis et al. (2015) and implies subconvex demand, as shown by Mrázová and Neary (2013). Thus, our model falls into the category of recent trade models delivering the familiar pro-competitive effects of trade.⁷

Finally, our paper also contributes to a recent strand of literature that explores the relationship between trade and matching in labor markets. Existing labor market literature has traditionally focused on vertical differentiation, emphasizing gains from positive assortative matching between firms and workers. Ohnsorge and Trefler (2007) as well as Costinot and Vogel (2010) discuss vertical skill differentiation that lead to perfect positive assortative matching in equilibrium, which implies that trade will not entail additional gains from better matching. In contrast to these papers, we discuss horizontal differentiation of workers with a variable average quality of matching. Focusing on a case where assortative matching is imperfect, Davidson et al. (2008) show that trade openness potentially enhances the degree of positive assortative matching. Using a large-scale Swedish data set, Davidson et al. (2012, 2014) demonstrate that this effect is empirically important. Our paper reinforces this point in showing that this channel also works with

⁶Arkolakis et al. (2012) has invigorated a renewed discussion of gains from trade. For a recent survey of this literature, see Costinot and Rodriguez-Clare (2014).

⁷This categorization of trade models has recently emerged from attempts to move away from CES demand structures to allow for endogenous markups. Subconvexity of demand functions imply that any scenario leading to lower firm-sales in a certain market, such as entry of foreign firms into the domestic market, also leads to lower price markups on goods markets. For a detailed discussion, see Zhelobodko et al. (2012) and Mrázová and Neary (2014, 2013).

horizontal matching. Moreover, we incorporate these matching-based gains in a model that includes most of the other welfare channels highlighted by modern trade theory, and we use this model to analyze the matching effects not just of trade but also of migration.⁸

The remainder of the paper is organized as follows. In Section 2.2 we describe the general model framework and characterize the autarky equilibrium. In Section 2.3, we then discuss the effects of a transition from autarky to free trade and the scenario of piecemeal trade liberalization. In Section 2.4, we introduce labor mobility and analyze the effects of migration, first looking at a migration equilibrium and then comparing "trade cum migration" with trade alone. Section 2.5 concludes.

2.2 The Modeling Framework

Our model economy is endowed with a mass L of workers, which are differentiated by the *types* of skills they possess. A skill type is best thought of as a specific combination of abilities to perform different types of tasks. We assume that the entire space of skill types may be characterized by a circle with circumference 2H, henceforth called the skill circle, whereby H measures the degree of horizontal skill differentiation present in the labor force. Each location on the circle represents a skill type, and types that are more similar are located closer to each other. This implies a continuous metric of similarity between different skill types. Moreover, using a circle to represent skill differences implies that each worker has the same average similarity to all other workers. Thus, skill heterogeneity is horizontal in nature. We assume a uniform distribution of the labor force L over the entire circle, which implies that a mass of $\frac{L}{2H}$ ds workers is located within an interval of length ds on the skill circle.

In order to set up production, a firm has to choose a certain location on the skill circle, which then determines that firm's ideal skill type. When working for this firm, workers will be differently productive, depending on the distance between their skills and the firm's ideal skill type. As will become evident below, this implies that firms are facing upward

⁸Positive assortative matching also arises in Helpman et al. (2010) where firms are heterogeneous as in Melitz (2003). The reason is that firms may engage in costly screening to secure a minimum level of ability of hired workers, and more productive firms have a higher incentive to screen. But there is a crucial difference. In the present paper as well as in Davidson et al. (2008), skills are specific *ex ante*. In contrast, Helpman et al. (2010) assume *ex post* specificity: The ability of a worker revealed through firm-specific screening is specific to the match thus established. Ex ante, workers are identical in that each worker's ability is drawn from the same distribution function at the time of hiring. Hence, a matching problem comparable to this paper does not exist in their model.

sloping supply schedules for efficiency units of labor. Thus, they have wage setting power, whereby the resulting markups depend on the pattern of firm locations on the skill circle.

Consumer preferences are described by a translog expenditure function, which implies love of variety. Firm behavior is structured in two stages. In *stage one*, potential entrepreneurs decide on whether to enter and, if so, where to locate on the skill circle. Setting up production at a certain point on the circle requires a fixed labor input α , defined in terms of efficiency units of the corresponding ideal skill type. In addition, production requires β units of this input per unit of the good produced. In *stage two*, firms set profit maximizing goods prices as well as wage rates, based on their market power on the goods as well as the labor market. We assume that firms pursue Bertrand strategies and that they are small enough to take aggregate variables as given. Stage two thus leads to a Bertrand-Nash equilibrium in prices and wage rates, conditional on the number and skill positions of firms determined in stage one. Stage one decisions anticipate the Bertrand-Nash equilibria of stage two (subgame perfection). We assume free entry of an infinite number of potential entrepreneurs with zero outside options. Hence, equilibrium in stage one is determined by a zero profit condition.

The remainder of this section first looks at the second stage, including a detailed characterization of firms' wage setting power on the labor market. This is followed by a characterization of the zero profit equilibrium determined in stage one and by a characterization of an equilibrium where the economy is closed on both the goods and the labor market. A final subsection comments on the types of distortions involved in this equilibrium. Subsequent sections will then look at different scenarios of opening up the economy on the goods market and the labor market, respectively.

2.2.1 Price and Wage Setting with Worker Heterogeneity

2.2.1.1 Labor Supply

For each variety that a firm may conceivably produce, technology is characterized by an ideal combination of skills that are needed to perform the required tasks. This combination corresponds to a unique point on the skill circle, to be chosen when a firm enters in stage one. Workers with skill types that deviate from this optimal type may still be employed to produce this variety, but will prove less productive. We model this through a function f[d] which gives the number of efficiency units of labor delivered per physical unit of labor by a worker whose skills are represented by a point at distance d from the point representing the ideal type of skills. We assume that this function has the following properties: f'[d] < 0, f'[0] = 0, f''[d] < 0, and f[d] = f[-d]. This last property states that distance in either

direction on the circle has the same effect. Efficiency units delivered by different types of workers are perfect substitutes. Without loss of generality, we set $f[0] = 1.^9$

We assume enforceable contracts between firms and workers, specifying the quantity of, and price for, efficiency units of labor. Each worker knows her skill distance from all firms positioned on the skill circle as well as the productivity schedule f[d]. Thus, she knows the income that she will earn per physical unit of labor when working for a certain firm offering a certain wage rate per efficiency unit. Each worker inelastically supplies one unit of physical labor. All workers sort themselves into employment by different firms so as to maximize their individual incomes, given firm-specific wage offers as well as their skill distance to these firms. For any pair of wage rates between two neighboring firms, there will thus be a marginal worker who is indifferent between the two firms as their wage offers amount to an equal income per physical unit of labor. All inframarginal workers earn wages above their outside options. This implies that the entire employment surplus is appropriated by workers, which is consistent with a zero profit equilibrium. The reason for why firms are unable to appropriate any employment surplus through wage discrimination is that they are unable to observe an individual worker's skill type. This effectively rules out paying each worker a wage rate equal to her outside option; this outside option is simply not known to the firm.

Figure 2.2 illustrates this type of worker sorting. It looks at a sector of the skill circle encompassing the location of three neighboring firms with optimal skill types s_i , s_{i+1} and s_{i+2} , which are at distances $2m_{i,i+1}$ and $2m_{i+1,i+2}$ from each other.¹⁰ The concave curves depict firm-specific schedules $w_g f[d_g]$, g = i, i + 1, i + 2, giving the income that a worker at distance d_g from firm g's position may expect to earn per physical unit of labor when working for this firm, given that it offers a wage rate per efficiency unit equal to w_g . The skill distance d_g is measured both to the left and the right from s_g . We refer to $w_g f[d_g]$ as firm g's wage-income-schedule. Firm g's wage rate is found as $w_g f[0]$. We define $d_{i,r}$ such that all workers in the interval $[s_i, d_{i,r}]$ prefer working for firm i to working for firms i+1 or i+2, and similarly for the interval $[s_i - d_{i,\ell}, s_i]$ to the left. In other words, $d_{i,r}$ and $d_{i,\ell}$ measure the skill distance between firm i's ideal skill type and the marginal worker to

⁹One might ask why a firm should not always be able to secure the optimal combination of skills by employing convex combinations of workers embodying different combinations of skills. The answer is that doing so would entail a cost of communication between workers of different skill types. Therefore, other things equal, having the ideal skill type embodied in each worker is always less costly than combining different types of workers. The function f[d] above may be interpreted as representing such cost of combining different skill types.

¹⁰In the symmetric equilibrium considered below, it will prove useful to use $m_{i,i+1}$ to indicate the halfdistance (instead of the full distance) between firms i and i + 1.



Figure 2.2: The wage schedules

the right and left, respectively, who is indifferent between working for firm i and its two neighboring firms. We shall also refer to this distance as the *skill reach* of firm i.

If firm *i* sets a wage equal to w_i , then its skill reach to the right is determined by the condition $w_i f[d_{i,r}] = w_{i+1} f[2m_{i,i+1} - d_{i,r}]$; see the solid solid arrow at the bottom of Figure 2.2.¹¹ For a higher wage rate w'_i , a completely analogous condition $w'_i f[d'_{i,r}] =$ $w_{i+1} f[2m_{i,i+1} - d'_{i,r}]$ leads to a greater skill reach $d'_{i,r}$, indicated by the long-dashed arrow.¹² With firm-specific wages w'_i and w_{i+1} firm *i*'s skill reach extends beyond s_{i+1} . Firm *i* would thus be able to hire firm i + 1's ideal skill type, plus some workers to the right of s_{i+1} , up to point $s_i + d'_{i,r}$. In turn, firm i + 1 would be left employing workers in the interval $[s_i+d'_{i,r}, s_{i+1}+d'_{i+1,r}]$, with workers in the interval $[s_{i+1}+d_{i+1,r}, s_{i+2}+d_{i+2,r}]$ being employed

¹¹Note that we have replaced d_{i+1} by $2m_{i,i+1} - d_i$, in line with the aforementioned sorting of workers.

¹²Note that due to symmetry $f[2m_{i,i+1} - d'_i] = f[d'_i - 2m_{i,i+1}]$. This allows us to use the same condition determining marginal workers to the left and the right of s_{i+1} . Note also that workers at a distance $d'_{i,r} - 2m_{i,i+1}$ to the left of s_{i+1} would earn the marginal worker's income if working for firm i + 1, but they are better off working for firm i. The marginal worker is thus uniquely determined by the above condition.

by firm i + 2.¹³ Increasing its wage rate further to w''_i would allow firm i to out-compete firm i + 1 and start attracting workers from firm i + 2. The skill reach covered by w''_i is implicitly determined by $w''_i f[d''_{i,r}] = w_{i+2}f[2m_{i,i+1} + 2m_{i+1,i+2} - d''_{i,r}]$; see the short-dashed arrow in Figure 2.2. However, out-competing via high enough wages will never occur in the comparative static scenarios analyzed below, since any adjustment of the equilibrium number of firms occurs through firm exit and entry, driven by the condition of non-zero maximum profits.

In what follows we use \boldsymbol{w}_{-i} to denote the N-1 vector of wage rates set by all firms other than *i*, such that the first element is the wage set by the first neighbor to its right, and so on until the *N*-the element, which is the wage set by the first neighbor to its left.¹⁴ Moreover, \boldsymbol{m}_i denotes the *N*-dimensional vector $(2m_{i-1,i}, 2m_{i,i+1}, \ldots, 2m_{i-2,i-1})$, where we set i-1=N if i=1, and i+1=1 if i=N. We shall henceforth refer to \boldsymbol{m}_i as the distance vector viewed at from firm *i*'s perspective. Consistently with the definition of $\boldsymbol{w}_{-i}, 2m_{i-1,i}$ and $2m_{i,i+1}$ must be interpreted, respectively, as the distance between firm *i* and its first left-hand and first right-hand neighbor, and so on. It now follows from the above reasoning that the right-hand skill reach from firm *i*'s location on the skill circle may be written as $d_{i,r} = d_r[w_i, \boldsymbol{w}_{-i}, \boldsymbol{m}_i]$ and analogously for the skill reach to its left, $d_{i,\ell} = d_{\ell}[w_i, \boldsymbol{w}_{-i}, \boldsymbol{m}_i]$.¹⁵ Clearly, the skill reaches $d_{i,r}$ and $d_{i,\ell}$ are increasing in w_i and weakly increasing in \boldsymbol{m}_i , but weakly decreasing in \boldsymbol{w}_{-i} .

$$w_{i}f[d_{i,r}] = w_{i+j}f\left[\sum_{k=1}^{j} 2m_{i+k-1,i+k} - d_{i,r}\right] \text{ where }$$

$$j = \operatorname{argmax}_{j}\left\{w_{i+j}f\left[\sum_{k=1}^{j} 2m_{i+k-1,i+k} - d_{i,r}\right] \mid 1 \le j \le N - 1\right\},$$

$$(2.1)$$

where all *m*-terms are elements of the vector \mathbf{m}_i as defined above. This condition includes combinations of wage rates where firm *i* out-competes some of its nearest neighbors. In these expressions, i+j indicates firm *i*'s relevant competitor employing the marginal worker at distance $d_{i,r}$ from firm *i*'s ideal type. The second line identifies the relevant competitor as the firm which is the first to meet firm *i*'s wage offer as the skill distance increases. Equivalently, it is the firm where a marginal (indifferent) worker is found at the shortest distance $d_{i,r}$ from firm *i*. A completely analogous determination holds for the left-hand skill reach $d_{i,\ell}$.

¹³The distance $d_{i+2,r}$ lies to the right of the range covered by Figure 2.2.

¹⁴A well-defined labor supply function as derived in this subsection requires $N \ge 2$. We shall assume below that N is "large".

¹⁵Note that the function $d_r[\cdot]$ is uniform across firms, but the value of this function, in general, will not. The function $d_r[w_i, \boldsymbol{w}_{-i}, \boldsymbol{m}_i]$ is implicitly defined as the solution to the following condition:

The entire amount of efficiency units that firm i is able to attract through setting a wage rate w_i now follows as the integral over all efficiency units f[d] from distance zero up to distance $d_{i,r}$ plus the corresponding integral from zero to $d_{i,\ell}$. Writing

$$L^{S,\ell} = \int_{0}^{d_{\ell}[w_i, \boldsymbol{w}_{-i}, \boldsymbol{m}_i]} f[d] \frac{L}{2H} dd$$
$$L^{S,r} = \int_{0}^{d_r[w_i, \boldsymbol{w}_{-i}, \boldsymbol{m}_i]} f[d] \frac{L}{2H} dd$$

firm i's labor supply schedule now emerges as

$$L^{S}[w_{i}, \boldsymbol{w}_{-i}, \boldsymbol{m}_{i}] = \begin{cases} L^{S,\ell} + L^{S,r} & \text{if } d_{i,\ell} \leq -d_{i,r} \\ 0 & \text{else} \end{cases}$$
(2.2)

Intuitively, for a low enough wage rate w_i firm *i*'s labor supply will fall down to zero. This happens if the condition $d_{i,\ell} \leq -d_{i,r}$ is violated, in which case the skill reach covered by firm *i*'s neighbor to the left includes the skill reach that firm *i* is able to cover on its right. In other words, the overall distance covered by firm *i* then has zero measure. For wages above this threshold level, the firm faces a labor supply function for efficiency units which is increasing in its own wage. Moreover, the labor supply schedule is continuous in w_i except for points where a further increase in w_i reduces labor supply to the nearest competitor down to zero. But, as we have emphasized above, such out-competing of neighbors will never arise in the scenarios considered below. In what follows we shall use η_i to denote the elasticity of firm *i*'s labor supply function (2.2). Obviously, this elasticity is a function of w_i, w_{-i} , and m_i .

2.2.1.2 Goods Demand

To complete our description of a firm's market environment, we next turn to goods demand. Individual k derives utility from consumption of a bundle $C[c_k]$ of differentiated varieties $c_k = [c_{1k}, ..., c_{ik}, ..., c_{Nk}]$, where N denotes the number of varieties available. Throughout the paper, we use brackets [·] to collect arguments of a function and parentheses to collect algebraic expressions. We assume that $C[c_k]$ is homogeneous of degree one, hence the logarithmic indirect utility function is given by

$$\ln V_k = \ln y_k - \ln P[p], \tag{2.3}$$

where $P[p] = P[p_1, ..., p_i, ..., p_N]$ is the minimum unit expenditure function for all varieties *i*, and y_k denotes income of individual *k*. Following Diewert (1974) and Bergin and Feenstra (2000), we assume that preferences are characterized by a symmetric translog expenditure function.¹⁶ The unit expenditure function is given by

$$\ln P[p] = \frac{1}{2\gamma N} + \frac{1}{N} \sum_{i=1}^{N} \ln p_i + \frac{\gamma}{2N} \sum_{i=1}^{N} \sum_{j=1}^{N} \ln p_i (\ln p_j - \ln p_i), \qquad (2.4)$$

which is homogeneous of degree one. The parameter $\gamma > 0$ controls the degree of substitutability between varieties, a larger γ implying higher substitutability.¹⁷ Using Roy's identity, the Marshallian demand function for variety *i* can be derived as

$$q_{ik}[p, y_k] = \frac{\partial \ln P[p]}{\partial \ln p_i} \frac{y_k}{p_i} = \delta_i \frac{y_k}{p_i}, \qquad (2.5)$$

where

$$\delta_i = \frac{1}{N} + \gamma \left(\frac{1}{N} \sum_{j=1}^N \ln p_j - \ln p_i \right)$$
(2.6)

is the expenditure share for variety *i*. Thus, the preferences underlying the above expenditure function are homothetic. Inserting (2.6) into (2.5) and using Y to denote aggregate income, revenue from variety *i*, r_i , then follows as

$$r_i = \delta_i Y$$
 with (2.7)

$$\delta_i = \gamma \mathcal{W} \left[\exp\left\{ \frac{1}{\gamma N} + \overline{\ln p} \right\} \frac{q_i}{\gamma Y} \right], \qquad (2.8)$$

where $\overline{\ln p} := \sum_{i} \ln p_i / N$ and $\mathcal{W}[\cdot]$ denotes the Lambert function.¹⁸

¹⁶Recent applications of the symmetric translog expenditure system are Feenstra and Weinstein (2010), Arkolakis et al. (2010) and Ródriguez-López (2011). As Feenstra and Weinstein (2010) point out, another interesting feature of the this expenditure system is that it constitutes a second order Taylor approximation of any symmetric expenditure function.

¹⁷Feenstra (2003) derives a translog expenditure function of the type above allowing for a gap between the number of varieties *conceivably* available and the number of varieties available in a certain equilibrium. The specification used here, borrowed from Arkolakis et al. (2010), assumes that the number of varieties *conceivably* available is infinite and thus does not enter the expenditure function.

¹⁸The Lambert function $\mathcal{W}[z]$ defines the implicit solution to $xe^x = z$ for z > 0. Furthermore, it satisfies $\mathcal{W}_z = \frac{\mathcal{W}[z]}{(\mathcal{W}[z]+1)z} > 0$, $\mathcal{W}_{zz} < 0$, $\mathcal{W}[0] = 0$ and $\mathcal{W}[e] = 1$. Here as elsewhere in the paper, we use a subscript index to indicate partial derivatives whenever this proves convenient without causing confusion.

While (2.6) expresses the expenditure share as a function of $\ln p_i$, in (2.8) this share is expressed as a function of the quantity q_i ; Appendix A2.1 has the details. Given our preferences, no two firms will produce the same variety, so that we may use *i* to indicate firms.

2.2.1.3 Pricing Equilibrium

Armed with these representations of the firm's goods demand and labor supply, firm behavior in stage two may now be characterized by the following profit maximization problem:

s.t.:
$$\begin{array}{l} \max_{w_i} r_i - w_i L_i \\ q_i = \frac{L_i - \alpha}{\beta} \quad \text{with } L_i = L^S \left[w_i, \boldsymbol{w}_{-i}, \boldsymbol{m}_i \right], \quad \text{and} \\ q_i \ge 0. \end{array}$$
 (2.9)

In (2.9), r_i must be seen as given in (2.7) and (2.8) above. The restriction ensures that firm *i* is on its labor supply function and produces a positive quantity. We proceed under the assumption that the non-negativity constraint is non-binding. The corresponding restrictions on the parameter space are discussed in Appendix (A2.3). Note also that this maximization problem is conditional on the variables N and m_i which are determined in stage one.

We assume that firms pursue Bertrand strategies on both the goods and the labor market, meaning that they take the prices and wages set by their competitors as given. Moreover, each firm is assumed to be small enough to take the average log price $\overline{\ln p}$ as well as aggregate income Y as given beyond its own influence. Under these assumptions the perceived price elasticity of demand for variety *i* emerges as

$$\varepsilon_i[p_i, \overline{\ln p}, N] := -\frac{\mathrm{d}\ln q_i}{\mathrm{d}\ln p_i} = 1 - \frac{\mathrm{d}\ln\delta_i}{\mathrm{d}\ln p_i} = 1 + \frac{\gamma}{\delta_i} > 0.$$
(2.10)

This elasticity depends on prices and the number of firms. Thus, the markup of prices over marginal cost, determined by stage two pricing decisions, will be an endogenous variable.

The first order condition for profit maximization requires that perceived marginal revenue is equal to perceived marginal cost. It follows that the optimal wage chosen by firm i observes

$$p_i = \frac{\varepsilon_i}{\varepsilon_i - 1} \frac{\eta_i + 1}{\eta_i} w_i \beta.$$
(2.11)

Pricing thus involves a double markup.¹⁹ The first fraction in this pricing rule represents the markup that derives from the firm's price setting power on the goods market, and it is larger than 1 since $\varepsilon_i > 1$. From (2.10) and (2.6), we may write this markup as $\frac{\varepsilon_i}{\varepsilon_i-1} = \left(1 + \frac{\delta_i}{\gamma}\right) = \mathcal{W}\left[\frac{\eta_i}{w_i(\eta_i+1)}\exp\left\{1 + \frac{1}{\gamma N} + \overline{\ln p}\right\}\right]$, again using the Lambert function.²⁰ The expression inside \mathcal{W} is a "summary measure" of the conditions that firm *i* faces on the labor market as well as the goods market. Given $\mathcal{W}_Z > 0$, a higher average log-price of the firm's competitors and a lower degree of substitutability γ both lead to a higher markup. The same holds true for a smaller number of firms, whereas the markup is falling in perceived marginal cost. The second fraction in (2.11) represents the markup that derives from the firm's monopsony power on the labor market, where the firm faces a finite elasticity of supply $\eta_i < \infty$. Remember that η_i is a function of w_i , w_{-i} and m_i ; see (2.2) above.

Combining markup pricing as given in Equation (2.11) with firm-specific labor market clearing as given in the constraint in (2.9) implies $w_i = w \left[\boldsymbol{w}_{-i}, \boldsymbol{m}_i, N, \overline{\ln p}, Y \right]$. This is a best response function characterizing strategic interaction of firms in stage two.

When considering its optimal wage response, each firm takes as given the number of firms and the distance pattern determined in stage one and treats the macro-variables $\overline{\ln p}$ and Y as two constants. For ease of exposition, we shall drop the latter in what follows. The N best response functions in wages jointly determine N wage rates:

$$w_i^* = w^* [\boldsymbol{m}_i, N] \quad \text{for } i = 1, \dots, N$$
 (2.12)

Given these wage rates, Equation (2.11) determines equilibrium prices $p_i^* = p^* [\boldsymbol{m}_i, N]$. Moreover, equilibrium wage rates determine equilibrium profits according to problem (2.9). We shall henceforth refer equilibrium profits as $\pi_i^* = \pi^* [\boldsymbol{m}_i, N]$. The conditions under which such an equilibrium exists and is unique may be summarized by the following lemma.

¹⁹It is easy to verify that under the assumptions made, the second order condition is satisfied.

 $^{^{20}{\}rm This}$ derivation follows Arkolakis et al. (2010), for details see Appendix A2.1.

Lemma 1. If marginal profits are positive for output levels in the neighborhood of zero, and if the profit function is quasiconcave in the wage rate, then there exists a unique equilibrium in the Bertrand game of wage and price setting in stage two. A sufficient condition for the profit function to be quasiconcave is that the labor supply function is concave. For any given labor market environment, quasiconcavity of profits obtains if the marginal cost β is sufficiently low.

The proof of this lemma follows in Appendix A2.2. The first condition rules out corner solutions in which some firms find it optimal, conditional on entry, not to produce at all. For a given labor market environment $(H, f[d], \mathbf{m}_i \text{ and } L)$, marginal profits are high if the marginal cost β is low, and if the degree of substitutability in demand (captured by γ) is low. A low enough value of γ (low substitutability) ensures that the choke price for a new good is high enough, so that firms needing to set high prices due to tight labor market conditions $\mathbf{m}_i, \mathbf{w}_{-i}$ still face some demand for their good. Whatever the choke price, a low enough value of β will always ensure positive marginal profits. As regards quasiconcavity, β governs the weight of the curvature of the labor supply function in the curvature of the revenue function. Should labor supply be convex in the wage rate, a low enough value of β ensures that concavity of revenue in q_i leads to quasiconcavity of profits in w_i .

2.2.2 Entry Decision and the Equilibrium Distance Pattern

One way to think of the location choice in stage one is to view a firm's strategy space as a set of addresses it can choose, taking as given the addresses of other firms, and where the firm's pay-off is given by equilibrium profits as determined in the subsequent pricing game. This setup is chosen, for instance, in Economides (1989) and Vogel (2008) who analyze product differentiation, with consumers evenly distributed over a unit circle characterizing ideal product characteristics, and with utility quadratic and linear, respectively, in the distance between a consumer's and the firm's position on this circle. Analyzing existence and uniqueness of the equilibrium, one faces the challenge of characterizing the pricing game in stage two for alternative location choices in stage one, including asymmetric locations, that allows one to examine whether deviations from the symmetric location pattern are profitable. This is possible for linear or quadratic utility, respectively, in the setups considered by Economides (1989) and Vogel (2008).²¹ However, in our circular model of the labor market, where the labor supply function has a more general form, this proves

²¹The contribution in Economides (1989) is to demonstrate the existence of a symmetric subgame-perfect equilibrium in a three stage game of (i) entry, (ii) choice of variety and (iii) pricing. Vogel (2008)

intractable. We therefore choose a different approach, based on the observation that the address of a firm on the circle is not informative. We have shown above that equilibrium profits in the pricing game depend only on the distances to other firms, described by m_i , and not by their positions as such. Knowing about this, a firm seems unlikely to consider alternative addresses for its own while assuming all other firms' addresses are held fixed. This would imply that the firm assumes it can influence the overall pattern of distances, which seems questionable. Indeed, complete symmetry of the circle implies that the only way for an individual firm to affect the distance pattern is by means of entry or exit. We therefore reduce the firm's choice of entry and the position on the skill circle to the decision to enter or not, given its beliefs about the type of distance patterns that it may rationally expect to face upon entry.

We assume that there is an infinite number \overline{N} of *potential* entrants. Given the circumference H, any given number of entrants N renders a set of infinitely many possible N-dimensional distance vectors \boldsymbol{m} between these N firms. In the following, we use \mathcal{M}^N to denote this set. It is an exhaustive description of possible labor market environments that a firm may face, if the number of entering firms is N. Now look at these distance vectors from the point of view of a certain firm i, using the above definition of m_i as the N-dimensional vector $(2m_{i-1,i}, 2m_{i,i+1}, \dots, 2m_{i-2,i-1})$, where we set i - 1 = N if i = 1, and i + 1 = 1 if i = N. Our approach to solving the entry game rests on the assumption that firm i views possible realizations of N-1 distances as random variables, and that it forms beliefs about all conceivable distance patterns which we denote by $\mu_i[\mathbf{m}_i|N]$. The joint pdf μ_i assigns a unique probability to any conceivable distance vector (labor market environment) that firm i can possibly be confronted with upon entry, given that the total number of firms entering is N and the circumference of the circle space is 2H. A key observation now is that any one of these distance vectors implies a certain m_{i+1} , m_{i+2} , up to m_{i-1} , suitably applying the above definition of the firm-specific distance vector to firms i + 1 up to i - 1.

The strategy space for a firm is characterized by a binary decision variable \mathcal{I}_i , where $\mathcal{I}_i = 1$ indicates entry, and $\mathcal{I}_i = 0$ indicates non-entry. Firm *i*'s expected payoff, conditional on N is $\mathbb{E}_i[\pi^*[\boldsymbol{m}_i, N]]$, where \mathbb{E}_i denotes the expected value formed over all distance vectors viewed from firm *i*'s perspective and according to firm *i*'s set of conditional beliefs

develops a model similarly featuring three stages of decision making, but with firm heterogeneity in productivity and proving existence *and uniqueness* of the equilibrium. He demonstrates that, for linear utility, any one firm's market share and profit are determined only by its own productivity and by the average productivity across all firms. Moreover, he derives a relationship between the inter-firm pattern of productivities and the pattern of bilateral distances along the circle. Importantly, for homogeneous firms, this relationship implies a symmetric distance pattern.

 $\mu_i[\mathbf{m}_i|N]$. The key behavioral assumption now is that the firm's entry decision is based on expected second-stage profits associated with all possible distance patterns, that is,

$$\mathcal{I}_{i} = \begin{cases} 1 & \text{if } \mathbb{E}_{i} \left[\pi^{*}[\boldsymbol{m}_{i}, N] \right] \geq 0 \text{ and } \nu_{i}[N] > 0 \\ 0 & \text{otherwise} \end{cases} \quad \text{for all } i = 1 \dots \bar{N}. \tag{2.13}$$

In this decision rule, $\nu_i[N]$ denotes the probability of N according to firm *i*'s beliefs. Let $\mathcal{I}_i|N$ denote the decision outcome according to (2.13). Noting that $N = \sum_{j \neq i} \mathcal{I}_j + 1$, Equation (2.13) is readily interpreted as a best response function. Considering the set of outcomes $\mathcal{I}_i|N$ for all possible values of N, the equilibrium number of firms, N^e , is then defined by

$$\sum_{i=1}^{\bar{N}} \mathcal{I}_i | N^e \ge N^e \quad \text{and} \quad \sum_{i=1}^{\bar{N}} \mathcal{I}_i | \tilde{N} < \tilde{N} \text{ for } \tilde{N} > N^e \quad (2.14)$$

It is important to note that the summation in (2.14) is from 1 to \overline{N} .

Each and every \mathcal{I}_i has a corresponding set of infinitely many distance vectors \boldsymbol{m}_i , with an associated set of beliefs $\mu_i[\boldsymbol{m}_i|N]$.²² We now impose two consistency requirements on these beliefs that we argue are implied by the assumption of structural symmetry of firms, coupled with the assumption that firms are fully informed about the characteristics and logic of the circle (including that firms are symmetric). First, symmetry implies that beliefs are symmetric across firms, i.e., $\mu_i = \mu$ and $\nu_i = \nu$ for all *i*. Secondly, consistency requires that $\mu[\boldsymbol{m}_i|N]$ be zero for any distance vector that would imply negative profits for some of the *N* entrants. If some distance vectors are ruled out by this requirement, we re-scale probabilities of all remaining distance vectors, so that they sum up to 1. If for some N_0 all possible distance vectors $\boldsymbol{m}_i|N_0$ fall victim to this consistency requirement, firms know that if N_0 of them enter it will never be possible for all of them to make non-negative profits. Consistent beliefs about *N* then require $\nu[N_0] = 0$ and the decision rule (2.13) implies that an outcome with entry of N_0 firms is ruled out.

To summarize, we define beliefs as *consistent* if

$$\nu[N] = 0$$
 if $\pi[\boldsymbol{m}_{i+j}, N] < 0$ for at least one j and for all $\boldsymbol{m}_i \in \mathcal{M}_N$
 $\mu[\boldsymbol{m}_i|N] = 0$ if $\nu[N] > 0$ and $\pi[\boldsymbol{m}_{i+j}, N] < 0$ for at least one j

where j = 0, ..., N - 1 denotes the *j*th neighbor of firm *i*.

²²In the terminology of dynamic games with incomplete information, this set of possible labor market environments corresponds to an information set; see Mas-Colell et al., (1995, ch. 9).

Given consistent beliefs, we can prove that under plausible restrictions on the parameter space discussed below a symmetric equilibrium with $N^e > 0$ and zero profits, $\pi^*[\mathbf{m}_i, N^e] =$ 0 is the only equilibrium for this entry game. Our proof, detailed in Appendix A2.3, runs along the following logic. We first look at *symmetric* distance patterns. We demonstrate that there exists some N^{sym} such that for the symmetric distance vector $\mathbf{m}_{\text{sym}}|N^{\text{sym}}$ we have $\pi^*[\mathbf{m}_{\text{sym}}, N^{\text{sym}}] = 0$ and for $N > N^{\text{sym}}$ we have $\pi^*[\mathbf{m}_{\text{sym}}|N] < 0$. The logic of entry and equilibrium in Equations (2.13) and (2.14), coupled with consistent beliefs, then implies that any (symmetric or asymmetric) outcome with $N < N^{\text{sym}}$ cannot arise as an equilibrium. Next, turning to *asymmetric* distance patterns, we demonstrate that $N \ge N^{\text{sym}}$ necessarily involves negative profits for at least one entrant. Therefore, by the exact same logic of Equations (2.13) and (2.14) as well as consistency of beliefs, an asymmetric equilibrium with $N > N^{\text{sym}}$ cannot arise as an equilibrium. Taken together, all of this implies that the symmetric distance pattern with $N^e = N^{\text{sym}}$ is the only equilibrium.

A key element of this logic is the effect (on firms' maximum profits) of moving from a symmetric to an asymmetric distance pattern. This involves two channels. The first is a decrease in the average efficiency of labor use that comes with moving to asymmetry. Intuitively, starting out from a symmetric distance pattern, an asymmetric rearrangement of distances means that firms, on average, will see a reduction in labor supply at notionally unchanged wage rates. The second involves a change in labor supply elasticities that leads firms to adjust their wage markups. The disadvantage from the first channel of moving to asymmetry is reinforced by the second if a firm's labor supply elasticity is falling, which implies a reduction in monopsony power. It turns out, however, that for an arbitrary change in the distance pattern, the effect on the labor supply elasticity is ambiguous. For the above logic to go through, we therefore need further conditions guaranteeing that any move from a symmetric to an asymmetric distance pattern will have a negative effect on at least one firm's maximum profits. We may summarize this by the following lemma.

Lemma 2. Given that firms play entry strategies as described in (2.13), there exists a subgame-perfect equilibrium of entry as defined in (2.14) with a finite number of entering firms, symmetrically positioned on the skill circle, and this equilibrium is unique, provided that the following conditions are met: (i) Firms' beliefs about conceivable distance vectors and the number of entrants are consistent, (ii) the fixed cost are not too large relative to the size of the labor force and relative to the degree of product differentiation, so that at least one firm can charge a sufficiently high markup over marginal cost so as to break even, and (iii) the negative efficiency effect on the profits of a firm whose output decreases when moving from a symmetric to an asymmetric distance pattern is reinforced, or at least not

undone, by the effect of this change on the firm's monopsony power on the labor market (labor supply elasticity).

A detailed proof of this lemma is given in Appendix A2.3. The general intuition for conditions (i), (ii), and (iii) has been discussed above. As detailed in Appendix A2.3, condition (iii) is met, for instance, if the effect of moving from symmetry to asymmetry in the distance pattern on the slope of labor supply is sufficiently small in absolute value. Alternatively, it will be met if the marginal cost β is sufficiently low, meaning that the efficiency effect is large. Note that a low value of β is also required for Lemma 1. Condition (ii) ensures existence of a symmetric location pattern with positive second-stage equilibrium profits for at least one firm.

2.2.3 Autarky Equilibrium

Having established symmetry of the equilibrium in stage one, we now turn to the determination of m, the equilibrium distance between any two representative firms, as well as the solution for the goods price and the wage rate for the representative firm. In this section, we do this for the closed economy, thus paving the way for comparative analysis of various opening up scenarios in subsequent sections of the paper.

We first note that N, the number of firms is related to m through the circumference of the skill circle: m = H/N. Moreover, in a symmetric equilibrium we have $p_i = p$, with $\overline{\ln p} = \ln p$, as well as $w_i = w$. Next, we return to the above pricing rule (2.11), invoking symmetry in order to pin down the two markups on the goods and labor market. The elasticity of labor supply, given in (2.2) and evaluated at $w_i = w$, may be written as

$$\eta[m] := \left. \frac{\partial L_i^S}{\partial w_i} \frac{w_i}{L^S} \right|_{w_i = w} = -\frac{f[m]^2}{2F[m]f'[m]},\tag{2.15}$$

where $F[m] := \int_0^m f[d] dd$. Our assumption that $f''[m] \leq 0$ ensures that the labor supply elasticity is falling in m.²³

$$\frac{\partial \eta[m]}{\partial m} = \frac{-f[m]}{F[m]} - \frac{f[m]^2}{2\left(F[m]f'[m]\right)^2} \left(-f[m]f'[m] - F[m]f''[m]\right).$$

²³This follows directly from

Invoking symmetry in equation (2.6) simplifies the expressions for ε and δ , allowing us to write the profit maximizing price (2.11) as

$$p[m] = \rho[m]\psi[m]\beta, \qquad (2.16)$$

where
$$\rho[m] := 1 + \frac{1}{\gamma N[m]}$$
 and $\psi[m] := \frac{\eta[m] + 1}{\eta[m]}$. (2.17)

In (2.16), we have normalized the wage per efficiency unit to $1.^{24}$ Note that $\rho' > 0$ as well as $\psi' > 0$. Firms' monopsony power in the labor market increases as firms become larger and the number of firms falls. Equations (2.16) and (2.17) describe the first order condition on pricing: a higher distance between firms leads to a higher goods price p.

Next, we introduce θ to denote the average productivity of workers. Given a uniform distribution of the workforce around the circle, we have

$$\theta[m] = \frac{1}{m} \int_0^m f[d] \mathrm{d}d. \tag{2.18}$$

Notice that we have $\theta_m = (f[m] - \theta[m])/m < 0$ since f'[m] < 0. Given our wage normalization, $\theta[m]$ represents average income per worker. In a situation where workers assume ex ante that each point on the skill circle has the same probability of representing an ideal skill-type of a firm, $\theta[m]$ may be interpreted as a worker's expected nominal income. Aggregate income emerges as $Y = L\theta[m]$, and output per firm is

$$q[m] = \frac{1}{N[m]} \frac{L\theta[m]}{p[m]}.$$
(2.19)

The zero profit condition requires

$$p[m] = \frac{\alpha + \beta q[m]}{q[m]}.$$
(2.20)

Without loss of generality, we may now scale units, such that $\beta = 1$. The labor market clearing condition may then be written as $\alpha + q[m] = \frac{L}{N[m]}\theta[m]$, and aggregate variable

²⁴We are free to do so, since our equilibrium is homogeneous of degree zero in nominal prices. This can easily be seen from substituting (2.10) and (2.6) in (2.11), which yields $p_i = \left(1 + \frac{1}{\gamma N} + \overline{\ln p} - \ln p_i\right) \frac{\eta_i + 1}{\eta_i} w_i$.

labor input is $N[m]q[m] = L\theta[m] - \alpha N[m]$. Substituting these expressions in (2.20), we obtain the following representation of the zero profit condition:

$$p[m] = g[m] := \frac{L\theta[m]}{L\theta[m] - \alpha N[m]}.$$
(2.21)

Note that g[m] > 1 is the usual measure of the degree of economies of scale, i.e., the ratio of average to marginal cost, applied to the economy at large. We have $g' < 0.^{25}$ With zero profits, this ratio must be equal to the price relative to marginal cost. With $w\beta = 1$ from our scaling and normalization, this is exactly what we have in equation (2.21). Intuitively, with a higher distance between firms, zero profit requires a lower price.

Combining the zero profit condition (2.21) with the Bertrand pricing equation in (2.16), we finally arrive at the following condition that determines m, the half-distance at which firms symmetrically locate on the skill circle in an autarky equilibrium:

$$g[m] = \rho[m]\psi[m]. \tag{2.22}$$

This is the core condition that we use in the subsequent comparative static analysis.

In all of the welfare results to be derived below, we take an ex ante view, assuming that workers regard each point on the circle as being equally likely to become an ideal type. Given a symmetric equilibrium, expected utility of a worker is then equal to

$$\ln V = \ln \theta[m] - \left(\frac{1}{2\gamma N[m]} + \ln p[m]\right).$$
(2.23)

Intuitively, this welfare measure is rising in income and the number of firms in the market, and is falling in the price of a typical variety of goods. Note, however, that all of these variables are depending on the equilibrium value of m. While we know from above that θ and N are both falling in m, the relationship between p and m is ambiguous at this stage of our analysis. As we shall see below, whether p rises or falls with m depends on the type of exogenous shock considered. Hence equation (2.23), while revealing, is no comparative static result. Before moving to a comparative static analysis in Section 2.3 below, we address the question of whether a laissez faire equilibrium incorporates an optimal value of m. Given the multiple distortions present in this economy, the expected answer is "No." In the next subsection, we discuss these distortions in more detail, establishing the

²⁵Given our scaling assumption $\beta = 1$ and the normalization w = 1, $L\theta[m]$ is the economy-wide total cost, while $\alpha N[m]$ is the aggregate use of labor for fixed cost, both expressed in efficiency units of labor. Hence, the right-hand side of (2.21) is the aggregate equivalent to the ratio of average to marginal cost.

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conclusion that the laissez faire equilibrium involves a sub-optimally large value of m, which implies excess firm entry.

2.2.4 Distortions

The equilibrium described above involves four distortions. (i) When considering market entry, firms fail to take into account the positive effect of their entry on welfare through a larger number of varieties. Following Dixit and Stiglitz (1977), this is often referred to as "consumer-surplus distortion." (ii) Moreover, potential entrants ignore the positive effect on average productivity arising from a better quality of matches in the labor market. This is novel in the present model, relative to standard models of monopolistic competition, and we call it the "productivity distortion." Both, distortions (i) and (ii) constitute positive externalities, working towards insufficient entry in a laissez faire equilibrium. But entry also has negative externalities, having to do with markups on the goods and labor markets. More specifically, (iii) potential entrants anticipate both, a goods price markup as well as a wage markup, but fail to see that they will realize operating profits on such markups only at the expense of incumbent firms, due to the overall resource constraint. Following Mankiw and Whinston (1986), this may be called the "businessstealing" effect. And finally, (iv) potential entrants fail to anticipate that their entry will reduce the magnitudes of these same markups, due to enhanced competition. In a zero profit equilibrium, operating profits compensate for fixed cost, hence this "procompetitive" effect, as well as the "business-stealing" effect, works towards excessive entry.

As is well known, in the standard CES version of the monopolistic competition model distorsions (i) and (iii) offset each other and firm entry is efficient. In Appendix A2.5 we show that in this model the net result of distortions (i)-(iv) is excess entry. Thus, the model inherits the "excess entry" result established by Salop (1979) for the circular city model.²⁶ Moreover the result is in line with Bilbiie et al. (2008), who find that in a monopolistic competition equilibrium with symmetric translog preferences the business-stealing effect dominates the consumer-surplus effect, giving rise to excess entry.²⁷ The excess-entry result plays a crucial role in the determination of the gains from globalization below, as those unfold partly through a mitigation of distortions.

 $^{^{26}\}mathrm{As}$ an example for circular labor markets, see Helsley and Strange (1990).

 $^{^{27}\}mathrm{A}$ further case in point has been established for preferences of the constant absolute risk aversion by Behrens and Murata (2012).

2.3 Symmetric Trading Equilibrium

In this section, we explore the gains as well as the wage inequality effects from trade. The first subsection compares autarky with free trade, whereby we introduce trade simply by allowing for the number of countries to increase beyond 1 (which is autarky) and allowing for firms in all countries to sell on all national markets without any border frictions. Mrázová and Neary (2014) call this the extensive margin of globalization. In the second subsection we then turn to the intensive margin of globalization by holding fixed (at 2) the number of countries, but allowing for trade to be costly and looking at marginal reduction of this cost. In both subsections, we rule out cross-border hiring of workers, i.e., ruling out international migration, which will be taken up in the next section. Both trade and migration is analyzed assuming countries to be fully symmetric, including the extent of worker heterogeneity, so as to clearly isolate the channels that emanate from horizontal worker heterogeneity as such.

Given worker heterogeneity, we must expect different workers to be affected differently in the trade and migration scenarios considered below. In order to address welfare effects, we must therefore specify the exact definition of aggregate welfare. We offer two alternative views, both leading to the same results. The first is to look at real income of the worker with average productivity $\theta[m]$, as given in (2.18). Given the assumed uniform distribution of workers over the skill circle, any increase in this income implies that workers whose income has fallen may be compensated through a (costless) lump-sum transfer system. In this sense, a rise in $\theta[m]$ may interpreted as a Pareto improvement. The second definition of aggregate welfare exploits the fact that the model only determines m, the half-distance between two neighboring firms, but leaves the exact positioning of firms on the skill circle undetermined. It is therefore natural to treat the exact positioning of firms as unknown (ex ante) to workers, and to assume that all workers view all points on the circle as equally likely to become an ideal skill type of some firm. With these assumptions, the real income of the worker with average productivity $\theta[m]$ may be interpreted as as a worker's expected utility. Since workers are assumed to be risk-neutral, an increase in expected utility will increase a worker's welfare.

2.3.1 Free Trade

We assume that there are k symmetric countries and we denote the total number of firms worldwide by $N^T := kN$. Absent all barriers, prices for domestic and imported goods are equal, and given by

$$p[m] = \left(1 + \frac{1}{\gamma k N[m]}\right) \psi[m].$$
(2.24)

This expression reflects the fact that firms now take into account foreign competitors, but it keeps the simplified form familiar from the autarky equilibrium; see (2.17). Absent all trade barriers, prices of imported and domestic varieties are fully symmetric, whence the price of any variety consumed is equal to the average price. In what follows, we define $\rho^T[m] := 1 + \frac{1}{k\gamma N[m]}$ as the goods price markup under free trade. It is obvious that $\rho^T[m] < \rho[m]$.

Total demand per variety remains unchanged, since the lower domestic demand is compensated by the larger number of countries:

$$q[m] = \frac{kL\theta[m]}{kN[m]p} = \frac{L\theta[m]}{N[m]p}.$$
(2.25)

The labor market clearing condition similarly remains unaffected. The equilibrium condition that determines m then follows as

$$g[m] = \rho^T[m]\psi[m]. \tag{2.26}$$

The following proposition summarizes the comparison between autarky, k = 1, and free trade among k > 1 countries.

Proposition 1. Opening up to free trade among k symmetric countries (with k > 1) has the following effects, relative to an autarky equilibrium (where k = 1): (i) There is exit of firms in each country, with an increase in the total number of varieties available to the consumer. (ii) There is a higher wage markup, coupled with a lower price markup, but goods prices are unambiguously lower. (iii) Each country's labor market suffers from a fall in the average matching quality, with lower average income. (iv) Each country enjoys a higher real income and higher aggregate welfare. (v) Wage inequality increases.

Proof: A formal proof is relegated to Appendix A2.6.1.

The increase in variety (i) and the pro-competitive effect on the goods market (ii) are standard results in trade models with monopolistic competition and endogenous markups. The novel insight here relates to adverse labor market effects: A lower number of domestic firms lowers the degree of competition on labor markets, increasing the wage markup. But the pro-competitive effect dominates, leading to lower prices under free trade than under autarky (ii). In addition, the exit of firms makes it more difficult for workers to find firms matching well with their skills, causing a reduction in the productivity of the average worker (iii). However, the variety and pro-competitive effects more than compensate for this negative productivity effect, making the economy better off under free trade than under autarky (iv). On account of f'[m] < 0 exit of some firms will reduce the lower bound of wages. Since the upper bound of wages is fixed at f[0] = 1, and given a uniform distribution of workers over the skill circle, this entails an increase in wage inequality.

This positive welfare effect in this proposition reflects the excess entry property of the laissez faire equilibrium, whence an exit of firms entails a first order welfare gain. This holds true whatever the cause of the exit. In the present scenario, this first order gain from dm > 0 is driven by opening up borders, dk > 0, which exerts a positive effect on household welfare through a larger number of product varieties available. However, workers are differently affected depending on their location on the skill circle. While the maximum wage rate paid to a worker remains unchanged, the ideal workers in the trade equilibrium are different from those of the autarky equilibrium. Statement (iv) of the proposition invokes the usual compensation argument in defining the aggregate welfare effect as the change in indirect utility of the worker who receives the average level of real income. Moreover, given the increase in m, the lower bound of wages paid will be falling. Hence, some workers even suffer a lower "nominal" wage rate because of a larger distance to the nearest firm on the skill circle.

2.3.2 Costly Trade and Piecemeal Trade Liberalization

The superiority of free trade to autarky does not imply that a piecemeal liberalization in a world with costly trade is always beneficial. We stick to the symmetric case, but for simplicity reduce the number of countries to k = 2, using an asterisk to denote the foreign country. Suppose that firms face iceberg transport cost $\tau > 1$ for exports. A domestic firm that sells q_i units on the domestic market and q_i^* units on the export market then needs a labor input equal to $\alpha + q_i + \tau q_i^*$.²⁸ We assume that markets are segmented, and

²⁸Remember that we have scaled units such that the marginal production cost β equal unity.

therefore, firms can set market specific quantities independently. The firm thus maximizes profits with respect to the wage, which determines its labor supply and hence total output $\bar{q}_i = q_i + \tau q_i^*$, and with respect to the quantity sold on the domestic market observing $q^* = \frac{1}{\tau}(\bar{q}_i - q_i)$. Hence, it solves the following maximization problem:

$$\max_{w_i,q_i} \{r_i + r_i^* - w_i(\alpha + \bar{q}_i)\}$$
s.t.: $r_i = \delta_i Y, \quad r_i^* = \delta_i^* Y^*$

$$\bar{q}_i = q_i + \tau q_i^* \quad \text{with} \quad q_i \ge 0 \text{ and } q_i^* \ge 0$$

$$\alpha + \bar{q}_i = L^S[w_i, \boldsymbol{w}_{-i}, \boldsymbol{m}_i]$$

$$(2.27)$$

whereby

$$\delta_i = \frac{1}{N^T} + \gamma \left(\overline{\ln p} - \ln p_i\right) = \gamma \mathcal{W} \left[\exp\left\{\frac{1}{\gamma N} + \overline{\ln p}\right\} \frac{q_i}{\gamma Y}\right] \quad \text{and} \quad (2.28)$$

$$\delta_i^* = \frac{1}{N^T} + \gamma \left(\overline{\ln p} - \ln p_i^*\right) = \gamma \mathcal{W} \left[\exp\left\{\frac{1}{\gamma N} + \overline{\ln p}\right\} \frac{q_i^*}{\gamma Y} \right].$$
(2.29)

In these equations, $\overline{\ln p} = \frac{1}{N} \sum_{j=1}^{N} \ln p_j + \frac{1}{N^*} \sum_{j^*=1}^{N^*} \ln p_{j^*}$ denotes the log average price of competitors, where j and j^* index firm i's domestic and foreign competitors. Due to symmetry, the average log price is the same across markets.²⁹ The first order condition with respect to q_i commands that marginal revenue be equalized across markets, more specifically, that $p_i\left(\frac{\varepsilon-1}{\varepsilon}\right) = \frac{p_i^*}{\tau}\left(\frac{\varepsilon^*-1}{\varepsilon^*}\right)$. The first order condition with respect to w_i demands that, as above, marginal revenue equal perceived marginal cost.³⁰ Acknowleding symmetric locations and identical wages and the normalization of the symmetric equilibrium wage to unity, we obtain the following optimal pricing conditions:

$$p = \frac{\varepsilon}{\varepsilon - 1} \psi[m]$$
 with $\frac{\varepsilon}{\varepsilon - 1} = 1 + \frac{\delta}{\gamma}$ (2.30)

$$p^* = \frac{\varepsilon^*}{\varepsilon^* - 1} \psi[m] \tau$$
 with $\frac{\varepsilon^*}{\varepsilon^* - 1} = 1 + \frac{\delta^*}{\gamma}$ (2.31)

²⁹Due to symmetry, the expenditure functions are the same in both countries, but expenditure shares for domestic and imported goods are different. Expenditure shares are obtained by differentiation of the log expenditure function, i.e. $\delta_i := \frac{\partial \ln P}{\partial \ln p_i}$ and $\delta_i^* := \frac{\partial \ln P}{\partial \ln p_i^*}$, and then applying the same logic as outlined in Appendix A2.1 to express them in terms of q_i and q_i^* , respectively.

³⁰See Appendix A2.6.2 for details.

The labor market clearing condition is

$$N[m] (\alpha + q[p, p^*, m] + \tau q^*[p, p^*, m]) = L\theta[m].$$
(2.32)

In contrast to the autarky and the free trade case, the pricing conditions cannot be simplified further because individual firms' prices in (2.28) are not equal to average prices in the economy. The equilibrium skill reach of the representative firm, m, as well as domestic and export prices are determined by the system of equations (2.30), (2.31) and (2.32). This system is the analogue to the free trade equilibrium condition (2.26) above.³¹

Our preferences imply that a finite level of real trade costs might be prohibitive. We denote this prohibitive level of trade costs by $\bar{\tau}$, and it is determined implicitly by $\delta_i^* = 0$ in (2.28). Note that with $\delta_i^* = 0$ the price elasticity of demand for foreign goods becomes infinite; see (2.10). Note also that high values of γ imply low values of $\bar{\tau}$. We may now state the following proposition on piecemeal trade liberalization.

Proposition 2. For two identical countries in a trading equilibrium, a decrease in trade $costs \tau$ within the non-prohibitive range, $\tau \in [1, \overline{\tau})$, has the following effects: (i) There is exit of firms in each country. (ii) The price of imported varieties falls, but the change in the price of domestically produced goods is ambiguous: it falls at low initial levels of τ , and it increases at high initial levels of τ . (iii) Aggregate welfare rises for sufficiently low initial levels of τ , and it falls for sufficiently high initial levels of τ . (iv) Wage inequality is increasing.

Proof: A formal proof is relegated to Appendix A2.6.3.

Part (iii) of this proposition may seem puzzling at first sight. According to standard results on piecemeal trade liberalization, in this fully symmetric economy a *uniform* proportional reduction of trade barriers across all varieties should be a welfare increasing "liberalization formula"; see Fukushima (1979). The key difference here arises from the labor market distortion. Liberalization involves two opposing effects. First, a lower price for imported varieties leads firms to lower their price markup on domestic goods; a procompetitive effect that is positive for welfare. Note that this effect arises even at the prohibitive margin with $\tau = \bar{\tau}$ where no imports take place in the initial equilibrium.³² At the same time, however, as firms in both countries ship more output to foreign markets,

³¹As detailed in Appendix A2.6.3, for comparative statics it proves convenient to rewrite the system of equations in terms of the endogenous variables m, W, W^* .

³²For $\tau = \bar{\tau}$ the trading equilibrium is quantitatively identical to the autarky equilibrium considered in Section 2.2.3. This can be shown by inserting the implicit solution for $\bar{\tau}$, obtained by setting $\delta^* = 0$, into
they use up more resources for transport, which bids up wage rates and causes firm exits in both countries.³³ Fewer domestic firms imply larger markups on the labor market as well as a lower average quality of matches between firms and worker skills. The magnitude of this effect clearly depends on the initial level of trade costs; it is strongest at $\tau = \bar{\tau}$ and disappears for $\tau = 1$. The proof in the Appendix demonstrates that for $\tau = \bar{\tau}$ initially, the adverse labor market effect of a marginal reduction of τ dominates, not just in terms of higher prices for domestic varieties, but also in terms of welfare so that liberalization is welfare reducing. Since we can also demonstrate that free trade, $\tau = 1$, is better than autarky, $\tau = \bar{\tau}$, there is a threshold value $\tilde{\tau}$, with $1 < \tilde{\tau} < \bar{\tau}$, such that piecemeal liberalization starting from $\tau < \tilde{\tau}$ is unambiguously welfare increasing. Proposition 1 implies that $\tilde{\tau} > 1$.

Invoking costless compensation, we use average income to evaluate aggregate welfare effects in an economy where heterogeneous workers are affected differently. Using the indirect utility function we see that welfare is affected by changes in prices of domestic and imported goods as well as by the change in m, which affects both average income and the number of available varieties. The change in welfare can be expressed as

$$\widehat{V} = \left(\frac{\partial \ln \theta}{\partial \ln m} - \frac{\partial \ln P}{\partial \ln m}\right)\widehat{m} - N\delta\widehat{p} - N\delta^*\widehat{p}^*.$$
(2.33)

The increase in m, induced by a decrease in trade costs, affects welfare negatively through a decrease in average income $\theta_m[m] < 0$ and a decrease in the number of firms, which implies an increase in the ideal price index $P_m[m] > 0$. The effects of changes in prices of domestic and imported goods are weighted by the respective expenditure shares. For a high initial level of trade costs the expenditure share for imported goods is small, so that consumers hardly benefit from the decrease in the price of imports, while being much affected by the change in the price of domestic goods, which is positive for a high initial level of trade costs. Hence, for a high initial level of τ the overall effect of a decrease in the trade cost level on welfare is negative. In contrast, for a low initial value of trade costs, the negative effect through a decrease in the number of firms becomes smaller, approaching zero as τ converges to one. Furthermore, the higher the expenditure share for important therefore

the pricing condition (2.30). Yet, the disciplinary effect of a decrease in import prices works through $\overline{\ln p}$ in equation (2.30), even if $\delta^* = 0$.

³³This is the mechanism underlying the well-known home market effect for *asymmetric* countries, first noted by Krugman (1980). Of course, the home market effect as such does not arise here, since countries are assumed symmetric.

also the competitive effect on domestic prices through the product market. Hence, we find a U-shaped relationship between welfare and the level of trade costs.

2.4 Migration

So far, we have analyzed the effects of product market integration under the assumption that workers are immobile across countries. Intuitively, if we allow for migration, then some workers in both countries will find their skills matching better with a firm in the foreign country. This constitutes an incentive for two-way migration. In this section, we show that a "free trade cum migration" equilibrium delivers higher welfare than a "free trade only" equilibrium. Furthermore, we show that under a slightly stronger assumption about the curvature of f[d], piecemeal integration of labor markets, unlike piecemeal trade liberalization, is unambiguously welfare increasing. Our model highlights two welfare increasing effects of migration: First, integration of labor markets reduces monopsony power, as domestic firms now compete for workers not only with other domestic firms, but also with foreign firms. Second, migration entails efficiency gains by improving the average matching quality, as workers in both countries are now able to find better skill matches for employment. Even though the number of available varieties might fall, compared to the free trade equilibrium, the efficiency gains and the pro-competitive gains on the labor market are always dominating, leading to a positive welfare effect.

2.4.1 Modeling Migration

For simplicity, we consider the case of two symmetric countries, which implies the same number of firms in both countries, as well as equal prices and wages. This simplification allows us to focus on the part of migration that is related to the idea of skill mismatch. We deliberately ignore differences in average wages or in the cost of living that would clearly constitute migration incentives as well.³⁴ We model the cost of migration as reducing the productivity of a worker to a fraction $1 - \lambda$, if this worker moves to the other country. A domestic worker working for a domestic firm at distance d, delivering f[d] efficiency units, thus delivers only $f[d](1 - \lambda)$ efficiency units when working for a foreign firm at

³⁴Labor mobility and free entry imply that there is also the possibility of an agglomeration equilibrium, where all workers and firms work and produce in the same country. This is ruled out, if the trade cost level is sufficiently low, compared to the cost of migration. Throughout this section, we assume free trade, hence our results are not impaired by instability. In the case of zero cost of both trade and migration, the equilibrium outcomes in the dispersed and the agglomeration equilibrium are the same in terms of prices and welfare.

the same skill distance d.³⁵ Symmetry of countries also means that the degree of skill differentiation among the labor force is the same.

We analyze international migration as an entry and pricing game with two stages and Bertrand behavior analogous to sections 2.2 and 2.3 above, occurring simultaneously in both countries, whereby each firm takes into account the possibility of hiring workers from the other country. Conditions similar to the ones discussed in Section 2.2.2 ensure existence and uniqueness of the symmetric alternating location equilibrium for non-prohibitive migration cost; see Appendix A2.7.1 for details. By alternating pattern, we mean any one firm facing two neighboring firms from the other country.

2.4.2 Labor Supply with Integrated Labor Markets

We continue using 2m to denote the skill distance between two firms located in the same country. In the alternating equilibrium the firm's direct competitor on the labor market, which is located in the foreign country, is then found at distance m in the skill space.³⁶ The sorting cut-offs, i.e., the maximum distances of native workers d^n and migrant workers d^m from their firms, are derived as follows. For a domestic firm i, taking the foreign wage w^* as given, the cut-off for native workers, $d_i^n = d_i^n [w_i, \bar{w}^*, m, \lambda]$, is determined by

$$w_i f[d_i^n] = \bar{w}^* f[m - d_i^n] (1 - \lambda).$$
(2.34)

Analogously, the cut-off for migrant workers, $d_i^m = d_i^m[w_i, \bar{w}^*, m, \lambda]$, is determined by

$$w_i f[d_i^m] = \bar{w}^* f[m - d_i^m] \frac{1}{1 - \lambda}.$$
(2.35)

As the level of migration costs falls, the cut-offs converge. At $\lambda = 0$ they coincide at m/2.

Under symmetry, the employment and migration pattern will be as follows: The domestic firm employs domestic workers with skill-types in the interval $(\bar{s}_0 - d^n, \bar{s}_0 + d^n)$, and foreign workers (migrants) located in the interval $(\bar{s}_0 - d^m, \bar{s}_0 + d^m)$, while the foreign firm located at $\bar{s}_0 + m$ will employ foreign workers located in the interval $(\bar{s}_0 + m - d^n, \bar{s}_0 + m + d^n)$ and domestic workers (migrants) with skill types in the interval $(\bar{s}_0 + m - d^n, \bar{s}_0 + m + d^n)$. Notice that $d^n + d^m = m$.

³⁵The proportionality assumption is convenient for modeling, yet it is not crucial. A general characterization of the specifications generating the results derived in this section is found in Appendix A2.7.5.
³⁶Note that without migration 2m measures the distance to the nearest competitor.

The supply of efficiency units as a function of the firm's wage now emerges as

$$L^{ES,M}[w_i, \bar{w}^*, m, \lambda, L, H] = \frac{L}{H} \left(\int_{0}^{d_i^n[w_i, \bar{w}^*, m, \lambda]} f[d] dd + \int_{0}^{d_i^m[w_i, \bar{w}^*, m, \lambda]} f[d] (1-\lambda) dd \right)$$
(2.36)

where $d_i^n[w_i, \bar{w}^*, m, \lambda]$ and $d_i^m[w_i, \bar{w}^*, m, \lambda]$ are given by (2.34), (2.35), respectively. Let $d^n = d^n[m, \lambda]$ and $d^m = d^m[m, \lambda] := m - d^n[m, \lambda]$ denote the cut-offs in the symmetric equilibrium. These two variables measure the skill reach of a representative firm for domestic and foreign workers, respectively. With $\lambda > 0$, we have $d^m < d^n$. As before, m may be interpreted as a mismatch indicator, but the average distance between worker skills and a firm's ideal type across employment of domestic and foreign workers is now equal to m/2, whereas without migration it was equal to m. In a symmetric equilibrium, average productivity then emerges as

$$\theta^{M}[m,\lambda] := \frac{1}{m} \left(\int_{0}^{d^{n}} f[d] \mathrm{d}d + \int_{0}^{d^{m}} f[d](1-\lambda) \mathrm{d}d \right).$$

$$(2.37)$$

By complete analogy to (2.15), the perceived elasticity of effective labor supply, evaluated at the symmetric equilibrium, can be derived as³⁷

$$\eta^{M}[m,\lambda]\big|_{w_{i}=\bar{w}^{*}} = \frac{2f[d^{n}]^{2}}{f'[d^{n}] + (1-\lambda)f'[m-d^{n}]} \frac{-1}{\int_{0}^{d^{n}} f[d]\mathrm{d}d + (1-\lambda)\int_{0}^{d^{m}} f[d]\mathrm{d}d}.$$
 (2.38)

Note that the labor supply function is subject to the constraint $d^m[m, \lambda] \geq 0$, which ensures that both cut-offs lie in between the positions of the domestic and the foreign firm. This condition is equivalent to the condition that the migration cost level λ is not prohibitive.³⁸ As migration costs approach the prohibitive level, the supply of efficiency units of labor becomes equal to the supply under autarky. This is readily verified by inserting $d^n = m$ and $d^m = 0$ into (2.36).

Interestingly, even if the level of migration costs is prohibitive, firm behavior is influenced by the mere potential of migration through the perceived elasticity of labor supply.³⁹ The possibility of attracting migrants by setting higher wages and thus increasing the supply of efficiency units implies that firms perceive a higher elasticity of supply, even if they

 $^{^{37}}$ For details of the derivation see Appendix A2.7.2

³⁸Otherwise, if migration costs are too large relative to firm size, firms cannot attract any migrants in the first place and the supply curve looks different since they then compete again only with firms from the same country.

 $^{^{39}\}mathrm{We}$ thank Vitor Trindade for pointing this out to us.

do not employ any migrant in equilibrium. Let $\bar{\lambda}$ denote the prohibitive level of migration costs, determined by setting $d^m[m, \lambda] = 0$. The perceived wage elasticity of labor supply evaluated at $\bar{\lambda}$ is given by

$$\eta^{M}[m,\bar{\lambda}] = \frac{2f[m]^{2}}{f'[m] + (1-\bar{\lambda})f'[0]} \frac{-1}{F[m]}.$$
(2.39)

Note that concavity of f[d] is sufficient to ensure that $\eta^{M}[m, \bar{\lambda}]$ is larger than the elasticity of supply under autarky as given in (2.15). It is important to note at this point, that with prohibitive λ , the symmetric alternating location pattern does not constitute an equilibrium as defined in (2.14). The reason is precisely that in this situation, labor market competition is greater than in autarkic labor markets, while labor supply is the same. Firms can and will avoid this situation, for example, by simultaneously decreasing the distance to one of their foreign neighbors, leading to a de-facto autarkic labor market equilibrium. Nevertheless, the second-stage pricing equilibrium evaluated at the symmetric alternating location pattern and prohibitive cost of migration proves very helpful as a reference case for the equilibrium outcomes of the cases of non-prohibitive migration cost, for which the symmetric alternating location pattern does constitute the unique equilibrium of the two-stage game.

We show in Appendix A2.7.2 that $\eta^{M}[m, \lambda]$ increases as λ falls, provided that f'''[d] is not too large. In what follows, we assume that this condition holds.⁴⁰ By analogy to (2.17), we now use $\psi^{M}[m, \lambda] := (\eta^{M}[m, \lambda] + 1) / \eta^{M}[m, \lambda]$ to denote the wage distortion under migration. For a given level of m, the magnitude of this distortion is unambiguously lower with migration and $\lambda \in [0, \overline{\lambda}]$ than without.

In addition to the wage distortion, migration also affects the average quality of skill matches between workers and firms. It is obvious that for prohibitively high migration costs, $\lambda = \overline{\lambda}$, the average matching quality, as given in equation (2.37), is the same as under autarky, given in (2.18): $\theta^M[m, \overline{\lambda}] = \theta[m]$. Moreover, as we prove in the appendix, $\theta^M_{\lambda} < 0$. In other words, the matching quality unambiguously increases as λ falls, reaching $\theta^M[m, 0] = \theta[m/2]$ for frictionless migration where $\lambda = 0$. It is instructive to see how

⁴⁰The reasoning behind this condition is as follows: A higher λ leads firms to increase the share of migrants employed by shifting d^n outwards and d^m inwards. If the curvature of f[d] falls (in absolute terms) as the cut-offs move to the right, an increase in λ helps firms to avoid competition by employing more native workers in the range where the curvature of f[d] is lower and fewer migrants in the range where the curvature of f[d] is lower and fewer migrants in the range too much (in absolute terms) as the cut-off moves to the right.

effective labor supply to a representative firm is affected by the cost of migration. Under frictionless migration, $\lambda = 0$, labor supply (2.36) emerges as

$$L^{ES,M} = 2\frac{L}{H} \int_0^{\frac{m}{2}} f[d] dd = \frac{2L}{N^M} \theta^M[m,0] = \frac{L}{N} \theta[m/2].$$
 (2.40)

Note that $N^M = \frac{2H}{m} = 2N$, where N is the number of firms in each country. Comparing this to the autarky case, both the number of firms and workers are doubled. However, we know from above that for $\lambda < \bar{\lambda}$ we have $\theta^M > \theta$. Hence, with migration firms face a larger supply of efficiency units of labor than under autarky. The reason is that, while employing the same number of workers as under autarky, each firm now finds workers with skills closer to its optimal type. Importantly, all of this is conditional upon a given level of m, which is determined by the firm entry condition. As we shall see below, equilibrium adjustment of the number of firms after opening up to migration, driven by a lower wage markup, might bring about firm exit which has a countervailing, negative effect on average productivity.

2.4.3 The "Trade cum Migration" Equilibrium

We complete the description of a "trade cum migration" equilibrium for non-prohibitive migration costs by a zero profit condition that determines the number of firms or, equivalently, the distance between a neighboring domestic and foreign firm on the skill circle, which is now equal to m. We look at the case of free trade. As in (2.26), we formulate this condition as stating that the double markup is equal to the inverse of the degree of economies of scale:

$$g^{M}[m,\lambda] = \rho^{T}[m]\psi^{M}[m,\lambda].$$
(2.41)

In this equation, $\rho^{T}[m]$ denotes the free trade price markup over perceived marginal cost obtaining in a free trade equilibrium without migration. Under free trade, this markup simplifies to $1 + 1/(\gamma N^{M})$, where N^{M} is the number of firms world-wide; see equation (2.24). Unlike the wage markup, the price markup is not affected by allowing for migration. The term $\psi^{M}[m, \lambda]$ denotes the wage markup in a migration equilibrium, as introduced above. The term $g^{M}[m, \lambda]$ on the left measures the degree of scale economies, taking into account the labor market clearing condition, which now reads as $\alpha + q =$

 $(m/H)L\theta^{M}[m,\lambda]$, as well as goods market clearing, which requires $q = L\theta^{M}[m,\lambda]/(pN)$. This measure thus reads as

$$g^{M}[m,\lambda] := \frac{L\theta^{M}[m,\lambda]}{L\theta^{M}[m,\lambda] - \alpha H/m}.$$
(2.42)

In order to understand the effects of labor market integration, we now proceed in two steps. We first look at a situation where migration is allowed in principle, but where the costs of migration are prohibitively large, $\lambda = \bar{\lambda}$, and compare this case with the equilibrium outcome under national labor markets. Importantly, as we have discussed above, the case of prohibitive migration cost we are referring to in this section describes the second-stage pricing equilibrium for a symmetric alternating location pattern, but does not constitute a subgame-perfect equilibrium as defined in (2.14). It serves only as a reference case for the second step, where we look at the effects of successively lowering the costs of migration, starting from non-prohibitive levels of λ , for which the symmetric alternating location pattern does constitute a subgame-perfect equilibrium.

Proposition 3. Compared to a free trade equilibrium with national labor markets, welfare is unambigously higher in the second-stage "trade cum migration" equilibrium with two symmetric countries, symmetric alternating firm locations, and a prohibitively high level of the cost of migration. The number of firms in each country is unambigously smaller in both countries.

Proof: The analytical details of the proof are relegated to Appendix A2.7.3.

A key point to understand this proposition is that the excess entry property of the autarky equilibrium demonstrated in Section 2.2.4 is inherited by the second-stage zero-profit equilibrium with symmetric alternating location patterns for any $\lambda \in [0, \overline{\lambda}]$. While the productivity distortion is not affected as long as no one migrates, the wage markup is affected because firms perceive a larger elasticity of labor supply. By lowering the wage markup, opening up labor markets to migration implies that the number of firms in the zero-profit equilibrium is smaller, even if the cost of migration is prohibitively high. And given that the free trade equilibrium involves excessive firm entry, this entails a positive welfare effect. With a lower wage markup distortion relative to the productivity distortion, the allocation is now closer to the social optimum.

Proposition 4. In a "trade cum migration" equilibrium with two symmetric countries, piecemeal integration of labor markets through a marginal reduction in the cost of migration has an ambiguous effect on the number of firms. However, it unambiguously leads to

lower prices and an increase in welfare in both countries, irrespective of the initial level of migration costs $\lambda \in [0, \overline{\lambda}]$.

Proof: The analytical details of the proof are relegated to Appendix A2.7.4.

The intuition for this proposition is best grasped from Figure 2.3, which depicts the schedules $g^{M}[m, \lambda]$ and $\rho^{T}[m]\psi^{M}[m, \lambda]$, identifying the equilibrium value of m at the intersection, in line with the zero profit equilibrium condition (2.42). The vertical axis of Figure 2.3 may be interpreted as measuring goods prices. Remember that $g^{M}[m, \lambda]$ measures the inverse degree of scale economies, which is equivalent to the markup required for zero profits. An increase in m makes firms larger, but it also lowers the productivity of the average worker. The appendix shows that the size effect always dominates, whence the g^{M} -line is downward-sloping. The $\rho^{T}[m]\psi^{M}[m, \lambda]$ -line depicts the double markup, reflecting monopoly power on the goods market and monopsony power on the labor market, respectively. This line is unambiguously upward-sloping, as a lower number of firms (higher m) reduces both the perceived price elasticity of goods demand as well the perceived labor supply elasticity with respect to the wage rate. We know from proposition 3 above that the intersection point for $\lambda = \overline{\lambda}$ involves a lower value of m than in the free trade equilibrium with national labor markets, which is determined by $g[m] = \rho^{T}[m]\psi[m].^{41}$

Now consider a reduction in λ from $\bar{\lambda}$ to $\lambda_1 \in [0, \bar{\lambda})$. For a notionally unchanged value of m, this improves the productivity of the average worker through a higher inframarginal surplus on migrant labor as well as through a resorting of workers from native employment into migration.⁴² This means that the g^M -line is shifted down by a reduction in λ . As regards the markup schedule $\rho^T[m]\psi^M[m,\lambda]$, we have shown above that the perceived elasticity of labor supply increases with a lower cost of migration, meaning that for a notionally unchanged m firms charge a lower wage markup $\psi^M[m,\lambda]$. Thus, the markup schedule shifts down as well, rendering an ambiguous effect on m. In the figure, the case $g^M[m,\lambda_1]$ ($g^M[m,\lambda_1]'$) depicts a relatively weak (strong) shift in the g^M -line, leading to an increase (a decrease) in m. The ambiguity in the adjustment of m implies that wage inequality under migration can generally be lower or higher than in the free trade equilibrium. However, the equilibrium unambiguously moves down on the vertical axis, which implies lower goods prices.

⁴¹Moving from an equilibrium with national labor markets to a "trade cum migration" equilibrium with $\lambda = \bar{\lambda}$ leaves g unaffected, $g[m] = g^M[m, \bar{\lambda}]$, while reducing the wage markup, $\psi[m] > \psi^M[m, \bar{\lambda}]$.

⁴²Note that for a constant m the average skill distance between workers and their firm's ideal type remains constant, equal to m/2. The productivity gain arises from savings in migration costs.



Figure 2.3: Comparative statics of the skill reach m

The welfare effect is determined by the change in real income and the number of varieties. Real income is given by $\theta^M[m,\lambda]/p[m]$, where average "nominal" income is measured by $\theta^M[m,\lambda]$, the productivity of the average worker. Invoking the indirect utility function, the welfare effect of our scenario may be described as

$$\hat{V} = \frac{\partial \ln \left[\theta^M/p\right]}{\partial \lambda} \cdot d\lambda + \frac{\partial \ln \left[\theta^M/p\right]}{\partial m} \cdot dm - \frac{1}{4\gamma H} \cdot dm$$
(2.43)

The first term describes the direct effect of lower migration costs, $d\lambda < 0$, on real income. From the above we know that this term is unambiguously positive. The remaining terms involving dm are ambiguous in their entirety, because dm as caused by $d\lambda < 0$ is ambiguous. However, we know from the above discussion of the distortions present in this economy that the autarky equilibrium involves excess firm entry, and from the proof of proposition 3 we know that any second-stage "trade cum migration" equilibrium with symmetric alternating firm locations inherits this excess entry property. Therefore, the positive real income effect of firm exit in the second term must dominate the negative variety effect in the third term. In other words, if the equilibrium adjustment depicted in Figure 2.3 leads to dm > 0, then the overall effect of $d\lambda < 0$ on welfare is positive. If dm < 0, then the welfare effect is less straightforward. While the final term of this expression is then unambiguously positive, the first two terms seem ambiguous. However, we show in the appendix that the first two terms of (2.43) are unambiguously positive for any initial $\lambda \in [0, \overline{\lambda}]$, if we insert $dm = (\partial m/\partial \lambda) \cdot d\lambda$. Referring to our discussion subsequent to propositions 1 and 2, we repeat that individual households are affected differently, due to skill heterogeneity. Speaking of an aggregate welfare effect implies the existence of a costless (lump-sum) redistribution mechanism.

2.5 Conclusion

In this paper, we propose an important qualification to the common narrative of of varietybased gains from trade. Traditional models of monopolistic competition stress the importance of a large resource base for a large degree of product differentiation, if production is subject to a non-convex technology. By opening up to trade, even small countries may enjoy the benefits of a large resource base. Domestic firms may be driven out of the market, but this has no adverse effect. If anything, it increases the average productivity level through a positive selection effect.

This view neglects an important fact of modern manufacturing: Product differentiation relies on the availability of differentiated inputs, including non-traded inputs like labor. If producing a specific variety of a good requires a specific bundle of skills, then the skill-diversity of the labor force, rather than its size, determines the degree of product differentiation supplied by the market. In this paper, we have shown that trade is a somewhat less benign force in an environment where product differentiation is based on worker heterogeneity than portrayed in conventional models of monopolistic competition. In particular, trade-induced firm exit worsens the average quality of matches between the type of skills that workers bring to their firms and the specific skill requirements of the goods produced by these firms. In addition, product differentiation implies that firms have monopsony power in the labor market, whence trade-induced exit of firms increases the resulting distortion between the marginal productivity of labor and the wage rate. This works against the conventional pro-competitive effect of trade on the goods markets where trade lowers the markup between marginal cost and prices. Labor market integration gives rise to a migration incentive, whereby firms engage in cross-border hiring even under complete symmetry between countries. Migration essentially has effects that are opposite to those of trade.

We have developed a model which allows us to rigorously pin down these effects and to weigh them against the effects familiar from conventional models of monopolistic competition. In our model product differentiation is rooted in preferences represented by a translog expenditure function. When entering the market, firms decide upon which type of good to produce, based on a circular representation of skill heterogeneity among the

work force, where each worker has the potential to serve as an "ideal" worker for a specific type of good. A non-convex technology implies a finite number of firms. A worker's supply of efficiency units is inversely related to the distance between her skill-position on the circle and the ideal skill position of the firm she works for. Having positioned themselves on the circle upon entry, firms engage in Bertrand competition on goods and labor markets, setting a double markup.

Using this model, we have explored both trade and migration scenarios. Comparing free trade with autarky in a symmetric many-country-world, we find that the variety and procompetitive effects on goods markets unambiguously dominate the adverse effects from a lower average quality of matches between firms and workers and from higher markups on the labor market. Looking at piecemeal trade liberalization between two symmetric countries, we find an ambiguity: If liberalization takes place from a high initial level of trade costs, then it causes a lowering of aggregate welfare, whereas it increases aggregate welfare, if the initial level of trade costs is already below a certain threshold.

Starting from a free trade equilibrium in a symmetric two-country-world, integrating labor markets leads to two-way migration. Firms and workers in both countries face an incentive for cross-border hiring, even though the initial equilibrium features international wage equalization. Thus, our view of product differentiation based on worker heterogeneity generates a novel force of migration, contributing to an improved understanding of two-way migration, which looms large in the data but has so far lacked convincing explanation in standard models of migration. Interestingly, potential migration exerts a positive welfare effect on both countries, even if migration costs are prohibitively large. Contrary to piecemeal trade liberalization, a piecemeal reduction in the cost of migration is unambiguously welfare increasing. The reason is that it improves the quality of matches while at the same time lowering firms' monopsony power on labor markets. From the simple fact that trade and migration have opposite effects it also follows that trade and migration are complements, rather than substitutes. The model clearly advocates opening up labor markets simultaneously with trade liberalization.

Appendix A.2

A2.1 Expenditure Share and Markup

Starting out from Equation (2.6), we obtain

$$\delta_i = \frac{1}{N} + \gamma \overline{\ln p} - \gamma \ln \frac{\delta_i Y}{q_i}$$

by inserting $p_i = \frac{\delta_i Y}{q_i}$. This can be rewritten as

$$\frac{\delta_i}{\gamma} + \ln \frac{\delta_i}{\gamma} = \frac{1}{\gamma N} + \overline{\ln p} - \ln \frac{Y}{q_i} - \ln \gamma$$

and applying the Lambert function $\mathcal{W}[z]$ which is defined as the solution to $xe^x = z$ or, equivalently, to $\ln x + x = \ln z$, yields $\delta_i = \delta[q_i, \overline{\ln p}, N, Y]$ as defined in Equation (2.8).

Similar logic can be applied to obtain an explicit solution for the optimal price as determined by (2.11). Defining perceived marginal cost as $\tilde{w}_i := [(\eta_i + 1)/\eta_i]w_i\beta$ and observing (2.6) and (2.10) the first-order condition (2.11) can be written as

$$\frac{p_i}{\tilde{w}_i} + \ln p_i = 1 + \frac{1}{\gamma N} + \overline{\ln p}.$$
(A2.1)

The left-hand side is an implicit function of the profit maximizing price p_i . Rewriting (A2.1) as

$$\frac{p_i}{\tilde{w}_i} + \ln p_i - \ln \tilde{w}_i = 1 + \frac{1}{\gamma N} + \overline{\ln p} - \ln \tilde{w}_i \tag{A2.2}$$

and applying the Lambert function to the left-hand side, we obtain the following explicit solution for p_i

$$p_i = \mathcal{W}\left[\tilde{w}_i^{-1} \exp\left\{1 + \frac{1}{\gamma N} + \overline{\ln p}\right\}\right]\tilde{w}_i.$$
 (A2.3)

which implies that the price markup obeys

$$\frac{\varepsilon_i}{\varepsilon_i - 1} = \mathcal{W}\left[\frac{\eta_i}{w_i(\eta_i + 1)} \exp\left\{1 + \frac{1}{\gamma N} + \overline{\ln p}\right\}\right].$$

A2.2 Existence and Uniqueness of the Pricing Equilibrium (Lemma 1)

We invoke the Index Theory approach outlined in (c.p. Vives, 2001, p. 48) to proof that under certain restrictions on the parameter space, there is a unique solution to second stage game. It follows, that $\pi^*[\boldsymbol{m}, N]$ is unique. The Index Theorem approach is based on

the Poincaré-Hopf Index Theorem, which implies that a solution to a system of reaction functions is unique if

- i). payoff functions are quasiconcave in firms' own strategies,
- ii). the strategy space is convex and compact and all equilibria are interior,
- iii). the Hessian is negative definite at the equilibrium point.

The proof proceeds as follows: We show that condition i) holds if the elasticity of marginal labor supply is not too large and condition ii) holds if marginal revenue is positive for output levels arbitrarily close to zero. Then, we show that condition iii) is always fulfilled in a transformed game where firms' strategies are *log* wages. Since conditions i) and ii) also hold in the transformed game, the Index Theorem implies that the transformed game has a unique solution. Since $\ln w$ is a positive monotone transformation of w for w > 0, this, in turn, implies uniqueness of the solution to the original game.

i) Quasi-concavity of the profit function. In the second stage, firms take the distance pattern \boldsymbol{m}_i , aggregate income Y and the average log price $\ln p$ as given and determine their optimal wage as best response against other firms' wage choices \boldsymbol{w}_{-i} by maximizing profits as in (2.9). The set of permissible strategies is bounded from below by $w_{\alpha i} :=$ $L^{-1}[\alpha, \boldsymbol{w}_{-i}, \boldsymbol{m}_i] > 0$, which denotes the wage-level where the second constraint in (2.9) binds.⁴³ Moreover, firms never set wages above the *choke price* divided by the marginal labor requirement β , where

$$p_{choke} := p_{choke}[N] = \lim_{q_i \to 0} mr_i = \exp\left[\frac{1}{\gamma N} + \overline{\ln p}\right] \quad \text{with}$$
$$mr_i := mr[q_i, N, Y, \overline{\ln p}] = \frac{\partial r_i}{\partial q_i} = \frac{r_i}{(W_i^q + 1)q_i} > 0$$

that is, the price at which demand approaches zero. Hence, there is a common upper bound on firms' strategies $\bar{w} = \frac{\exp\left[\frac{1}{\gamma N} + \overline{\ln p}\right]}{\beta}$ and so firm *i*'s strategy set is $S_i = [w_{\alpha i}, \bar{w}].^{44}$ In the above and the subsequent equations, we use $W_i^q := \mathcal{W}\left[\exp\left\{\frac{1}{\gamma N} + \overline{\ln p}\right\}\frac{q_i}{\gamma Y}\right]$ to denote the markup. Moreover, we henceforth denote with $L_i := L^S[w_i, \boldsymbol{w}_{-i}, \boldsymbol{m}_i]$ firm *i*'s labor supply.

 $^{^{43}}w_{\alpha i}$ approaches zero as all firms lower their wages towards zero. We assume that $w_{\alpha i}$ is positive because otherwise $\ln w$ (which we will be working with below) is not defined. This assumption has no bearing on the equilibrium outcomes. Moreover, excluding the possibility of zero wages can be justified by assuming that at a zero wage, workers prefer not to work and hence, firms need to pay at least the reservation wage.

⁴⁴Note that p_{choke} is the upper bound on marginal revenue and $w\beta$ is the lower bound of firms' marginal cost. Hence, wages above p_{choke}/β entail negative marginal profits independent of other firms' choices and are thus strictly dominated.

A sufficient condition for $\pi[w_i, \boldsymbol{w}_{-i}, \boldsymbol{m}_i, N]$ to be quasiconcave in the firm's own strategy is that $\frac{\partial^2 \pi_i}{\partial w_i^2} < 0$ whenever $\frac{\partial \pi_i}{\partial w_i} \geq 0$. Marginal profits are given by

$$\frac{\partial \pi_i}{\partial w_i} = \left(\frac{mr_i}{\beta} - w_i\right) \frac{\partial L_i}{\partial w_i} - L_i \qquad \text{if } \frac{\partial L_i}{\partial w_i} \exists,$$

where

$$\frac{\partial L_i}{\partial w_i} = \frac{L}{2H} \sum_{c=\ell,r} f[d_{i,c}] \frac{\mathrm{d}d_{i,c}}{\mathrm{d}w_i} > 0 \quad \text{with} \quad \frac{\mathrm{d}d_{i,c}}{\mathrm{d}w_i} = \frac{f[d_{i,c}]}{-w_i f'[d_{i,c}] - w_c f'[2m_{i,c} - d_{i,c}]} > 0.$$
(A2.4)

Marginal profits change in the firm's wage according to

$$\frac{\partial^2 \pi_i}{\partial w_i^2} = \frac{\partial mr_i}{\partial q_i} \frac{1}{\beta^2} \left(\frac{\partial L_i}{\partial w_i}\right)^2 - 2\frac{\partial L_i}{\partial w_i} + \left(\frac{mr_i[q_i]}{\beta} - w_i\right) \frac{\partial^2 L_i}{\partial w_i^2} \quad \text{if } \frac{\partial L_i}{\partial w_i} \exists, \qquad (A2.5)$$

where

$$\frac{\partial^2 L_i}{\partial w_i^2} = \frac{L}{2H} \left(\sum_{c=\ell,r} 3f'[d_{i,c}] \left(\frac{\mathrm{d}d_{i,c}}{\mathrm{d}w_i} \right)^2 + (w_i f''[d_{i,c}] - w_c f''[2m_{i,c} - d_{i,c}]) \left(\frac{\mathrm{d}d_{i,c}}{\mathrm{d}w_i} \right)^3 \right) \stackrel{<}{\leq} 0$$

$$(A2.6)$$

$$\frac{\partial mr_i}{\partial q_i} = -\frac{mr_i}{q_i} \frac{W_i^q (W_i^q + 2)}{(W_i^q + 1)^2}$$

Rewriting Equation (A2.5), we obtain

$$\frac{\alpha + \beta q_i}{\beta q_i} \cdot |\varepsilon_{mr,i}| \ge \frac{\eta_{mls,i}}{\eta_i} \tag{A2.8}$$

as a sufficient condition for quasiconcavity, where

$$\varepsilon_{mr,i} = \frac{\partial mr_i}{\partial q_i} \frac{q_i}{mr_i} = -\frac{W_i^q (W_i^q + 2)}{(W_i^q + 1)^2} \le 0$$
$$\eta_{mls,i} = \frac{\partial^2 L_i}{\partial w_i^2} w_i \bigg/ \frac{\partial L_i}{\partial w_i} \le 0.$$

With concave revenue in q_i , quasiconcavity of profits clearly obtains while the labor supply function is concave, since this implies that revenue is also concave in w_i and that the cost function $w_i L_i$ is convex in w_i . Concavity of the labor supply function implies that the wage elasticity of marginal labor supply η_{mls} is negative and, therefore, condition (A2.8) clearly holds. More generally, condition (A2.8) holds if η_{mls} is not too large relative to η . Moreover, condition (A2.8) holds irrespective of the curvature of the labor supply

function if $\frac{L_i}{L_i-\alpha} = \frac{\alpha+\beta q}{\beta q}$, the inverse degree of economies of scale, is large. This is always the case for low levels of the marginal cost β . To again more intuition about the role of β , note that $1/\beta$ is the derivative of q_i with respect to L_i , hence for any given level, slope, and curvature of L_i , β determines the relative weight of the curvature of revenue on the curvature of the profit function. Hence, whenever $\frac{\partial L_i}{\partial w_i} \exists$, quasiconcavity obtains if β is sufficiently small or if the labor supply function is concave.

Whenever firm *i* chooses a wage so that its neighbor i + j is just overbid and *i* starts competing with the next relevant competitor i + j', j' > j, the labor supply function and thus the profit function exhibits a kink and $\frac{\partial L_i}{\partial w_i} \not\equiv$. However, we can show that the labor supply function is always flatter after the kink and hence, the kinks do not impair the concavity of the profit function. Let $\tilde{w}_{i,c} := \tilde{w}_{i,c}[\boldsymbol{w}_{-i}, \boldsymbol{m}_i]$ denote the wage where the relevant competitor on side $c = \ell, r$ is just overbid. Then, (A2.4) implies that

$$\lim_{w_i \to \tilde{w}_{i,c}} \frac{\partial L_i^c}{\partial w_i} = \frac{L}{2H} \frac{f[d_{i,c}[\tilde{w}_{i,c}]]^2}{-\tilde{w}_{i,c}f'[d_{i,c}[\tilde{w}_{i,c}]] - w_{i+j}f'[2m_{i,i+j} - d_{i,c}[\tilde{w}_{i,c}]]} \quad \text{and} \quad (A2.9)$$

$$\lim_{w_i \to \tilde{w}_{i,c}^+} \frac{\partial L_i^c}{\partial w_i} = \frac{L}{2H} \frac{f[d_{i,c}[\tilde{w}_{i,c}]]^2}{-\tilde{w}_i f'[d_{i,c}[\tilde{w}_{i,c}]] - w_{i+j'} f'[2m_{i,i+j'} - d_{i,c}[\tilde{w}_{i,c}]]}.$$
(A2.10)

If i+j was overbid by i+j' at its own location, $\lim_{w_i \to \tilde{w}_{i,c}} \frac{\partial L_i^c}{\partial w_i} \ge \lim_{w_i \to \tilde{w}_{i,c}} \frac{\partial L_i^c}{\partial w_i}$ follows from $-f'[2m_{i,i+j'} - d_{i,c}[\tilde{w}_{i,c}]] > -f'[2m_{i,i+j} - d_{i,c}[\tilde{w}_{i,c}]] > 0$ and $w_{i+j'} > w_{i+j}$.

If i+j was overbid by i at its own location, $\lim_{w_i \to \tilde{w}_{i,c}^-} \frac{\partial L_i^c}{\partial w_i} \ge \lim_{w_i \to \tilde{w}_{i,c}^+} \frac{\partial L_i^c}{\partial w_i}$ follows from $2m_{i,i+j'} - d_{i,c}[\tilde{w}_{i,c}]] < 0$ and $-f'[2m_{i,i+j'} - d_{i,c}[\tilde{w}_{i,c}]] > 0 > -f'[2m_{i,i+j} - d_{i,c}[\tilde{w}_{i,c}]] > 0.$

A similar argument applies to the slope of the labor supply on firm *i*'s other side if it also exhibits a kink at $\tilde{w}_{i,c}$. Otherwise, the derivative of the labor supply function on that side exists. It follows that $\lim_{w_i \to \tilde{w}_{i,c}} \frac{\partial \pi_i}{\partial w_i} \ge \lim_{w_i \to \tilde{w}_{i,c}} \frac{\partial \pi_i}{\partial w_i}$ if $\left(\frac{mr_i}{\beta} - w_i\right) > 0$. If $\left(\frac{mr_i}{\beta} - w_i\right) < 0$, then $\lim_{w_i \to \tilde{w}_{i,c}} \frac{\partial \pi_i}{\partial w_i}$, $\lim_{w_i \to \tilde{w}^+} \frac{\partial \pi_i}{\partial w_i} < 0$.

This proves that under the conditions specified above, profits are globally quasiconcave.

ii) The strategy space is convex and compact, and all solutions are interior if the degree of substitutability of products γ is sufficiently small. Firm *i*'s strategy space is given by the interval $S_i = [\underline{w}_{\alpha,i}, \overline{w}]$ and hence it is convex, closed and bounded. Interior solutions require that the slopes of the profit functions at the boundaries of the strategy space point inwards. At the lower bound, this condition holds if marginal revenue at \overline{w}_i , that is, at $q_i = 0$, is sufficiently large. Sufficiently small values of γ for any fixed number of firms, a given average price, fixed and variable cost, and labor market conditions $\mathbf{w}_{-i}, \mathbf{m}_i$, ensure that $\frac{\partial \pi_i}{\partial w_i}\Big|_{w_i = \underline{w}_i} = \left(\frac{p_{choke}}{\beta} - \underline{w}_i\right) \frac{\partial L_i}{\partial w_i}\Big|_{w_i = \underline{w}_i} - \alpha > 0$. $L_i[\overline{w}, \mathbf{w}_{-i}, \mathbf{m}_i] > \alpha$ if $\overline{w} > w_{\alpha,i}$ implies $\frac{\partial \pi_i}{\partial w_i}\Big|_{w_i = \overline{w}_i} < 0$.

iii) The Hessian of the log-transformed game is negative definite at the equilibrium point. We prove negative definiteness of the Hessian by showing that the game in transformed strategies $\ln w_i \in \tilde{S}_i$, where $\tilde{S}_i = [\ln w_{\alpha,i}, \ln \bar{w}]$, exhibits diagonal dominance at the equilibrium point where

$$\frac{\partial \pi_i}{\partial \ln w_i} = 0 \qquad \forall i$$

Diagonal dominance at the equilibrium point requires that

$$\left|\frac{\partial^2 \pi_i}{\partial \ln w_i^2}\right| - \sum_{j \neq i}^N \left|\frac{\partial^2 \pi_i}{\partial \ln w_i \partial \ln w_j}\right| > 0, \tag{A2.11}$$

where

$$\frac{\partial^2 \pi_i}{\partial \ln w_i^2} = w_i \frac{\partial \pi_i}{\partial w_i} + w_i^2 \frac{\partial^2 \pi_i}{\partial w_i^2} = w_i^2 \frac{\partial^2 \pi_i}{\partial w_i^2} \qquad \text{since} \qquad \frac{w_i \partial \pi_i}{\partial w_i} = 0$$
$$\frac{\partial^2 \pi_i}{\partial \ln w_i \ln w_j} = \begin{cases} w_i w_j \frac{\partial^2 \pi_i}{\partial w_i w_j} & \text{for } j = \ell, r\\ 0 & \text{for } j \neq i, \ell, r \end{cases}$$

In an interior equilibrium no firm is overbid. This implies that around the equilibrium point the labor supply function is smooth and we do not need to worry about the kinks. Moreover, it implies that firm *i*'s relevant competitors are its immediate neighbors, that is, $\ell = i - 1$ and r = i + 1.

Firm *i*'s marginal profits change in its neighbors' log wages according to

$$\frac{\partial^2 \pi_i}{\partial w_i \partial w_c} w_i w_c = \frac{\partial mr_i}{\partial q_i} \frac{1}{\beta^2} \frac{\partial L_i}{\partial w_i} \frac{\partial L_i}{\partial w_c} w_i w_c - \frac{\partial L_i}{\partial w_c} w_i w_c + \left(\frac{mr_i}{\beta} - w_i\right) \frac{\partial^2 L_i}{\partial w_i \partial w_c} w_i w_c \leq 0$$
(A2.12)

where

$$\frac{\partial L_i}{\partial w_c} w_c = \frac{L}{2H} f[d_{i,c}] \frac{\mathrm{d}d_{i,c}}{\mathrm{d}w_c} w_c < 0 \quad \text{since} \quad \frac{\mathrm{d}d_{i,c}}{\mathrm{d}w_c} = \frac{f[2m - d_{i,c}]}{w_i f'[d_{i,c}] + w_c f'[2m_{i,c} - d_{i,c}]} < 0 \tag{A2.13}$$

$$\frac{\partial^2 L_i}{\partial w_i \partial w_c} w_i w_c = \frac{L}{2H} \left(2f'[d_{i,c}] \frac{\mathrm{d}d_{i,c}}{\mathrm{d}w_i} w_i \frac{\mathrm{d}d_{i,c}}{\mathrm{d}w_c} w_c + f'[2m_{i,c} - d_{i,c}] \frac{\mathrm{d}d_{i,c}}{\mathrm{d}w_i} w_i \frac{\mathrm{d}d_{i,c}}{\mathrm{d}w_i} w_c + f'[2m_{i,c} - d_{i,c}] \frac{\mathrm{d}d_{i,c}}{\mathrm{d}w_i} w_i \frac{\mathrm{d}d_{i,c}}{\mathrm{d}w_i} w_c + (w_i f''[d_{i,c}] - w_c f''[2m_{i,c} - d_{i,c}]) \frac{\mathrm{d}d_{i,c}}{\mathrm{d}w_i} \frac{\mathrm{d}d_{i,c}}{\mathrm{d}w_i} w_i \frac{\mathrm{d}d_{i,c}}{\mathrm{d}w_c} w_c \right)$$

$$= \frac{L}{2H} \left(-2f'[d_{i,c}] \left(\frac{\mathrm{d}d_{i,c}}{\mathrm{d}w_i} w_i \right)^2 + f'[2m_{i,c} - d_{i,c}] \frac{\mathrm{d}d_{i,c}}{\mathrm{d}w_i} w_i \frac{\mathrm{d}d_{i,c}}{\mathrm{d}w_i} w_c - \left(w_i f''[d_{i,c}] - w_c f''[2m_{i,c} - d_{i,c}] \right) \frac{\mathrm{d}d_{i,c}}{\mathrm{d}w_i} \left(\frac{\mathrm{d}d_{i,c}}{\mathrm{d}w_i} w_i \right)^2 \right) \stackrel{<}{\leq} 0.$$
(A2.14)

The second step follows from $\frac{\mathrm{d}d_{i,c}}{\mathrm{d}w_c}w_c = \frac{\mathrm{d}d_{i,c}}{\mathrm{d}w_i}w_i$. Since the first two terms in Equation (A2.14) are always positive, it holds that

$$\left|\frac{\partial^2 \pi_i}{\partial w_i \partial w_c} w_i w_c\right| \leq \frac{\partial mr_i}{\partial q_i} \frac{1}{\beta^2} \frac{\partial L_i}{\partial w_i} \frac{\partial L_i}{\partial w_c} w_i w_c - \frac{\partial L_i}{\partial w_c} w_i w_c + \left| \left(\frac{mr_i}{\beta} - w_i\right) \frac{\partial^2 L_i}{\partial w_i \partial w_c} w_i w_c \right|.$$

Provided that condition i) holds, diagonal dominance as defined in Equation (A2.11) at the equilibrium point obtains if

$$\begin{aligned} &-\frac{\partial mr_{i}}{\partial q_{i}}\frac{1}{\beta^{2}}\left(\frac{\partial L_{i}}{\partial w_{i}}w_{i}\right)^{2}+2\frac{\partial L_{i}}{\partial w_{i}}w_{i}^{2}-\left(\frac{mr_{i}}{\beta}-w_{i}\right)\frac{\partial^{2}L_{i}}{\partial w_{i}^{2}}w_{i}^{2}\\ &\geq\sum_{c=\ell,r}\left(\frac{\partial mr_{i}}{\partial q_{i}}\frac{1}{\beta^{2}}\frac{\partial L_{i}}{\partial w_{i}}\frac{\partial L_{i}}{\partial w_{c}}w_{i}w_{c}-\frac{\partial L_{i}}{\partial w_{c}}w_{i}w_{c}+\left(\frac{mr_{i}}{\beta}-w_{i}\right)\frac{\partial^{2}L_{i}}{\partial w_{i}\partial w_{c}}w_{i}w_{c}\right)\\ \Leftrightarrow &-\frac{\partial mr_{i}}{\partial q_{i}}\frac{1}{\beta^{2}}\left(\frac{\partial L_{i}}{\partial w_{i}}w_{i}\right)\left(\frac{\partial L_{i}}{\partial w_{i}}w_{i}+\sum_{c=\ell,r}\frac{\partial L_{i}}{\partial w_{c}}w_{c}\right)+\frac{\partial L_{i}}{\partial w_{i}}w_{i}^{2}+w_{i}\left(\frac{\partial L_{i}}{\partial w_{i}}w_{i}+\sum_{c=\ell,r}\frac{\partial L_{i}}{\partial w_{c}}w_{c}\right)\\ &-\left(\frac{mr_{i}}{\beta}-w_{i}\right)\left(\frac{\partial^{2}L_{i}}{\partial w_{i}^{2}}w_{i}^{2}-\sum_{c=\ell,r}\frac{\partial^{2}L_{i}}{\partial w_{i}\partial w_{c}}w_{i}w_{c}\right)\geq0\\ &\Leftrightarrow &\frac{mr_{i}}{\beta}\frac{\partial L_{i}}{\partial w_{i}}w_{i}\geq0\end{aligned}$$

The last step follows from

$$\frac{\partial L_i}{\partial w_i}w_i = -\sum_{c=\ell,r}\frac{\partial L_i}{\partial w_c}w_c \quad \text{and} \quad \frac{\partial^2 L_i}{\partial w_i^2}w_i^2 - \sum_{c=\ell,r}\frac{\partial^2 L_i}{\partial w_i\partial w_c}w_iw_c = -\frac{\partial L_i}{\partial w_i}w_i. \quad (A2.15)$$

This proves that the game in log transformed strategies exhibits diagonal dominance at the equilibrium point.

Since conditions i) and ii) clearly also hold for the transformed game, there exists a unique solution to this game. Since $\ln w$ is a monotone transformation of w for w > 0, uniqueness in the transformed game implies uniqueness of equilibrium in the original game. This completes the proof.

A2.3 Proof of Existence and Uniqueness of the Entry Equilibrium (Lemma 2)

We first prove that under condition ii) of Lemma 2 there is a unique number of firms $N^{\text{sym}} \geq 1$ corresponding to a (symmetric) second stage equilibrium with $\pi^*[\boldsymbol{m_{sym}}, N^{\text{sym}}] = 0$. Moreover, we show that $\pi^*[\boldsymbol{m_{sym}}, N] = 0$ is decreasing in N.

Existence and uniqueness of the second-stage zero-profit equilibrium for symmetric distance patterns. As described in Section 2.2.3, for symmetric distance patterns a second-stage zero-profit equilbrium is given by a root of the function

$$G[m] := \pi^*[\boldsymbol{m}_{sym}, N] = \beta \rho[m] \psi[m] - \beta g[m]$$
(A2.16)

where g[m] > 1 is the inverse of an aggregate version of the familiar measure of the degree of scale economies, i.e., the ratio of average to marginal cost. We expect this to be falling in m: The larger firm size m, and the smaller the number of firms, the closer average cost to marginal cost. In turn, $\rho[m] := 1 + \frac{1}{\gamma N[m]}$ and $\psi[m] := \frac{\eta[m]+1}{\eta[m]}$ are the two markups on the goods and the labor market, respectively. Given that a symmetric equilibrium has N = H/m, we have $\rho_m = 1/(\gamma H) > 0$. As shown in Section 2.2.3, $\eta_m < 0$, whence we have $\psi_m = -\eta_m/\eta[m]^2 > 0$. As expected from intuition, both markups are falling in the number of firms and thus rising in the half-distance between two neighboring firms, m. Note that G[m] > 0 implies positive profits, while G[m] < 0 implies that firms make losses.

The following conditions are *sufficient* for a symmetric zero-profit equilibrium to *exist* and to be *unique*: a) G[H] > 0, b) G[m] is continuous and $G_m > 0$ in the interval $(\tilde{m}, H]$, where \tilde{m} is defined by $\frac{L}{N[\tilde{m}]} \theta[\tilde{m}] = \alpha$.

Condition a) requires that a single firm in the market makes at least zero profits, that is,

$$\frac{L\theta[H]}{L\theta[H] - \alpha} \le \left(1 + \frac{1}{\gamma}\right)\psi[H]. \tag{A2.17}$$

Observing that $\psi[m]$ increases in m, we can set $\psi[H]$ on the right-hand side to its minimum level of unity to obtain

$$\frac{\alpha}{L\beta}(1+\gamma) \le \frac{F[H]}{H} \tag{A2.18}$$

which is a sufficient condition for (A2.17). It shows, that given α, β, L and H, the degree of substitutability of goods in the utility function γ , that governs the price elasticity of demand, must not be too large. Relating back to (A2.17) in its original form, these

restrictions imply that the price markup over marginal cost that a single firm can choose exceeds its average cost.⁴⁵

Condition b) requires that firm entry, which is associated with a decrease in the skillreach m, lowers profits in the relevant range where firms produce positive output, that is, for $m \in (\tilde{m}, H]$. Since we know from above that $\rho_m > 0$ as well as $\psi_m > 0$, condition b) is satisfied if $g_m < 0$. It is straightforward to show that

$$g_m[m] = \frac{\frac{L}{H}f[m]}{\frac{mL}{H}\theta[m] - \alpha} \left(1 - \frac{\frac{mL}{H}\theta[m]}{\frac{mL}{H}\theta[m] - \alpha}\right) < 0 \quad \text{for } m \in (\tilde{m}, H].$$
(A2.19)

Hence, there exists a unique $N^{\text{sym}} \geq 1$ satisfying $G[m] = \pi^*[\boldsymbol{m}_{sym}, N \text{sym}] = 0$. Condition b) and $m = \frac{2H}{N}$ imply $\frac{\partial \pi^*[\boldsymbol{m}_{sym}, N]}{\partial N} < 0$.

Existence and uniqueness of the symmetric sub-game perfect equilibrium With firm entry determined by (2.13) and consistent beliefs as described in Section (2.2.2), existence of N^{sym} satisfying $\pi^*[\mathbf{m}_{sym}, N^{\text{sym}}] = 0$ implies that no (symmetric or asymmetric) distance pattern involving a number of firms smaller N^{sym} can be an equilibrium according to (2.14).

To prove that $m_{sym}|N^{sym}$ is the unique equilibrium, it remains to show that there is no other distance pattern with $N \ge N^{\text{sym}}$ that is consistent with (2.13) and (2.14). We do so by showing that every asymmetric distance pattern with $N \geq N^{\text{sym}}$ firms and every symmetric distance pattern with $N > N^{\text{sym}}$ firms implies negative profits for at least one firm, which implies $\nu(N) = 0$ for all $N > N^{\text{sym}}$. The result for symmetric distance vectors follows readily from $\frac{\partial \pi^*[\boldsymbol{m}_{sym},N]}{\partial N} < 0$. The proof for asymmetric location patterns is slightly more involved and requires restrictions on the parameter space. It runs along the following line of argument. We conjecture that the symmetric zero profit solution characterized by $\pi^*[\mathbf{m}_{sum}, N^{sym}] = 0$ is an equilibrium and then consider any possible change towards an asymmetric location pattern featuring the same or a larger number of firms. Since the symmetric location pattern maximizes labor supply per firm, such a change must bring about a decrease in q for at least one firm. Let i be the firm that produces the smallest quantity in any arbitrarily chosen asymmetric location pattern with N^{sym} firms. Then, we can show that if the marginal cost β are sufficiently small, firm j's profits must be negative in the asymmetric pattern. Hence, no asymmetric location pattern can be an equilibrium consistent with optimal entry choices of entrants and non-entrants.

⁴⁵This condition is well known from the standard New Trade Theory model with homogeneous workers (cp. Equation (10) in Krugman, 1980).

From the point of view of any firm i, a zero-profit equilibrium is characterized by

$$\rho[N, q_i, \boldsymbol{q}_{-i}] \cdot \psi[\boldsymbol{m}_i, N] = g[q_i] \quad \text{where} \quad g[q_i] = \frac{L_i}{L_i - \alpha} = \frac{\alpha + \beta q_i}{\beta q_i}, \quad \forall$$

which states that the product of markups equals the inverse of the degree of economies of scale (cp. Equation (2.22)).⁴⁶ Note that $q_i = \frac{L_i[\boldsymbol{m}_i,N]-\alpha}{\beta}$ is also a function of the location pattern and so are $\rho[N, q_i, \boldsymbol{q}_{-i}]$ and $g[q_i]$.⁴⁷ However, it will prove important that $g[\cdot]$ and $\rho[\cdot]$ depend on \boldsymbol{m}_i only through output quantities, since we may therefore pin down the changes in $g[\cdot]$ and $\rho[\cdot]$ for firm j for an arbitrary change in the location pattern, since, by definition, q_j decreases whenever we move away from symmetry.

From the point of view of any firm, the change towards an asymmetric location pattern can be described in terms of changes in potentially all elements of the distance vector \boldsymbol{m}_i . Its profits are affected by corresponding changes in the markups and the degree of economies of scale. In the new location pattern, firm *i*'s profits will be negative if and only if the total markup ($\rho_i \psi_i$) increases by less (falls by more) than the inverse of the degree of economies of scale, g_i . That is, a sufficient condition for $\pi^*[\boldsymbol{m}_i, N^{\text{sym}}] < 0$ for all $\boldsymbol{m}_i \neq \boldsymbol{m}_{sym}$ is that

$$d(\rho_i \cdot \psi_i) = \rho_i d\psi_i + \psi_i d\rho_i < dg_i, \quad \text{where}$$

$$dg_i = \frac{\partial g[q_i]}{\partial q_i} \frac{\partial q_i}{\partial L_i} dL_i = -\frac{\alpha}{(\beta q_i)^2} dL_i \quad \text{with} \quad dL_i = \sum_{k=1}^{N} \frac{\partial L_i}{\partial m_{k,k+1}} dm_{k,k+1}$$
(A2.20)
(A2.21)

$$\mathrm{d}\rho_i = \sum_{k}^{N} \frac{\partial \rho_i}{\partial q_k} \frac{\partial q_k}{\partial L_k} \mathrm{d}L_k \tag{A2.22}$$

$$d\psi_i = \frac{1}{\eta_i} \frac{dL_i}{L_i} - \frac{1}{\eta_i} \sum_{k}^{N} \frac{\frac{\partial^2 L_i}{\partial w_i \partial m_{k,k+1}}}{\frac{\partial L_i}{\partial w_i}} dm_{k,k+1}$$
(A2.23)

Note that L_i depends on the distances between *all* firms and not just firm *i*'s neighbors, because it is a function of firm *i*'s own and its neighbors' equilibrium wages in the second stage, which jointly solve all firms' first-order conditions and therefore depend on the complete distance vector.

$$\pi_i^* = w_i^* L_i \left(\psi_i \rho_i \frac{L_i - \alpha}{L_i} - 1 \right).$$

Then, for $w_i^*, L_i > 0, \pi_i^* = 0$ iff $\rho_i \psi_i = g_i$.

⁴⁶Using the first-order condition (2.11), we can write optimum profits $\pi^*[\boldsymbol{m}_i, N]$ of any firm as

⁴⁷The dependence of ρ_i on \boldsymbol{q}_{-i} derives from the dependence of ρ_i on total expenditure $Y = \sum_{k}^{N} r_i[q_k]$.

Consider the problem of firm j, defined as the firm that produces the smallest amount of output in the asymmetric allocation. Then it is true that $dL_j < 0$ and $dg_j > 0$. Moreover, in the asymmetric allocation it is true that $q_j \leq \frac{1}{N} \sum_k q_k$, which, by concavity of the revenue function, implies $\ln p_j \geq \overline{\ln p}$. Therefore, it follows from $\rho_j = 1 + \frac{\delta_j}{\gamma}$ that

$$\mathrm{d}\rho_j = \frac{1}{\gamma} \left(\delta_j^{asym} - \delta_j^{sym} \right) = \overline{\ln p} - \ln p_i \le 0.$$

Firm j's price markup weakly decreases because its expenditure share is weakly smaller in the asymmetric location pattern. Note that an asymmetric location pattern where all firms produce the same quantity is conceivable. In this situations, the above statements hold with equality. The decrease in the degree of economies of scale $dg_i > 0$ and the decrease in the price markup work towards lowering firm j's optimum profits. However, the effect of the change in the location pattern on the wage markup is ambiguous. The first term is strictly negative for $dL_j < 0$, but the second term, reflecting the sum of the elasticities of marginal labor supply with respect to the change in the location pattern, is difficult to sign. It represents the change in competitiveness of firm j's labor market environment due to changes in the distances to its neighbors and the equilibrium wage adjustments to the change in the overall distance pattern. Therefore, according to Equation (A2.21), it holds that firm j's optimum profits decrease whenever the sum of the effects on the degree of economies of scale, the price markup, and negative effect on the wage markup due $dL_i < 0$ overcompensate a potentially positive effect on the wage markup due to a decrease in the degree of competitiveness of firm j's labor market environment. This is always true if the marginal cost β are small relative to the fixed cost α , as then, the effect on average cost is large compared to the adjustment in the wage markup, which is independent of β . Hence, for sufficiently small β is holds that every departure from symmetry (holding fixed N) leads to a decrease in firm i's profits. Since we are starting from the zero-profit equilibrium, firm i's profits will be negative in any asymmetric location pattern featuring the same number of firms as the symmetric starting point.

Thus, no asymmetric location pattern with $N = N^{\text{sym}}$ exists where all firms make positive profits. Moreover, the exact same rationale implies that no asymmetric pattern with a number of firms larger N^{sym} exists where all firms make positive profits. Hence, $N^e = N^{\text{sym}}$ is the unique equilibrium. This completes the proof.

A2.4 The Limiting Case of $H \rightarrow 0$

As we let the degree of skill heterogeneity approach zero, our equilibrium converges to the equilibrium of a monopolistic competition model with translog preferences. From the previous appendix it follows that if an equilibrium exists with some \bar{H} , it also exists for $H < \bar{H}$. In all of these equilibria, m will be smaller than \bar{H} , ensuring H/m = N > 1. Consider an exogenous decrease in the degree of skill differentiation $\hat{H} < 0$ within the interval $(0, \bar{H}]$. A smaller circumference means that the mass of labor on any interval of the skill circle increases. Holding m constant for a moment, this would allow firms to expand output without having to rely on workers with less suitable types of skills, thus increasing the degree of scale economies and decreasing g[m]. Moreover, from N = H/ma smaller H means a lower number of firms, which implies a higher goods price markup. But this, together with the size effect, implies positive profits. Hence, $\hat{N} = \hat{H}$ with $\hat{m} = 0$ is not an equilibrium adjustment. Totally differentiating (2.22), we obtain

$$\hat{m} = \frac{g_H - \psi[m]\rho_H}{-g_m + \psi[m]\rho_m + \rho[m]\psi_m} \frac{H}{m} \hat{H} = \frac{g[m](g[m] - 1) + \psi[m]\frac{m}{\gamma H}}{\frac{f[m]}{\theta[m]}g[m](g[m] - 1) + \psi[m]\frac{m}{\gamma H} + \frac{\psi_m m}{\psi[m]}} \hat{H}.$$
 (A2.24)

The "multiplier" in front of \hat{H} is positive, meaning that m falls as H decreases, but $f[m]/\theta[m] < 1$ and $\psi_m m/\psi[m] \ge 0$ imply that the multiplier can be greater or smaller one. Thus, the net effect on N = H/m is generally ambiguous. Now, let $H \to 0$, whence m = H/N must approach zero as well. Therefore, $f[m]/\theta[m]$ goes to unity and $\psi_m m/\psi[m] \ge 0$ goes to zero, so that the multiplier approaches unity and N converges to a constant N. Returning to the equilibrium condition (2.22) and letting $m \to 0$ ($\theta[m] \to 1, \psi[m] \to 1$) and $H/m = N \to N$. We finally obtain that N must satisfy

$$\frac{L}{L - \alpha \underline{N}} = 1 + \frac{1}{\gamma \underline{N}} \tag{A2.25}$$

which is the equilibrium condition for the number of firms in a Krugman (1979)-type model with homogeneous workers and translog preferences.

A2.5 The Constrained Social Optimum

The social planner maximizes log utility with respect to m and subject to the condition that price equals average cost (AC) and the endowment constraint which we can combine to $p = \frac{L\theta[m]}{L\theta[m] - \alpha N[m]}$:

$$\max_{m} \ln V = \ln \theta[m] - \left(\frac{1}{2\gamma N[m]} + \ln p[m]\right) \qquad \text{s.t.} \qquad p[m] = \frac{L\theta[m]}{L\theta[m] - \alpha N[m]}$$
(A2.26)

The first order condition results as

$$\frac{Lf[m]}{L\theta[m] - \frac{\alpha H}{m}} = 1 + \frac{m}{2\gamma H}.$$
(A2.27)

The second order condition for a maximum holds since, as we can show, the welfare function is globally concave, i.e.

$$\frac{\mathrm{d}^2 \ln V}{\mathrm{d}m^2} = -\frac{\left(L\theta_m[m] + \frac{\alpha H}{m^2}\right)^2}{\left(L\theta[m] - \frac{\alpha H}{m}\right)^2} + \frac{L\theta_{mm}[m] - 2\frac{\alpha H}{m^3}}{L\theta[m] - \frac{\alpha H}{m}} < 0.$$
(A2.28)

A sufficient condition for this to hold is

$$\theta_{mm}[m] := \frac{\partial^2 \theta[m]}{\partial m^2} = \frac{1}{m} \left(f'[m] - \frac{2}{m} f[m] + \frac{2}{m} \theta[m] \right) \le 0$$
(A2.29)

which requires $f[m] \ge \theta[m] + \frac{m}{2}f'[m]$. Since concavity of $f[\cdot]$ implies $f[m] \ge f\left[\frac{m}{2}\right] + \frac{m}{2}f'[m]$ and (by Jensen's inequality) $f\left[\frac{m}{2}\right] \ge \theta[m]$, it follows that $f[m] \ge f\left[\frac{m}{2}\right] + \frac{m}{2}f'[m] \ge \theta[m] + \frac{m}{2}f'[m]$ and therefore $\theta_{mm}[m] \le 0$ and $\frac{\partial^2 \ln V}{\partial m^2} < 0$ always hold.

To compare the planer's solution with the laissez faire equilibrium determined by (2.22) we rewrite (A2.27) as

$$g[m] = \frac{\theta[m]}{f[m]} \frac{1}{\psi[m]} \psi[m] \rho[m/2].$$
 (A2.30)

The difference between the two conditions appears on the right-hand side of this equation. Since $g_m < 0$, the social planer's solution implies a larger m than the market equilibrium, if the right-hand side is smaller than $\psi[m]\rho[m]$ for all values of m. Since $\rho_m > 0$,

$$\frac{\theta[m]}{f[m]}\frac{1}{\psi[m]} < 1 \tag{A2.31}$$

is a sufficient condition for this to hold. We show next that concavity of $f[\cdot]$ suffices to establish this result. Rearranging (A2.31) and inserting $\psi[m] = \frac{f[m]^2 - 2f'[m]m\theta[m]}{f[m]^2}$ yields $\frac{1 + \frac{2}{f[m]}f'[m]m}{f[m]} < \frac{1}{\theta}$ which holds a fortiori because concavity of $f[\cdot]$ implies that $\frac{1 + f'[m]m}{f[m]} < 1$. Hence, condition (A2.31) is fulfilled and it follows that the market equilibrium firm size is too small compared to the socially optimal allocation.

A2.6 Further Details of the Trading Equilibrium

A2.6.1 Proof of Proposition 1

(i) Log-differentiating the equilibrium condition (2.26) and setting k = 1, we obtain

$$\hat{m} = A \cdot \hat{k}$$
 with $A := \frac{\psi[m] \frac{1}{\gamma H}}{-g_m[m] + \psi[m] \frac{1}{\gamma H} + \rho^T[m] \psi_m[m]}$. (A2.32)

Since $g_m < 0$ and $\psi_m > 0$,⁴⁸ we find that 0 < A < 1 which implies $0 < \hat{m} = A \cdot \hat{k} < \hat{k}$. Hence, *m* increases and the number of firms in each country falls. However, A < 1 implies that the total number of available varieties $N^T = k \cdot N > N^A$ is still larger with trade than under autarky.

(ii) As the price markup depends negatively on the number of available varieties $k \cdot N$, it follows directly from the previous result that it must fall. Furthermore, we know from above that the wage markup increases. Log-differentiating(2.24) and again setting k = 1 yields

$$\hat{p} = B \cdot \hat{k} \quad \text{with} \quad B = \frac{\frac{m}{\gamma H}}{\left(1 + \frac{m}{\gamma H}\right)} \frac{g_m[m]}{\left(-g_m[m] + \psi[m]\frac{1}{\gamma H} + \rho^T[m]\psi_m[m]\right)}.$$
 (A2.33)

Since -1 < B < 0, it follows that $\hat{p} < 0$.

(iii) This follows from $\theta_m = \frac{1}{m} \left(f[m] - \theta[m] \right) < 0.$

(vi) Real income, $\theta[m]/p[m]$, must increase by virtue of the excess entry result demonstrated in A2.5. With higher real income and a larger variety available for consumption as established in (i), it follows from (2.23) that welfare of the worker earning average income increases.

A2.6.2 The First-Order Conditions with Two Symmetric Countries and Positive Trade Cost

Under the assumption that the constraints $q_i, q_i^* \ge 0$ never bind, we may write (2.27) as

$$\max_{w_i,q_i} \left\{ r_i[q_i, N, \overline{\ln p}, Y] + r_i^* \left[\frac{\bar{q}_i - q_i}{\tau}, N, \overline{\ln p}, Y \right] - w_i L_i \right\}.$$

The first order condition with respect to w_i then obtains as

$$\frac{p^*}{\tau} \left(\frac{\partial \ln p^*}{\partial \ln \frac{\bar{q}_i - q_i}{\tau}} + 1 \right) \frac{\partial L_i}{\partial w_i} = w_i \frac{\partial L_i}{\partial w_i} + L_i \quad \Leftrightarrow \quad p^* = \frac{\varepsilon_i^*}{\varepsilon_i^* - 1} \frac{\eta_i + 1}{\eta_i} w_i \tau$$

and the first order condition with respect to q_i reads

$$p\left(\frac{\partial \ln p}{\partial \ln q_i} + 1\right)\frac{\partial L_i}{\partial w_i} = \frac{p^*}{\tau}\left(\frac{\partial \ln p^*}{\partial \ln \frac{\bar{q}_i - q_i}{\tau}} + 1\right)\frac{\partial L_i}{\partial w_i} \quad \Leftrightarrow \quad p\frac{\varepsilon_i - 1}{\varepsilon_i} = \frac{p^*}{\tau}\frac{\varepsilon_i^* - 1}{\varepsilon_i^*}.$$

Both first order conditions together imply (2.30) and (2.31).

⁴⁸see Appendix A2.3 for details

A2.6.3 Proof of Proposition 2

In the symmetric equilibrium with identical countries the average price in the domestic and the foreign market is the same and given by $\overline{\ln p} = \overline{\ln p}^* = 1/2 \ln p + 1/2 \ln p^*$. Inserting $\overline{\ln p}$ and $\overline{\ln p}^*$ into the Z-terms in (2.30), (2.31), we can use the same logic as in A2.1 to obtain explicit solutions for p and p^* , where the price markups no longer depend on the own price, but only on the respective other price and the number of firms:

$$p = \frac{\mathcal{W}[\tilde{Z}]}{2}\psi \qquad \text{with } \tilde{Z} = \frac{2}{\psi}\exp\left\{2 + \frac{m}{\gamma H} + \ln p^*\right\}$$
(A2.34)

$$p^* = \frac{\mathcal{W}[\tilde{Z}^*]}{2}\psi\tau \quad \text{with } \tilde{Z}^* = \frac{2}{\psi\tau}\exp\left\{2 + \frac{m}{\gamma H} + \ln p\right\}.$$
 (A2.35)

Inserting $p = \frac{\mathcal{W}[\tilde{Z}]}{2}\psi$ and $p^* = \frac{\mathcal{W}[\tilde{Z}^*]}{2}\psi\tau$ into the \tilde{Z} -terms, we obtain

$$p = \mathcal{W}\left[\mathcal{W}[\tilde{Z}^*]\tau \exp\left\{2 + \frac{m}{\gamma H}\right\}\right]\frac{\psi}{2}$$
(A2.36)

$$p^* = \mathcal{W}\left[\frac{\mathcal{W}[\tilde{Z}]}{\tau} \exp\left\{2 + \frac{m}{\gamma H}\right\}\right] \frac{\psi}{2}\tau.$$
 (A2.37)

It proves convenient to focus on the price markup values $W = \mathcal{W}[\tilde{Z}]$ and $W^* = \mathcal{W}[\tilde{Z}^*]$ instead of prices. The corresponding system of equations determining these values emerges as

$$W = W[W^*, m] = \mathcal{W}\left[W^*\tau \exp\left\{2 + \frac{m}{\gamma H}\right\}\right]$$
(A2.38)

$$W^* = W^*[W, m] = \mathcal{W}\left[\frac{W}{\tau} \exp\left\{2 + \frac{m}{\gamma H}\right\}\right].$$
 (A2.39)

Note that for zero trade costs ($\tau = 1$) the price markups are identical. While the markup on domestic varieties increases in τ , the markup on foreign varieties falls in the level of trade costs. For any $\tau > 1$, it must therefore be true that $W > W^*$.

Note that the two country version of (A2.1) can be written as $p = \left(1 + \frac{1}{\gamma N^T} + \frac{1}{2} \ln p^* - \frac{1}{2} \ln p\right) \tilde{w}$ and analogously for p^* . In view of (A2.34) and (A2.35) it follows that $\frac{W}{2} = 1 + \frac{1}{\gamma N^T} + \frac{1}{2} \ln p^* - \frac{1}{2} \ln p$ and $\frac{W^*}{2} = 1 + \frac{1}{\gamma N^T} + \frac{1}{2} \ln p - \frac{1}{2} \ln p^*$. The expenditure shares in (2.28) can therefore be written as

$$\delta = \left(\frac{W}{2} - 1\right)\gamma$$
 and $\delta^* = \left(\frac{W^*}{2} - 1\right)\gamma.$ (A2.40)

Direct demand functions for foreign varieties in terms of W^* obtain as $q^* = \frac{\delta^* Y}{p^*} \left(1 - \frac{2}{W^*}\right) \frac{\gamma Y}{\psi}$. This implies that the prohibitive level of trade costs $\bar{\tau}$ for which

 $q^* = 0$ satisfies $\mathcal{W}\left[\frac{W}{\bar{\tau}}\exp\left\{2 + \frac{2}{\gamma N^T}\right\}\right] \equiv 2$. It follows that for non-prohibitive trade costs $W \geq W^* \geq 2$. Inserting demand and income $Y = L\theta$ into the labor market clearing condition (2.32), and rearranging terms gives

$$\gamma \left(2 - \frac{2}{W} - \frac{2}{W^*}\right) = \frac{\frac{L\theta[m]}{N[m]} - \alpha}{L\theta[m]} \psi[m]$$
$$\gamma h[W, W^*] = \frac{\psi[m]}{g[m]N[m]}.$$
(A2.41)

For easier reference the second line introduces $h[W, W^*] := \left(2 - \frac{2}{W} - \frac{2}{W^*}\right)$. (A2.41), (A2.38) and (A2.39) form our system of equations in W, W^* and m.

(i) Comparative statics of firm size and markups. The proof of proposition 2 requires that we solve this system for an exogenous change in τ . Doing so by log-linearization, we write the solution as $\widehat{W} = \omega \cdot \hat{\tau}$, $\widehat{W}^* = \omega^* \cdot \hat{\tau}$ and $\widehat{m} = \mu \cdot \hat{\tau}$. We next explore the sign of the elasticities ω, ω^* and μ . For notational convenience we suppress the functional dependence of N and ψ on m in the following, whenever it is not crucial. Log- differentiating (A2.41), (A2.38), (A2.39) leads to

$$\begin{bmatrix} -\frac{\partial \ln h}{\partial \ln W} & -\frac{\partial \ln h}{\partial \ln W^*} & \frac{\partial \ln \psi}{\partial \ln m} & -\frac{\partial \ln g}{\partial \ln m} & -\frac{\partial \ln N}{\partial \ln m} \\ -1 & \frac{\partial \ln W^*}{\partial \ln W^*} & -1 & \frac{\partial \ln W^*}{\partial \ln m} \\ \frac{\partial \ln W^*}{\partial \ln W} & -1 & \frac{\partial \ln W^*}{\partial \ln m} \end{bmatrix} \begin{bmatrix} \widehat{W} \\ \widehat{W}^* \\ \widehat{m} \end{bmatrix} = \begin{bmatrix} 0 \\ -\frac{\partial \ln W}{\partial \ln \tau} \cdot \widehat{\tau} \\ -\frac{\partial \ln W}{\partial \ln \tau} \cdot \widehat{\tau} \end{bmatrix} \begin{bmatrix} \frac{\partial \ln W}{\partial \ln \tau} \cdot \widehat{\tau} \\ -\frac{\partial \ln W}{\partial \ln \tau} \cdot \widehat{\tau} \end{bmatrix} \begin{bmatrix} \frac{\partial \ln W}{\partial \ln \tau} \cdot \widehat{\tau} \\ \frac{\partial \ln W^*}{\partial \ln \tau} \cdot \widehat{\tau} \end{bmatrix} \begin{bmatrix} \frac{\partial \ln W}{\partial \ln \tau} \cdot \widehat{\tau} \\ \frac{\partial \ln W^*}{\partial \ln \tau} \cdot \widehat{\tau} \end{bmatrix} \begin{bmatrix} \frac{\partial \ln W}{\partial \ln \tau} - \frac{\partial \ln W}{\partial \ln \tau} \\ \frac{\partial \ln W^*}{\partial \ln \tau} - \frac{1}{W^* - 1 - \frac{W^*}{W}} & \frac{\frac{Lf[m]}{N}}{\frac{L\theta[m]}{N} - \alpha} - \frac{f[m]}{\theta[m]} + 1 + \frac{\partial \ln \psi}{\partial \ln m} \\ \frac{\partial \ln W}{\partial \ln m} \end{bmatrix} \begin{bmatrix} \widehat{W} \\ \widehat{W}^* \\ \widehat{m} \end{bmatrix} = \begin{bmatrix} 0 \\ -\frac{1}{W^* + 1} \cdot \widehat{\tau} \\ \frac{1}{W^* + 1} \cdot \widehat{\tau} \end{bmatrix}.$$
(A2.42)

Denoting the 3×3 -matrix of derivatives by D, it follows that

$$\omega = \frac{1}{(W+1)(W^*+1)} \left[\left(\frac{\frac{Lf[m]}{N}}{\frac{L\theta[m]}{N} - \alpha} - \frac{f[m]}{\theta[m]} + 1 + \frac{\partial \ln \psi}{\partial \ln m} \right) W^* - \frac{1}{\gamma Nh[W,W^*]} \frac{4}{W^*} \right] \frac{1}{\det[D]}$$
(A2.43)
$$\omega^* = \frac{1}{(W+1)(W^*+1)} \left[- \left(\frac{\frac{Lf[m]}{N}}{\frac{L\theta[m]}{N} - \alpha} - \frac{f[m]}{\theta[m]} + 1 + \frac{\partial \ln \psi}{\partial \ln m} \right) W + \frac{1}{\gamma Nh[W,W^*]} \frac{4}{W} \right] \frac{1}{\det[D]}$$
(A2.44)
$$\mu = \frac{2W^*/W - 2W/W^*}{h[W,W^*](W+1)(W^*+1)} \frac{1}{\det[D]}.$$
(A2.45)

The signs of the elasticities hinge upon the sign of the determinant which is given by

$$\det[D] = \left(\frac{\frac{Lf[m]}{N}}{\frac{L\theta[m]}{N} - \alpha} - \frac{f[m]}{\theta[m]} + 1 + \frac{\partial \ln \psi}{\partial \ln m}\right) \frac{WW^* + W + W^*}{(W+1)(W^*+1)} - \frac{1}{\gamma Nh[W, W^*]} \frac{(2+W^*)\frac{2}{W} + (2+W)\frac{2}{W^*}}{(W+1)(W^*+1)}.$$
(A2.46)

Since $WW^* > 2$ and $W \ge W^*$, we have $WW^* + W + W^* > (2 + W^*)\frac{2}{W} + (2 + W)\frac{2}{W^*}$. This implies that $\det[D] > 0$ if

$$\frac{\frac{Lf[m]}{N}}{\frac{L\theta[m]}{N} - \alpha} - \frac{f[m]}{\theta[m]} + 1 + \frac{\partial \ln \psi}{\partial \ln m} > \frac{1}{\gamma Nh[W, W^*]}.$$
(A2.47)

We know from above that $\frac{f[m]}{\theta[m]} < 1$ and $\frac{\partial \ln \psi}{\partial \ln m} > 0$, and therefore, inequality (A2.47) holds if

$$\frac{\frac{Lf[m]}{N}}{\frac{L\theta[m]}{N} - \alpha} > \frac{1}{\gamma Nh[W, W^*]}.$$
(A2.48)

Using the equilibrium condition (A2.41), we can rewrite this as $\psi[m] \ge \theta[m]/f[m]$. We have proven in Appendix A2.5 that this inequality always holds. Hence, it follows that $\det[D] > 0$.

Returning to our elasticity ω , we note that $W^* \geq \frac{4}{W^*}$, det[D] > 0 and (A2.47) imply $\omega > 0$. By analogy, it follows that $\omega^* < 0$. And finally, $W \geq W^*$ implies that $\mu \leq 0$. For reasons pointed out in the text, μ is monotonic in the initial level of trade costs, converging to zero as τ approaches one. Looking at A2.45, the level of τ enters through W and W^* . The lower the trade cost level, the smaller the difference between W and W^* . At $\tau = 1$, price markups are identical and m = 0. This proves part (i) of the proposition.

(ii) Changes in prices. The proposition states that for $\hat{\tau} < 0$, $\hat{p}^* < 0$ while \hat{p} is ambiguous. The price of imported varieties is affected by the change in τ and the changes in both markups

$$\hat{p}^* = \left(\omega^* + \frac{\partial \ln \psi}{\partial \ln m}\mu + 1\right)\hat{\tau}$$
(A2.49)

where $\frac{\partial \ln \psi}{\partial \ln m} = \frac{-2mf''[m]F[m]}{f[m]^2\psi[m]} - \frac{2mf'[m]}{f[m]} > 0$. Inserting (A2.44) and (A2.45) shows that \hat{p}^* is positive if and only if

$$-\frac{d_{13}W - \frac{2}{W}\frac{2}{\gamma hN} + \frac{\partial \ln \psi}{\partial \ln m}\frac{1}{h[W,W^*]}\left(\frac{2W}{W^*} - \frac{2W^*}{W}\right)}{d_{13}(WW^* + W + W^*) - \frac{2}{\gamma h[W,W^*]N}\left(\frac{2+W^*}{W} + \frac{2+W}{W^*}\right)} + 1 > 0$$
(A2.50)

where d_{13} is the element in row 1 and column 3 of D. Canceling identical terms in the denominator and the numerator shows that this is true if $\frac{\frac{\partial \ln \psi}{\partial \ln m} \frac{1}{h[W,W^*]} \left(\frac{2W}{W^*} - \frac{2W^*}{W}\right)}{d_{13}(WW^* + W^*) - \frac{2W^*}{2h[W,W^*]N} \left(\frac{W^*}{W} + \frac{2+W}{W^*}\right)} < 0$

1. Noting that $d_{13} = \frac{\frac{Lf[m]}{N}}{\frac{L\theta[m]}{N} - \alpha} - \frac{f[m]}{\theta[m]} + 1 + \frac{\partial \ln \psi}{\partial \ln m}$ and observing the inequality in (A2.48), it follows that $WW^* + W^* \ge \frac{2W^*}{W} + \frac{4+2W}{W^*}$ and $WW^* + W^* \ge \frac{1}{h[W,W^*]} \left(\frac{2W}{W^*} - \frac{2W^*}{W}\right)$ is sufficient for the inequality in (A2.50) to hold. Using from above $W \ge W^* \ge 2$, it is straightforward to show that these two conditions are fulfilled.

The change in the domestic price obtains as

$$\hat{p} = \left(\omega + \frac{\partial \ln \psi}{\partial \ln m} \mu\right) \hat{\tau}.$$
(A2.51)

We know from above that $\omega > 0$; the pro-competitive effect of lower trade costs on the goods market. This is potentially offset by an increase in the wage markup. For τ close to one, the goods market effect clearly dominates as μ is close to zero.

Conversely, at $\bar{\tau}$ (prohibitive trade cost level), the labor market effect dominates. Inserting (A2.43) and (A2.45) gives

$$\hat{p} = \left[W^* \left(\frac{\frac{Lf[m]}{N}}{\frac{L\theta[m]}{N} - \alpha} - \frac{f[m]}{\theta[m]} + 1 + \frac{\partial \ln \psi}{\partial \ln m} \right) - \frac{2}{\gamma N h[W, W^*]} \frac{2}{W^*} - \frac{\partial \ln \psi}{\partial \ln m} \frac{1}{h[W, W^*]} \left(\frac{2W}{W^*} - \frac{2W^*}{W} \right) \right] \times \frac{1}{(W+1)(W^*+1)} \frac{\hat{\tau}}{\det[D]}.$$
(A2.52)

Remember that prohibitive trade costs imply an infinite price elasticity and therefore a price markup of zero, whence $W^* = 2$. To see if $\hat{p} > 0$ for $\tau = \bar{\tau}$, as stated in proposition 2, we must therefore evaluate the bracketed term at $W^* = 2$. We obtain

$$-2\frac{\frac{Lf[m]}{N}}{\frac{L\theta[m]}{N}-\alpha} + 2\frac{f[m]}{\theta[m]} - 2 - 2\frac{\partial\ln\psi}{\partial\ln m} + \frac{2}{\gamma Nh[W,W^*]}\frac{2}{W^*} + \frac{\partial\ln\psi}{\partial\ln m}(W+2)$$
(A2.53)

Inserting the equilibrium condition (A2.41), which reduces to $\gamma h[W, W^*] = \frac{L\theta[m]/N - \alpha}{L\theta[m]} \psi = \frac{2}{W} \frac{1}{N}$ at $\tau = \bar{\tau}$, shows that the expression is negative, if

$$\psi W \frac{f[m]}{\theta[m]} < 2 \frac{f[m]}{\theta[m]} + W - 2 + W \frac{\partial \ln \psi}{\partial \ln m}.$$
(A2.54)

Inserting the explicit expressions for ψ and $\frac{d \ln \psi}{d \ln m}$ leads to

$$\frac{W}{\theta[m]} \frac{f[m]^2 - 2f'[m]F[m]}{f[m]} < W - 2 + \frac{2f[m]}{\theta[m]} + W\left(\frac{-2f''[m]\theta}{f[m]^2\psi} - \frac{2mf'[m]}{f[m]}\right).$$
(A2.55)

Since $f''[m] \leq 0$, the inequality holds if

$$\frac{W}{\theta[m]} \frac{f[m]^2 - 2f'[m]F[m]}{f[m]} < W - 2 + \frac{2f[m]}{\theta[m]} - W \frac{2mf'[m]}{f[m]}.$$
(A2.56)

Rearranging terms shows that this inequality holds if $f[m] < \theta[m]$, which is true given f'[m] < 0. This completes the proof of part (ii) of proposition 2.

(iii) Welfare. Indirect utility of the worker receiving average income in the equilibrium with trade costs is given by $\ln V = \ln \theta[m] - \ln P^T[p, p^*, m]$, where

$$\ln P^{T}[p, p^{*}, m] = \frac{1}{2\gamma N^{T}} + \frac{1}{N^{T}} \sum_{i=1}^{N^{T}} \ln p_{i} + \frac{\gamma}{2N^{T}} \sum_{i=1}^{N^{T}} \sum_{j=1}^{N^{T}} \ln p_{i} (\ln p_{j} - \ln p_{i})$$
(A2.57)

with $N^T = N + N^*$ and i, j indexing domestic and foreign varieties. Under symmetry, which implies $N^* = N = N^T/2$, the price index simplifies to

$$\ln P^{T}[p, p^{*}, m] = \frac{1}{4\gamma N} + \frac{1}{2}\ln p + \frac{1}{2}\ln p^{*} - \frac{\gamma N}{4}\left(\ln p - \ln p^{*}\right)^{2}.$$
 (A2.58)

The change in indirect utility is then

$$\widehat{V} = \left(\frac{\partial \ln \theta}{\partial \ln m} - \frac{\partial \ln P}{\partial \ln m}\right)\widehat{m} - \frac{\partial \ln P}{\partial \ln p}\widehat{p} - \frac{\partial \ln P}{\partial \ln p^*}\widehat{p}^*$$
(A2.59)

with $\frac{\partial \ln \theta}{\partial \ln m} = \frac{f[m] - \theta[m]}{\theta[m]} < 0$, $\frac{\partial \ln P}{\partial \ln m} = \frac{1}{4\gamma N} + \frac{\gamma N}{4} \left(\ln p - \ln p^* \right)^2 > 0$, $\frac{\partial \ln P}{\partial \ln p} = \frac{1}{2} + \frac{\gamma N}{2} \left(\ln p - \ln p^* \right) \ge 0$ and $\frac{\partial \ln P}{\partial \ln p^*} = N\delta^* \ge 0$. Inserting yields equation (2.33).

Using the results that at the prohibitive level of trade costs $\delta^* = 0$, $\hat{p} > 0$ and $\hat{m} > 0$, it follows from (2.33) that $\hat{V} < 0$ at $\tau = \bar{\tau}$. Since at $\tau = 1$ it holds that $\hat{m} = 0$, $\hat{p} < 0$ and $\hat{p}^* < 0$, it follows that $\hat{V} > 0$ at $\tau = 1$.

A2.7 Additional Details of the Trade and Migration Equilibrium

A2.7.1 Conditions for Existence and Uniqueness of the Symmetric Equilibrium with Trade and Migration

In this section we briefly show that with free trade and migration, qualitatively similar restrictions on the parameter space and the shape of $f[\cdot]$ ensure existence and uniqueness of the symmetric equilibrium. In analogy to Section A2.3 we show that qualitatively similar conditions are needed for quasiconcavity of the profit function and existence of an interior solution. Log diagonal dominance is shown to hold at the equilibrium point, guaranteeing uniqueness of the second stage wage equilibrium. Then, we describe conditions under

which the symmetric alternating pattern is the only pattern consistent with free entry when migration cost are non-prohibitive.

Quasi-concavity of profits. Firm i's labor supply function with integrated labor markets in the general case (asymmetric location pattern and domestic or foreign identity of neighbors) is given by

$$L_i^M = \sum_{c=\ell,r} \left(L_{i,c}^n + L_{i,c}^m \right) \qquad \text{with} \tag{A2.60}$$

$$L_{i,c}^{n} = \begin{cases} \frac{L}{H}F[d_{i,c}^{n}] & \text{if } d_{i,c}^{n} > -d_{i,c'}^{n} \\ 0 & \text{otherwise} \end{cases} \quad \text{and} \quad L_{i,c}^{m} = \begin{cases} \frac{L}{H}(1-\lambda)F[d_{i,c}^{m}] & \text{if } d_{i,c}^{m} > -d_{i,c}^{m} \\ 0 & \text{otherwise} \end{cases}$$

for $c, c' = \ell, r, c \neq c'$. We now denote with c, c' the *relevant* competitor of firm *i* on either side.⁴⁹ Note that with integrated labor markets and positive migration cost, firm *i*'s relevant competitor for natives on a given side may be a different firm than firm *i*'s relevant competitor migrant labor on that same side.⁵⁰

The cutoff for native workers on side $c = \ell, r, d_{i,c}^n$, is determined by $w_i f[d_{i,c}^n] = w_c f[m_c^n - d_{i,c}^n]$ if c is a domestic firm and by $w_i f[d_{i,c}^m] = w_c^* f[m_c^n - d_{i,c}^m](1-\lambda)$ if c is a foreign firm. The cutoff for native workers, $d_{i,c}^m$, is determined by $w_i f[d_{i,c}^m] = w_c f[m_c^m - d_{i,c}^m]$ is a domestic firm and by $w_i f[d_{i,c}^m](1-\lambda) = w_c^* f[m_c^m - d_{i,c}^m]$ if c is a foreign firm. We denote with m_c^n, m_c^m the distance to the respective relevant competitor. The slope of a firm's supply of native labor when competing with a firm in the other country is

$$\frac{\partial L_{i,c}^n}{\partial w_i} = \frac{L}{H} f[d_{i,c}^n] \frac{\mathrm{d}d_{i,c}^n}{\mathrm{d}w_i} = \frac{L}{H} \frac{f[d_{i,c}^n]^2}{-w_i f'[d_{i,c}^n] - w_c^*(1-\lambda)f'[m_{i,c}^n - d_{i,c}^n]} \tag{A2.61}$$

and when competing with a firm from the same country it is

$$\frac{\partial L_{i,c}^n}{\partial w_i} = \frac{L}{H} f[d_{i,c}^n] \frac{\mathrm{d}d_{i,c}^n}{\mathrm{d}w_i} = \frac{L}{H} \frac{f[d_{i,c}^n]^2}{-w_i f'[d_{i,c}^n] - w_c f'[m_{i,c}^n - d_{i,c}^n]}.$$
 (A2.62)

Analogously, the slope of the supply of migrant labor when the competitor is foreign is

$$\frac{\partial L_{i,c}^m}{\partial w_i} = \frac{L}{H} (1-\lambda) f[d_{i,c}^m] \frac{\mathrm{d}d_{i,c}^m}{\mathrm{d}w_i} = \frac{L}{H} \frac{(1-\lambda) f[d_{i,c}^m]^2}{-w_i f'[d_{i,c}^m] - \frac{w_c^*}{(1-\lambda)} f'[m_{i,c}^m - d_{i,c}^m]}.$$
 (A2.63)

⁴⁹The relevant competitor can be identified in similar way as explained in footnote ¹⁵.

⁵⁰With asymmetric locations and positive λ , it is conceivable that the competitor for natives, firm i + 1, is overbid by a foreign firm i + 2 with regard to migrants but not natives.

When the competitor is in the same country, it is

$$\frac{\partial L_{i,c}^m}{\partial w_i} = \frac{L}{H} (1-\lambda) f[d_{i,c}^m] \frac{\mathrm{d}d_{i,c}^m}{\mathrm{d}w_i} = \frac{L}{H} \frac{(1-\lambda) f[d_{i,c}^m]^2}{-w_i f'[d_{i,c}^m] - w_c f'[m_{i,c}^m - d_{i,c}^m]}.$$
 (A2.64)

As above, quasiconcavity of profits holds if condition (A2.8) is fullfilled, and if the labor supply function becomes flatter at the kinks. Using the defining equations for the cutoffs with a foreign neighbor and Equations (A2.61)-(A2.64) it is straightforward to show that all possibles cases (the competitor who is overbid is foreign or domestic, the next competitor is foreign or domestic), the respective labor supply schedule for natives and migrants becomes flatter at the kinks. Hence, quasiconcavity obtains under the restriction that the elasticity of marginal labor supply is not too large if positive. A similar condition on the choke price as above ensures that all solutions are interior.

Diagonal dominance at the equilibrium point. Using

$$\frac{\partial^2 L_i}{\partial w_i^2} = \sum_{c=\ell,r} \left(\frac{\partial^2 L_{i,c}^n}{\partial w_i^2} + \frac{\partial^2 L_{i,c}^m}{\partial w_i^2} \right) \quad \text{and} \quad \frac{\partial^2 L_i}{\partial w_i \partial w_c} = \frac{\partial^2 L_{i,c}^n}{\partial w_i \partial w_c} + \frac{\partial^2 L_{i,c}^m}{\partial w_i \partial w_c} \quad (A2.65)$$

where, if c is a foreign competitor,

$$\begin{split} \frac{\partial^2 L_{i,c}^n}{\partial w_i^2} &= \frac{L}{2H} \left(3f'[d_{i,c}^n] \left(\frac{\mathrm{d}d_{i,c}^n}{\mathrm{d}w_i} \right)^2 + \left(w_i f''[d_{i,c}^n] - w_c^*(1-\lambda) f''[m_{i,c}^n - d_{i,c}^n] \right) \left(\frac{\mathrm{d}d_{i,c}^n}{\mathrm{d}w_i} \right)^3 \right) \\ \frac{\partial^2 L_{i,c}^n}{\partial w_i^2} &= \frac{L}{2H} \left(3(1-\lambda) f'[d_{i,c}^m] \left(\frac{\mathrm{d}d_{i,c}^n}{\mathrm{d}w_i} \right)^2 + \left(w_i(1-\lambda) f''[d_{i,c}^m] - w_c^* f''[m_{i,c}^m - d_{i,c}^m] \right) \left(\frac{\mathrm{d}d_{i,c}^n}{\mathrm{d}w_i} \right)^3 \right) \\ \frac{\partial^2 L_{i,c}^n}{\partial w_i \partial w_c} &= \frac{L}{2H} \left(2f'[d_{i,c}^n] \frac{\mathrm{d}d_{i,c}^n}{\mathrm{d}w_i} \frac{\mathrm{d}d_{i,c}^n}{\mathrm{d}w_c^*} + (1-\lambda) f'[m_{i,c}^n - d_{i,c}^n] \left(\frac{\mathrm{d}d_{i,c}^n}{\mathrm{d}w_i} \right)^2 \\ &+ \left(w_i f''[d_{i,c}^n] - w_c^*(1-\lambda) f''[m_{i,c}^n - d_{i,c}^n] \right) \left(\frac{\mathrm{d}d_{i,c}^n}{\mathrm{d}w_i} \right)^2 \frac{\mathrm{d}d_{i,c}^n}{\mathrm{d}w_c^*} + f'[m_{i,c}^m - d_{i,c}^n] \left(\frac{\mathrm{d}d_{i,c}^n}{\mathrm{d}w_i} \right)^2 \\ &+ \left(w_i(1-\lambda) f'[d_{i,c}^m] \frac{\mathrm{d}d_{i,c}^m}{\mathrm{d}w_i} \frac{\mathrm{d}d_{i,c}^n}{\mathrm{d}w_c^*} + f'[m_{i,c}^m - d_{i,c}^n] \right) \left(\frac{\mathrm{d}d_{i,c}^n}{\mathrm{d}w_i} \right)^2 \\ &+ \left(w_i(1-\lambda) f''[d_{i,c}^m] - w_c^* f''[m_{i,c}^m - d_{i,c}^m] \right) \left(\frac{\mathrm{d}d_{i,c}^m}{\mathrm{d}w_i} \right)^2 \frac{\mathrm{d}d_{i,c}^m}{\mathrm{d}w_c^*} + f'[m_{i,c}^m - d_{i,c}^n] \right) \left(\frac{\mathrm{d}d_{i,c}^m}{\mathrm{d}w_i} \right)^2 \end{split}$$

and

$$\begin{split} \frac{\partial^2 L_{i,c}^n}{\partial w_i^2} &= \frac{L}{2H} \left(3f'[d_{i,c}^n] \left(\frac{\mathrm{d}d_{i,c}^n}{\mathrm{d}w_i} \right)^2 + \left(w_i f''[d_{i,c}^n] - w_c f''[m_{i,c}^n - d_{i,c}^n] \right) \left(\frac{\mathrm{d}d_{i,c}^n}{\mathrm{d}w_i} \right)^3 \right) \\ \frac{\partial^2 L_{i,c}^m}{\partial w_i^2} &= \frac{L}{2H} \left(3(1-\lambda)f'[d_{i,c}^m] \left(\frac{\mathrm{d}d_{i,c}^m}{\mathrm{d}w_i} \right)^2 + \left(w_i f''[d_{i,c}^m] - w_c f''[m_{i,c}^m - d_{i,c}^m] \right) \left(\frac{\mathrm{d}d_{i,c}^m}{\mathrm{d}w_i} \right)^3 \right) \\ \frac{\partial^2 L_{i,c}^n}{\partial w_i \partial w_c} &= \frac{L}{2H} \left(2f'[d_{i,c}^n] \frac{\mathrm{d}d_{i,c}^n}{\mathrm{d}w_i} \frac{\mathrm{d}d_{i,c}^n}{\mathrm{d}w_c} + f'[m_{i,c}^n - d_{i,c}^n] \left(\frac{\mathrm{d}d_{i,c}^n}{\mathrm{d}w_i} \right)^2 \right. \\ &+ \left(w_i f''[d_{i,c}^n] - w_c f''[m_{i,c}^n - d_{i,c}^n] \right) \left(\frac{\mathrm{d}d_{i,c}^n}{\mathrm{d}w_i} \right)^2 \frac{\mathrm{d}d_{i,c}^n}{\mathrm{d}w_c} + f'[m_{i,c}^m - d_{i,c}^m] \left(\frac{\mathrm{d}d_{i,c}^n}{\mathrm{d}w_c} \right) \\ &+ \left(w_i f''[d_{i,c}^n] - w_c f''[m_{i,c}^n - d_{i,c}^n] \right) \left(\frac{\mathrm{d}d_{i,c}^n}{\mathrm{d}w_i} \right)^2 \frac{\mathrm{d}d_{i,c}^n}{\mathrm{d}w_c} \right) \\ &+ \left(w_i f''[d_{i,c}^m] - w_c f''[m_{i,c}^m - d_{i,c}^m] \right) \left(\frac{\mathrm{d}d_{i,c}^m}{\mathrm{d}w_i} \right)^2 \frac{\mathrm{d}d_{i,c}^n}{\mathrm{d}w_c} \right) \\ \end{split}$$

if c is a domestic competitor, we can show that Equation (A2.15) also holds for the case of migration. It follows that log diagonal dominance in accordance with Equation (A2.11) also holds. Hence, the second-stage wage equilibrium with migration is unique.

Existence and uniqueness of the symmetric alternating location equilibrium. A condition on the fixed cost relative to the size of the labor force similar to (A2.17) can be derived that ensures existence of a symmetric second-stage equilbrium with symmetric distance pattern and zero profits. Moreover, it holds that $G^M[m] := \rho^T[m, \lambda]\psi^T[m] - g^M[m, \lambda]$ is monotonously increasing in m, hence the symmetric zero-profit solution is unique and second-stage profits for symmetric distance vectors are decreasing in N. To show that under the same assumption on consistency of beliefs as described in Section 2.2.2, the symmetric alternating distance pattern is the unique equilibrium as defined in (2.14), we need again a restriction on the magnitude of the change in the wage markup relative to the change in $g^M[m, \lambda]$. Analogously to the proof in Section A2.3, a small enough level of β always assures that this condition holds. By the same logic as outlined in Section A2.3, uniqueness of the symmetric equilibrium can be proven by showing that moving from the symmetric alternating equilibrium to any asymmetric pattern with the same or a larger number of firms implies negative profits for at least on firm.

Note that besides the alternating pattern another fully symmetric loction structure is conceivable, namely, one where each firm has one domestic neighbor and one foreign neighbor. However, as we show next, the alternating pattern is the one that maximizes labor supply per firm. With equal wages and one relevant domestic neighbor at a distance $m_{i,c}$, labor supply from the side where the domestic neighbor is located is given by

$$L_{i}^{M,D} = \frac{L}{2H} (2-\lambda) \int_{0}^{m_{i,c}/2} f[d] \mathrm{d}d$$
 (A2.66)

for $\lambda \in [0, \overline{\lambda}]$. If, instead, the competitor at distance $m_{i,c}$ is foreign, the labor supply is

$$L^{M,F} = \frac{L}{2H} \int_0^{d^m_{i,c}} f[d] dd + \frac{L}{2H} (1-\lambda) \int_0^{d^m_{i,c}} f[d] dd$$
(A2.67)

where $d_{i,c}^m \leq \frac{m_{i,c}}{2}$, $\frac{m_{i,c}}{2} \leq d_{i,c}^n < m$ and $d_{i,c}^m + d_{i,c}^n = m_{i,c}$. For notational convenience I henceforth set L/(2H) = 1. Then, the difference in supply of efficiency units for a given wage results as

$$L^{M,F} - L^{M,D} = \int_{m_{i,c}/2}^{d_{i,c}^n} f[d] dd - (1-\lambda) \int_{d_{i,c}^m}^{m_{i,c}/2} f[d] dd.$$
(A2.68)

Using the fact that with symmetric wages $\int_{d_{i,c}^m}^{m_{i,c}/2} f[d] dd = \int_{m_{i,c}/2}^{d_{i,c}^m} f[m_{i,c}-d] dd$ this can be rewritten as

$$L^{M,F} - L^{M,D} = \int_{m/2}^{d_{i,c}^n} \left(f[d] - (1-\lambda)f[m_{i,c} - d] \right) \mathrm{d}d \ge 0.$$
 (A2.69)

The inequality follows from $f[d] - (1 - \lambda)f[m_{i,c} - d] \ge 0 \forall \frac{m_{i,c}}{2} \le d_{i,c}^n < m_{i,c}$. Hence, in the symmetric equilibrium the labor supply for a given wage is (weakly) larger if the neighbor is foreign. If $\lambda = 0$, labor supply is identical in both cases. Hence, by the same logic that rules out asymmetric distance patterns with a number of firms larger or equal to the number of firms in the symmetric alternating zero-profit solution, non-alternating symmetric distance patterns cannot constitute an equilibrium as defined in (2.14), unless migration cost are zero. In the last case, the symmetric alternating and non-alternating equilibrium are indistinguishable.

A2.7.2 The Elasticity of Labor Supply

The elasticity of labor supply in the symmetric alternating equilibrium is defined as $\frac{\partial L^{ES,M}}{\partial w_i} \frac{w_i}{L^{ES,M}}$. From (2.36), (2.34), and (2.35), we obtain

$$\frac{\partial L^{ES,M}}{\partial w_i} = \frac{L}{H} \frac{\mathrm{d}d_i^n}{\mathrm{d}w_i} f[d_i^n] + (1-\lambda) \frac{L}{H} \frac{\mathrm{d}d_i^m}{\mathrm{d}w_i} f[d_i^m] \qquad \text{with} \tag{A2.70}$$

$$\frac{\mathrm{d}d_i^n}{\mathrm{d}w_i} = \frac{f[d_i^n]}{-w_i f'[d_i^n] - w^*(1-\lambda)f'[m-d_i^n]} \tag{A2.71}$$

$$\frac{\mathrm{d}d_i^m}{\mathrm{d}w_i} = \frac{(1-\lambda)f[d_i^m]}{-w_i(1-\lambda)f'[d_i^m] - w^*f'[m-d_i^m]}.$$
(A2.72)

Evaluating $\frac{\partial L^{ES,M}}{\partial w_i} \frac{w_i}{L^{ES,M}}$ at the symmetric equilibrium, where it holds that $w_i = w^* \equiv 1$, $d_i^n = d^n$, $d_i^m = d^m = m - d^n$ and $f[d^n] = (1 - \lambda)f[d^m]$, we obtain

$$\eta^{M} = \frac{\partial L^{ES,M}}{\partial w_{i}} \frac{w_{i}}{L^{ES}} \bigg|_{w_{i}=w} = \frac{L}{H} \left(\frac{f[d^{n}]^{2}}{-f'[d^{n}] - (1-\lambda)f'[m-d^{n}]} + \frac{(1-\lambda)^{2}f[d^{m}]^{2}}{-(1-\lambda)f'[d^{m}] - f'[m-d^{m}]} \right) \\ \times \frac{1}{\frac{L}{H} \left(\int_{0}^{d^{n}} f[d] \mathrm{d}d + (1-\lambda) \int_{0}^{d^{m}} f[d] \mathrm{d}d \right)}{\frac{L}{H} \left(\int_{0}^{d^{n}} f[d] \mathrm{d}d + (1-\lambda) \int_{0}^{d^{m}} f[d] \mathrm{d}d \right)} \\ = \frac{2f[d^{n}]^{2}}{f'[d^{n}] + (1-\lambda)f'[d^{m}]} \cdot \frac{-1}{\int_{0}^{d^{n}} f[d] \mathrm{d}d + (1-\lambda) \int_{0}^{d^{m}} f[d] \mathrm{d}d}$$
(A2.73)

as displayed in (2.38). The elasticity of labor supply decreases in m:

$$\eta_m^M = \eta^M \left[\frac{2f'[d^n]}{f[d^n]} \frac{\mathrm{d}d^n}{\mathrm{d}m} - \frac{-f''[d^n] \frac{\mathrm{d}d^n}{\mathrm{d}m} - (1-\lambda)f''[d^m] \frac{\mathrm{d}d^m}{\mathrm{d}m}}{-f'[d^n] - (1-\lambda)f'[d^m]} - \frac{f[d^n]}{m\theta^M} \right] < 0, \qquad (A2.74)$$

where $\frac{\mathrm{d}d^n}{\mathrm{d}m} = \frac{(1-\lambda)f'[d^m]}{f'[d^n]+(1-\lambda)f'[d^m]} > 0$ and $\frac{\mathrm{d}d^m}{\mathrm{d}m} = \frac{f'[d^n]}{f'[d^n]+(1-\lambda)f'[d^m]} > 0$. Furthermore, provided that $f'''[\cdot]$ is not too positive, η^M decreases in λ :

$$\eta_{\lambda}^{M} = \eta^{M} \left[\underbrace{\frac{2f'[d^{n}]}{f[d^{n}]} \frac{\mathrm{d}d^{n}}{\mathrm{d}\lambda}}_{<0} + \underbrace{\frac{f''[d^{n}] \frac{\mathrm{d}d^{n}}{\mathrm{d}\lambda} + (1-\lambda)f''[d^{m}] \frac{\mathrm{d}d^{m}}{\mathrm{d}\lambda} + f'[d^{m}]}_{<0}}_{<0} + \underbrace{\frac{F[d^{m}]}{F[d^{n}] + (1-\lambda)F[d^{m}]}}_{>0} \right] < 0$$
(A2.75)

with $\frac{\mathrm{d}d^n}{\mathrm{d}\lambda} = \frac{f[d^m]}{-f'[d^n] - (1-\lambda)f'[d^m]} > 0$ and $\frac{\mathrm{d}d^m}{\mathrm{d}\lambda} = -\frac{\mathrm{d}d^n}{\mathrm{d}\lambda} < 0$. $\eta^M_\lambda < 0$ follows from the fact that the first term in the brackets (in absolute terms) exceeds the third, since

$$\frac{2f'[d^n]}{f[d^n]} \frac{\mathrm{d}d^n}{\mathrm{d}\lambda} = \underbrace{2\frac{f[d^m]}{f[d^n]} \cdot \frac{f'[d^n]}{f'[d^n] + (1-\lambda)f'[d^m]}}_{\ge 1} \ge \underbrace{\frac{F[d^m]}{F[d^n] + (1-\lambda)F[d^m]}}_{<1}.$$
 (A2.76)

A2.7.3 Analytical Details of the Proof of Proposition 3

The number of firms is too large in the migration equilibrium. The social planner solves the same maximization problem as in Appendix A2.5, additionally taking into account the integrated labor market.⁵¹ The first order condition of the planner then obtains as

$$\frac{Lf\left[d^{n}\right]}{L\theta^{M} - \frac{\alpha H}{m}} = 1 + \frac{m}{4\gamma H}.$$
(A2.77)

where d^n, θ^M are shorthands for $d^n[m, \lambda], \theta^M[m, \lambda]$, respectively. A comparison with the market solution (2.41) shows that, as before, the number of firms in the market equilibrium is too large if the markup distortion is larger than the productivity distortion. We can show that this is the case in the migration equilibrium with nonprohibitive λ . The relevant condition is $\psi^M > \frac{\theta^M}{f[d^n]}$. Inserting for ψ^M this is equivalent to $1 - \frac{m\theta^M(f'[d^n] + (1-\lambda)f'[d^m])}{2f[d^n]^2} > \frac{\theta^M}{f[d^n]}$. This, in turn, holds if $1 - \frac{m\theta^M f'[d^n]}{2f[d^n]^2} > \frac{\theta^M}{f[d^n]}$, since $-f'[d^m](1-\lambda)/(2f[d^n]^2) \ge 0$. Rewriting the condition leads to $f[d^n] > \theta^M + \frac{m}{2} \frac{f'[d^n]}{f[d^n]} \theta^M$. We will show below that $f\left[\frac{d^n}{2}\right] \ge \theta^M$. Then, this inequality holds if

$$f[d^n] > f\left[\frac{d^n}{2}\right] + \frac{m}{2} \frac{f'[d^n]}{f[d^n]} \theta^M.$$
(A2.78)

Concavity of $f[\cdot]$ implies that $f[d^n] \ge f\left[\frac{d^n}{2}\right] + f'[d^n]\frac{d^n}{2}$. Moreover, we have that $f\left[\frac{d^n}{2}\right] + f'[d^n]\frac{d^n}{2} > f\left[\frac{d^n}{2}\right] + f'[d^n]\frac{m}{2}\frac{\theta^M}{f[d^n]}$ because $m \ge d^n$ and $\theta^M > f[d^n]$. Therefore, (A2.78) holds a fortiori. Hence, the markup distortion exceeds the productivity distortion and consequently, the number of firms in the market equilibrium with migration is too large.⁵²

⁵¹Note that this assumes that either the planner maximizes welfare for both countries or takes as given that a planner in the foreign country solves the exact same problem.

⁵²There is a subtle point to this proof in that $\theta^{M}[m, \lambda]$ is not necessarily concave in m, if there is migration. As a result, the social welfare function is not globally concave. However, it can be shown that the first oder condition in A2.77 still describes a global maximum and that the social welfare function is monotonously increasing in the relevant range. Details of the proof are available upon request.

Proof that $\theta^M \leq f\left[\frac{d^n}{2}\right]$. Using the expression for θ^M in (2.37) and Jensen's inequality which states that $f\left[E[x]\right] \geq E\left[f[x]\right]$ for concave functions f[x], we can state

$$\theta^{M} = \frac{1}{m} \int_{0}^{d^{n}} f[d] \mathrm{d}d + (1-\lambda) \frac{1}{m} \int_{0}^{d^{m}} f[d] \mathrm{d}d \le \frac{d^{n}}{m} f\left[\frac{d^{n}}{2}\right] + (1-\lambda) \frac{d^{m}}{m} f\left[\frac{d^{m}}{2}\right] \quad (A2.79)$$

Since $d^n + d^m = m$, we have that $\theta^M \leq \frac{d^n}{m} f\left[\frac{d^n}{2}\right] + (1-\lambda)\frac{d^m}{m} f\left[\frac{d^m}{2}\right]$. This reduces to $\theta^M \leq f\left[\frac{d^n}{2}\right]$ provided that $(1-\lambda)f\left[\frac{d^m}{2}\right] \leq f\left[\frac{d^n}{2}\right]$. From (2.34) and (2.35) it follows that a symmetric equilibrium is characterized by $(1-\lambda) = f[d^n]/f[d^m]$, so the condition becomes $\frac{f\left[\frac{d^m}{2}\right]}{f\left[\frac{d^n}{2}\right]} \leq \frac{f[d^m]}{f[d^n]}$, which is implied by $d^m \leq d^n$ and $f''[\cdot] \leq 0$. This completes the proof.

A2.7.4 Proof of Proposition 4

Totally differentiating the equilibrium condition (2.41) yields $\hat{m} = C \cdot \hat{\lambda}$ where C is given by⁵³

$$C = \frac{g_{\lambda}^{M} - \rho^{T}\psi_{\lambda}^{M}}{-g_{m}^{M} + \rho^{T}\psi_{m}^{M} + \psi^{M}\rho_{m}^{T}}\frac{\lambda}{m} \leq 0 \quad \text{with}$$

$$g_{\lambda}^{M} = \frac{L\theta_{\lambda}^{M}}{L\theta^{M} - \alpha N} - \frac{L\theta^{M}}{\left(L\theta^{M} - \alpha N\right)^{2}}L\theta_{\lambda}^{M} > 0 \quad \text{and} \quad \theta_{\lambda}^{M} = -\frac{1}{m}\int_{0}^{d^{m}} f[d]dd < 0$$
(A2.81)

$$g_m^M = \frac{L\theta_m^M}{L\theta^M - \alpha N} - \frac{L\theta^M}{\left(L\theta^M - \alpha N\right)^2} \left(L\theta_m^M + \frac{\alpha N}{m}\right) < 0 \quad \text{and} \quad \theta_m^M = \frac{1}{m} \left(f[d^n] - \theta^M\right) < 0$$
(A2.82)

$$\psi_{\lambda}^{M} = -\frac{1}{(\eta^{M})^{2}} \cdot \eta_{\lambda}^{M} > 0 \qquad \text{with } \eta_{\lambda}^{M} \text{ as in (A2.75)}$$
(A2.83)

$$\psi_m^M = -\frac{1}{(\eta^M)^2} \cdot \eta_m^M > 0 \qquad \text{with } \eta_m^M \text{ as in (A2.74)}$$
(A2.84)

$$\rho_m^T = \frac{1}{2\gamma H} > 0. \tag{A2.85}$$

While the denominator of C is always positive (a larger firm size m decreases the markup needed for zero profits g^M and increases both the price markup and the wage markup), the sign of the numerator depends on whether the effect of λ on g^M (which is positive) is stronger than the effect on the wage markup (which is also positive). In either case, prices fall as migration costs fall.

⁵³Note that for notational convenience here and in the following we omit the functional dependence of $g^M, \psi^M, \rho^M, \theta^M, d^n$ on m and, where relevant, on λ .
The effect on average income is ambiguous. While the partial effect of lower migration costs is positive, there is a countervailing effect when the general equilibrium adjustments lead to firm exit. In either case, however, real income increases when migration costs fall, as the decrease in prices overcompensates the potential decrease in average income. We show this by log-differentiating real income $\frac{\theta^M}{p} = \frac{L\theta^M - \frac{\alpha H}{m}}{L}$ as obtained by rewriting (2.41):

$$d\ln\left[\frac{\theta^{M}}{p}\right] = \frac{\partial\ln\left[\frac{\theta^{M}}{p}\right]\lambda}{\partial\lambda} \cdot \hat{\lambda} + \frac{\partial\ln\left[\frac{\theta^{M}}{p}\right]m}{\partial m} \cdot \hat{m}$$
(A2.86)

with

$$\frac{\partial \ln\left[\frac{\theta^M}{p}\right]}{\partial \lambda} = \frac{L\theta^M_\lambda}{L\theta^M - \frac{\alpha H}{m}} < 0 \quad \text{and} \tag{A2.87}$$

$$\frac{\partial \ln\left[\frac{\theta^M}{p}\right]}{\partial m} = \frac{L\theta_m^M + \frac{\alpha H}{m^2}}{L\theta^M - \frac{\alpha H}{m}} > 0.$$
(A2.88)

In these equations $\theta_{\lambda}^{M} = -\frac{1}{m} \int_{0}^{d^{m}} f[d] dd < 0$ and $\theta_{m}^{M} = \frac{1}{m} \left(f[d^{n}] - \theta^{M} \right) < 0$. Note that $\frac{\partial \ln\left[\frac{\theta^{M}}{p}\right]}{\partial m} > 0$ in the relevant range follows from (A2.77). Hence, the log-change in real income induced by a decrease in λ is clearly positive, if \hat{m} is also positive. To show that real income also increases if \hat{m} is negative we use (A2.80) as well as (A2.87) and (A2.88) to rewrite (A2.86) as

$$d\ln\left[\frac{\theta^{M}}{p}\right] = \frac{\lambda}{\left(L\theta^{M} - \alpha N\right)\left(-g_{m}^{M} + \rho\psi_{m}^{M} + \psi^{M}\rho_{m}\right)} \times \left[\left(L\theta_{m}^{M} + \frac{\alpha N}{m}\right)\left(g_{\lambda}^{M} - \rho\psi_{\lambda}^{M}\right) + \left(-g_{m}^{M} + \rho\psi_{m}^{M} + \psi^{M}\rho_{m}\right)L\theta_{\lambda}^{M}\right]\hat{\lambda}.$$
(A2.89)

We know that the first fraction on the right-hand side above is positive, hence we must show that the square-bracketed term is negative. Using

$$\left(L\theta_m^M + \frac{\alpha N}{m}\right)g_{\lambda}^M = \left[\frac{L\theta_m^M + \frac{\alpha N}{m}}{L\theta^M - \alpha N} - \frac{L\theta^M \left(L\theta_m^M + \frac{\alpha N}{m}\right)}{(L\theta^M - \alpha N)^2}\right] \cdot L\theta_{\lambda}^M$$
(A2.90)

and

$$L\theta_{\lambda}^{M}g_{m}^{M} = \left[\frac{L\theta_{m}^{M}}{L\theta^{M} - \alpha N} - \frac{L\theta^{M}\left(L\theta_{m}^{M} + \frac{\alpha N}{m}\right)}{(L\theta^{M} - \alpha N)^{2}}\right] \cdot L\theta_{\lambda}^{M}$$
(A2.91)

we can reduce the expression in squared brackets on the right-hand side of (A2.89) to

$$L\theta_{\lambda}^{M}\left(\frac{\frac{\alpha N}{m}}{L\theta^{M}-\alpha N}+\psi_{m}^{M}\rho+\rho_{m}\psi^{M}\right)-\left(L\theta_{m}^{M}+\frac{\alpha N}{m}\right)\rho\psi_{\lambda}^{M}.$$
(A2.92)

This is negative since $\theta_{\lambda}^{M} < 0$ and $\psi_{\lambda}^{M} > 0$. Hence, a decrease in λ raises real income also if it leads to exit of firms. This completes the proof of proposition 4.

A2.7.5 Robustness with Respect to the Specification of Migration Costs

The proofs of proposition 3 and 4 reveal that our results are valid for more general specifications of migration costs. The positive welfare effect of the potential of migration established in proposition 3 stems from a first-order welfare gain due the reduction of the markup distortion. Hence, the validity of proposition 3 is maintained, provided that the excess-entry property of the autarky equilibrium is preserved. The proof of proposition 4 shows that positive welfare gains from lower migration costs occur, provided that $\theta_{\lambda}^{M} < 0$ and $\eta_{\lambda}^{M} < 0$, and that the excess-entry result holds. It is relatively straightforward that this holds for a wide range of migration costs specifications.

Where is the Value Added? Trade Liberalization and Production Networks^{*}

3.1 Introduction

The global value chain is increasingly fragmented. Single stages of a good's production may each be performed in a different country and trade along the production chain is surging. Value added from early stages of production may thus cross borders multiple times and is then "double-counted" in export statistics. This implies that gross export flows do not accurately measure the value added a country transfers to a trade partner. Xing and Detert (2010) document that only about 4% of the value of an iPhone assembled in China and exported to the United States is Chinese value added. Linden et al. (2009) come to similar results for the iPod. On the world level, the ratio of value added exports to gross exports, as measured in official trade statistics, has declined dramatically. Johnson and Noguera (2012c) document a decline in the ratio from 65% in 1970 to 45% in 2009 for global manufacturing exports.

Fragmentation of the global value chain makes it increasingly difficult to track who produces for whom, which, in turn, makes it difficult to disentangle the effects of trade liberalization on the global pattern of production. Moreover, production linkages imply that the welfare effects of regional trade policies on third countries can be very diverse.

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Production fragmentation multiplies the potential gains from specialization and magnifies the importance of fundamental determinants of trade relationships such as relative productivity differences and geographical proximity. It renders the effect of a decrease in trade barriers heterogeneous and non-linear, depending on the initial level of and the potential for production fragmentation, as shown by Yi (2003). Baldwin and Lopez-Gonzalez (2015) document that the current engagement in trade along the production chain is very unevenly distributed across the globe. It is highly concentrated and takes place within networks among geographically close nations, especially in North America, East Asia, and Europe.

In this paper, we analyze how trade liberalization has shaped the pattern of who produces for whom, how much it contributed to global production fragmentation, and whether it facilitated the formation of production networks. We focus on a major event of trade liberalization in the past decade: China's accession to the WTO in 2001. We simulate the impact of the associated tariff cuts on China's trade and value added trade relationships on the sectoral bilateral level to analyze the change in the composition of China's trade, the value added and welfare effects across the globe, and their interaction with fundamental determinants of trade relationships.

To that end, we derive a structural expression for value added trade in a general equilibrium multi-country multi-sector trade model of the Eaton and Kortum (2002) type with input-output linkages, building on the work of Caliendo and Parro (2015) and Johnson and Noguera (2012b). Using the model, we derive a definition for international supply and demand networks between value added source sectors and final goods producing downstream sectors that can be compared across sectors, countries, and time. Based on the World Input-Output Database (WIOD), we construct a panel dataset of value added trade for 40 countries and decompose exports into value added exports, exports of foreign value added, and double-counting, following the methodology developed by Koopman et al. (2014). Combining WIOD with tariff data, we estimate the model's structural parameters and calibrate it to 2000, the year preceeding China's accession to the WTO. This forms the basis for our counterfactual analysis of a change in the tariff structure to the level in 2007.

To preview our results, we find that China's WTO entry can account for large parts of the structural changes in China's sectoral bilateral sourcing patterns, such as the disproportional strengthening of production networks with its neighboring countries, as well as its aggregate level of production fragmentation. The change in the composition of China's exports predicted by the change to the counterfactual equilibrium accounts for about 45% of the actual decrease in China's value added exports to exports ratio between 2000 and

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2007. This amounts to about 7% of the increase in production fragmentation observed on the global scale. Moreover, we find that China's WTO accession was the driving force behind the strengthening of supply and demand networks with Japan, Korea, and Australia, and significantly shaped its value added trade relationships with the United States. China gained in importance as a location for processing value added into final goods for almost all countries, but particularly for the nearby Asian economies, which could, at the same time, foster their positions as major sources of foreign value added in China's final goods production. Even conditional on geographical proximity, we find that initially stronger networks became even more intense, suggesting that a magnification effect of trade costs is at work. With respect to welfare, we find that the WTO accession led to a 0.6 percentage point increase in real income for China. The largest gains (2.6 percentage points) accrued to Australia, which was also among the countries facing the highest tariff cuts on imports from China. We find positive welfare effects for China's neighboring countries and no evidence of negative welfare consequences for the United States. In fact, only a few countries, primarily European, appear to have been marginally adversely affected.

Our results are interesting in view of related literature that evaluates the welfare effects of trade with China. di Giovanni et al. (2014) estimate the gains from trading with China relative to a situation where China is in complete autarky using a variant of the model developed by Caliendo and Parro (2015). Their qualitative results strongly resemble the pattern we find for the WTO accession. Ghosh and Rao (2010) find a similar pattern in an evaluation study of China's WTO entry based on a CGE model and GTAP data. Those studies, as well as ours, complement micro-level evidence that has drawn a more pessimistic picture of the consequences of trading with China, particularly for the United States (see, e.g., Autor et al., 2013). Those results are not necessarily contradictory to ours, given their short-term perspective on local employment. In contrast, our results reflect long-term effects and include general equilibrium adjustments, allowing for sectoral labor mobility to facilitate the value added increases on the national level, and for lower prices to increase real income.

Our paper is also related to structural gravity applications. To take into account general equilibrium effects of trade liberalization, this strand of literature resorts to counterfactual policy experiments, simulating effects of trade cost changes on (gross) trade patterns and welfare in general equilibrium. Several studies investigate the effects of abolishing the Canada-U.S. border, (e.g., Anderson and van Wincoop, 2003; Bergstrand et al., 2013). Other studies simulate the gains from trade versus autarky (see, e.g., Eaton and Kortum, 2002) or free trade agreement (FTA) formation (Egger et al., 2011; Egger and Larch, 2011) or assess the effects of trade imbalances on welfare (Dekle et al., 2007). Caliendo

and Parro (2015) introduce input-output linkages in a multi-sector Eaton and Kortum (2002) type gravity model and simulate the welfare effect of tariff cuts in the wake of the North American Free Trade Agreement (NAFTA).¹ We contribute to this strand of literature by making explicit the value added flows between countries and sectors, both theoretically and empirically, and by analyzing how they were affected by a major event of trade liberalization.

A growing body of literature documents value added trade flows (see, e.g., Johnson and Noguera, 2012b,c; Baldwin and Lopez-Gonzalez, 2015). Hummels et al. (2001), Daudin et al. (2011), and Johnson and Noguera (2012b) develop measures of vertical specialization, which are incorporated into a general accounting formula for value added in trade developed by Koopman et al. (2014) and Wang et al. (2013).² Vertical specialization changes the perspective on many aspects of trade, such as revealed comparative advantage (Koopman et al., 2014; Wang et al., 2013), exchange rates (Bems and Johnson, 2012), business cycle co-movements (Giovanni and Levchenko, 2010), the elasticity of trade with respect to tariff cuts (Yi, 2003), and the home bias in trade (Yi, 2010). Vertical specialization can also explain why trade collapsed relatively stronger than GDP during the recent global financial crisis (Bems et al., 2011; Bénassy-Quéré et al., 2009).

Johnson and Noguera (2012d) provide first empirical evidence on how the global value chain reacts to changes in trade costs. They employ a gravity equation to study the effects of distance and FTA formation on trade in value added. However, due to thirdcountry effects, their estimates from this bilateral model must be interpreted with care. Value added of one country reaches the final consumer in another country via all other countries. Noguera (2012) derives a gravity equation for bilateral value added trade from an Armington model with final and intermediate goods trade using a first-order approximation to the highly non-linear relationship between bilateral value added flows and the standard gravity variables. Acknowledging all higher order relationships, we show that a gravity relationship holds on the bilateral cross-sectoral level. Moreover, we show why the same fails to hold at the aggregate bilateral level. Our results strongly suggest that the effects of trade costs (and other gravity variables of interest) on value added trade need to be assessed using a structural model and counterfactual simulation rather than reduced form gravity estimations.

¹A comprehensive summary of the welfare implications of trade liberalization in different formulations of the gravity model (single vs. multi-sector, input-output linkages, homogenous vs. heterogeneous firms, etc.) is provided by Costinot and Rodriguez-Clare (2014).

²The methodology for tracing value added in foreign consumption builds on methods developed for multiregional input-output analysis, which are also used in the literature on the factor content of trade (see, e.g., Trefler and Zhu, 2010).

Building on the insight of Yi (2003), who shows that both the initial degree of and the potential for production fragmentation render the effects of tariff liberalization non-linear and heterogeneous, we analyze the regional and global trade and value added effects of one of the major instances of trade liberalization in the past decade – China's entry into the WTO. In our model, production fragmentation across borders arises as a consequence of Ricardian productivity advantages in the production of differentiated varieties that serve as inputs for a sectoral composite good. Regardless of the possibly infinite number of travel routes through other sectors in other countries where value added can occur before the good is assembled into its final form, the pattern and intensity of value added trade relationships are determined by the well-known fundamental factors of the Eaton-Kortum world – productivity and geography – as well as by differences in production technology with respect to cross-sectoral intermediate input usage.

Our analysis of the impact of trade liberalization involves an implicit comparison with alternative explanations for the increase in trade along the value chain over time that derives from the literature on production fragmentation. One strand of this literature revolves around the idea that production of a good can be characterized as the completion of a set of tasks. Tasks are either performed sequentially (Costinut et al., 2013) or ordered according to a specific criterion, such as tradability (Grossman and Rossi-Hansberg, 2008). Differences in country characteristics, for example, in level of development or relative factor prices, lead to a pattern of specialization based on comparative advantage. Another strand of literature focuses on production fragmentation as a problem of firms' internal organization (for an overview, see Helpman, 2006). Recent work in this field highlights the role of contractual frictions (Antrás and Chor, 2013) and communication costs (Keller and Yeaple, 2013). Improvements in communication technology have facilitated the unbundling of production processes into finer steps and eased the flow of knowledge across borders. Moreover, improvements in institutional quality and property rights protection have lowered the cost of production relocation. Finally, increased demand for technologically more complex goods, in conjunction with economic growth and non-homotheticity of preferences, provide a demand-driven explanation. The importance of each of these explanations is an empirical question. We seek to contribute by quantifying the effect of a major event of trade liberalization on the observed regional and global trends in the 2000s.

The paper proceeds as follows. In Section 3.2 we describe the gravity model with inputoutput linkages developed by Caliendo and Parro (2015) and derive structural expressions for value added trade on different levels of aggregation. We show how trade liberalization affects gross exports and value added trade differently. In Section 3.3 we propose a definition for supply and demand networks in the context of the model and provide summary statistics on those measures based on the WIOD. Section 3.4 explains how we identify the model's key parameters, namely, value added and input-output coefficients, as well as a sectoral measure of productivity dispersion. In Section 3.5 we describe the counterfactual experiment and present simulation results for the impact of China's WTO accession on gross exports, value added trade, production networks, and welfare.

3.2 A Model for Trade in Value Added

We begin with a brief description of production and trade in the multi-sector input-output gravity model developed by Caliendo and Parro (2015). Based on this framework, we then derive a structural expression for bilateral value added trade flows and decompose gross exports into value added components from different sources and production stages.

3.2.1 Production and Gross Exports

There are N countries indexed by i or n and J sectors indexed by j or k. The representative consumer derives utility from consumption of final goods from all sectors. Each sectoral final good is a composite of differentiated varieties that are sourced from different countries. We assume that preferences for sectoral composites are Cobb-Douglas and we denote with α_n^j the corresponding constant sectoral expenditure share.

Household income I_n comprises labor income and lump-sum tariff rebates. The labor force, L_n , of a country is mobile across sectors, but not across countries.

In each sector j a continuum of varieties ω^j is produced with labor $l_n^j(\omega^j)$ and composite intermediate inputs $m_n^{k,j}(\omega^j)$ from other sectors according to the following production function:

$$q_{n}^{j}(\omega^{j}) = x_{n}^{j}(\omega^{j})^{-\theta^{j}} \left[l_{n}^{j}(\omega^{j}) \right]^{\beta_{n}^{j}} \left[\prod_{k=1}^{J} m_{n}^{k,j}(\omega^{j})^{\gamma_{n}^{k,j}} \right]^{(1-\beta_{n}^{j})},$$
(3.1)

where $\beta_n^j \in [0,1]$ is the cost share of labor and $(1 - \beta_n^j)\gamma_n^{k,j}$ denotes the cost share of intermediates from source sector k, with $\gamma_n^{k,j} \in [0,1]$ and $\sum_{k=1}^J \gamma_n^{k,j} = 1$. $x_n^j(\omega^j)$ denotes the inverse efficiency of variety producer ω^j and θ^j governs the dispersion of efficiency across varieties in sector j. A higher θ^j implies greater dispersion. All varieties ω^j are aggregated to sector j's composite good q_n^j with a Dixit-Stiglitz CES technology. This composite is either used as intermediate input in other sectors or consumed as a final good.

The minimum cost c_n^j of an input bundle for a typical variety producer from sector jin country n depends on the wage rate w_n and the prices of composite intermediate goods p_n^k according to

$$c_{n}^{j} = \Upsilon_{n}^{j} w_{n}^{\beta_{n}^{j}} \left[\prod_{k=1}^{J} p_{n}^{k} \gamma_{n}^{k,j} \right]^{(1-\beta_{n}^{j})}, \qquad (3.2)$$

where Υ_n^j is a constant.³

Let κ_{in}^{j} denote the trade costs of delivering good j from country i to country n. We assume that these costs consist of iceberg trade costs $d_{in}^{j} \geq 1$, with $d_{nn}^{j} = 1$, and advalorem tariffs $\tau_{in}^{j} \geq 0$ such that $\kappa_{in}^{j} = (1 + \tau_{in}^{j})d_{in}^{j}$. Perfect competition and constant returns to scale imply that firms charge prices equal to unit costs, that is, the price of variety ω^{j} from country i in country n is given by $p(\omega^{j}) = x(\omega)^{\theta_{j}}c_{i}^{j}\kappa_{in}^{j}$. Producers search across all countries for the lowest-cost supplier. We assume that productivity levels $x(\omega^{j})$ are independent draws from an exponential distribution with a country- and sector-specific location parameter λ_{n}^{j} . Solving for the distribution of prices and integrating over the sets of goods for which any country is the lowest-cost supplier to country n, we obtain the price of the composite intermediate good in country n as

$$p_n^j = A^j \left(\sum_{i=1}^N \lambda_i^j \left(c_i^j \kappa_{in}^j \right)^{\frac{-1}{\theta^j}} \right)^{-\theta^j}, \qquad (3.3)$$

where A^j is a constant.⁴ Note that p_n^j depends on the prices of composites from all other sectors (via c_i^j). The strength of the correlation is governed by the cross-sectoral intermediate cost shares $\gamma_n^{k,j}$.

Ultimately, the model delivers a gravity equation. Country n's expenditure share π_{in}^{j} for source country *i*'s goods in sector *j* depends on *i*'s price relative to the price index and can be written as

$$\pi_{in}^{j} = \frac{\lambda_{i}^{j} \left[c_{i}^{j} \kappa_{in}^{j}\right]^{\frac{1}{\theta^{j}}}}{\sum_{i=1}^{N} \lambda_{i}^{j} \left[c_{i}^{j} \kappa_{in}^{j}\right]^{\frac{-1}{\theta^{j}}}}.$$
(3.4)

This trade share corresponds to the probability that i is the lowest cost supplier of a variety in sector j for country n. Equation (3.4) differs from the standard gravity equation in

³Note that the minimum costs of an input bundle are identical for all variety producers within a given sector and country since these costs differ only with regard to Hicks-neutral productivity shifters $x_n^j(\omega^j)$. ⁴Specifically, $A^j = \Gamma \left[1 + \theta(1 - \eta_j)\right]^{\frac{1}{1 - \eta_j}}$ where $\Gamma(\cdot)$ is the gamma function and η_j is the elasticity of substition between any two of all varieties that are bundled into the sectoral composite good.

that unit costs c_i^j depend on the costs of all sectoral composites and thus also on trade costs and tariffs in other sectors and between other country pairs.

3.2.2 General Equilibrium

Let Y_n^j denote the value of gross production of varieties in sector j. For each country n and sector j, market clearing requires that Y_n^j be equal to the sum of intermediates and final goods demand from all countries $i = 1, \ldots, N$. Hence, goods market clearing conditions are given by

$$Y_{n}^{j} = \sum_{i=1}^{N} \sum_{k=1}^{J} \frac{\pi_{ni}^{j}}{(1+\tau_{ni}^{j})} \gamma_{i}^{j,k} (1-\beta_{i}^{k}) Y_{i}^{k} + \sum_{i=1}^{N} \frac{\pi_{ni}^{j}}{(1+\tau_{ni}^{j})} \alpha_{i}^{j} I_{i}$$

$$= \sum_{i=1}^{N} \frac{\pi_{ni}^{j}}{(1+\tau_{ni}^{j})} \left(\sum_{k=1}^{J} \gamma_{i}^{j,k} (1-\beta_{i}^{k}) Y_{i}^{k} + \alpha_{i}^{j} I_{i} \right)$$

$$= \sum_{i=1}^{N} \frac{\pi_{ni}^{j}}{(1+\tau_{ni}^{j})} X_{i}^{j},$$
(3.5)

where national income I_i consists of labor income, tariff rebates R_i , and the (exogenous) trade surplus S_i , that is, $I_i = w_i L_i + R_i - S_i$. X_i^j denotes country *i*'s expenditure on sector *j* goods. The first term on the right-hand side equals demand of all sectors in all countries for intermediates from sector *j* varieties produced in *n*. The second term is final demand.⁵ Both intermediates and final goods demand are divided by $(1 + \tau_{ni}^j)$ to convert values from purchaser prices to producer prices. Tariff rebates are $R_i = \sum_{j=1}^J X_i^j \left(1 - \sum_{n=1}^N \frac{\pi_{ni}^j}{(1 + \tau_{ni}^j)}\right)$.

The model is closed with an income-equals-expenditure condition for each country n that takes into account trade imbalances. This condition mandates that the value of total imports plus the trade surplus equal the value of total exports plus domestic sales, which is equivalent to GDP Y_n :

$$\sum_{j=1}^{J} \left(\sum_{k=1}^{J} \gamma_n^{j,k} (1-\beta_n^k) Y_n^k + \alpha_n^j I_n \right) \sum_{i=1}^{N} \frac{\pi_{in}^j}{(1+\tau_{in}^j)} + S_n = \sum_{j=1}^{J} Y_n^j \equiv Y_n,$$

$$\sum_{j=1}^{J} X_n^j \sum_{i=1}^{N} \frac{\pi_{in}^j}{(1+\tau_{in}^j)} + S_n = Y_n$$
(3.6)

⁵Our exposition differs from that of Caliendo and Parro (2015), who use total expenditure on composite goods instead of total production of varieties as an endogenous variable. Hence, in Caliendo and Parro (2015), the value of gross production comprises all foreign varieties that are bundled into the composite good without generation of value added. However, we believe that the value of production of sectoral varieties is a more natural choice.

3.2.3 Comparative Statics in General Equilibrium

In this section, we describe how the model can be solved for changes in equilibrium outcomes induced by an exogenous change in the tariff structure, thus paving the way for our counterfactual analysis of China's WTO entry and its effect on exports, value added flows, and welfare. As suggested by Dekle et al. (2008), instead of solving the model for the new equilibrium, one can solve for equilibrium changes. This approach has the advantage that we do not need data on prices, iceberg trade costs, or productivity levels.

Denote with $\hat{x} \equiv x'/x$ the relative change in any variable x from its initial level x to the counterfactual level x'. The equilibrium change in input costs induced by a change in tariffs is then given by

$$\hat{c}_{n}^{j} = \hat{w}_{n}^{\beta_{n}^{j}} \left(\prod_{k=1}^{J} \left[\hat{p}_{n}^{k} \right]^{\gamma_{n}^{k,j}} \right)^{1-\beta_{n}^{j}}.$$
(3.7)

The change in the price index is

$$\hat{p}_n^j = \left(\sum_{i=1}^N \pi_{in}^j \left[\hat{\kappa}_{in}^j \hat{c}_i^j\right]^{-1/\theta^j}\right)^{-\theta^j}$$
(3.8)

and bilateral trade shares change according to

$$\hat{\pi}_{in}^j = \left(\frac{\hat{c}_i^j}{\hat{p}_n^j}\hat{\kappa}_{in}^j\right)^{-1/\theta^j}.$$
(3.9)

The counterfactual expenditure in each country and sector is

$$X_n^{j'} = \sum_{k=1}^J \gamma_n^{j,k} (1 - \beta_n^k) \left(\sum_{i=1}^N \frac{\pi_{ni}^{k'}}{1 + \tau_{ni}^{k'}} X_i^{k'} \right) + \alpha_n^j I_n',$$
(3.10)

where $F_n^j \equiv \sum_{i=1}^N \frac{\pi_{in}^j}{(1+\tau_{in}^j)}$ and $I'_n = \hat{w}_n w_n L_n + \sum_{j=1}^J X_n^{j'} (1-F_n^{j'}) - S_n$ and subject to the trade balance that requires

$$\sum_{j=1}^{J} F_n^{j'} X_n^{j'} + S_n = \sum_{j=1}^{J} \sum_{i=1}^{N} \frac{\pi_{ni}^{j'}}{1 + \tau_{ni}^{j'}} X_i^{j'}.$$
(3.11)

This system of equations can be solved with the search algorithm proposed by Alvarez and Lucas (2007).⁶

The welfare effects of a change in the tariff structure can be assessed by looking at the change in real income, which is given by

$$\widehat{W}_n = \frac{\widehat{I}_n}{\prod_{j=1}^J (\widehat{p}_n^j)^{\alpha_n^j}}$$
(3.12)

3.2.4 Value Added Trade

We use the model to derive an expression for value added trade flows based on the methodology developed by Johnson and Noguera (2012b). To compute value added trade flows between countries *i* and *n* we need information on bilateral final goods exports, a world input-output table, and labor cost shares (value added coefficients) in all countries and sectors. Expenditure on final goods from sector *j* is $C_n^j = \alpha_n^j I_n^j$. As established above, a fraction π_{hn}^j of this expenditure is devoted to varieties from country *h*. Then, expenditure in country *n* on final goods from country *h* (net of tariffs) is

$$C_{hn}^{j} = \frac{\pi_{hn}^{j}}{(1+\tau_{hn}^{j})} C_{n}^{j} = \frac{\lambda_{h}^{j} \left[c_{h}^{j} \kappa_{hn}^{j}\right]^{\frac{-1}{\theta^{j}}}}{(1+\tau_{hn}^{j}) \sum_{h=1}^{N} \lambda_{h}^{j} \left[c_{h}^{j} \kappa_{hn}^{j}\right]^{\frac{-1}{\theta^{j}}}} \alpha_{n}^{j} I_{n}.$$
(3.13)

The value added share $V_i^j(x_i^j) = \frac{l_i^j(x_i^j)w_i}{(x_i^j)^{\theta^j}c_i^j}$ in the production value of a typical variety in country *i* follows from Shepard's lemma:

$$V_i^j(x_i^j) = \left(x_i^j\right)^{\theta^j} \frac{\partial c_i^j}{\partial w_i} \frac{w_i}{\left(x_i^j\right)^{\theta^j} c_i^j} = \beta_i^j.$$
(3.14)

Note that this share is independent of the producer's efficiency level. Similarly, we can derive input-output coefficients, that is, the cost share of intermediates from sector k in country n in the production of goods in country i's sector j as

$$(1+\tau_{in}^{k})a_{i,n}^{k,j} = \frac{\partial c_{i}^{j}}{\partial p_{in}^{k}}\frac{p_{in}^{k}}{c_{i}^{j}} = \pi_{in}^{k}(1-\beta_{i}^{j})\gamma_{i}^{k,j}.$$
(3.15)

⁶The algorithm starts with an initial guess about a vector of wage changes, then computes price and trade share changes and the new expenditure levels based on those wage changes, then evaluates the trade balance condition, and then updates the wage change based on the error in the trade balance. This algorithm is also used by Dekle et al. (2008). Caliendo and Parro (2015) extend it to a multi-sector input-output version.

We define $a_{in}^{k,j}$ as the cost share net of tariffs because input-output coefficients are usually denoted in producer prices.

We collect all bilateral input-output coefficients $a_{in}^{k,j}$ in a $NJ \times NJ$ world input-output table **A**. Input coefficients are arranged in $N \times N$ submatrices of dimension $J \times J$, each of which comprises all cross-sectoral relationships of a country pair, that is, we write

$$\mathbf{A} = \begin{pmatrix} \mathbf{A}_{11} & \dots & \mathbf{A}_{1N} \\ \vdots & \ddots & \vdots \\ \mathbf{A}_{N1} & \dots & \mathbf{A}_{NN} \end{pmatrix}, \text{ where } \mathbf{A}_{in} = \begin{pmatrix} a_{in}^{1,1} & \dots & a_{in}^{1,J} \\ \vdots & \ddots & \vdots \\ a_{in}^{J,1} & \dots & a_{in}^{J,J} \end{pmatrix}.$$

Within each submatrix the row index k of $a_{in}^{k,j}$ corresponds to the supply sector and the column index j denotes the demand sector, while the indices i and n of the submatrix denote the source country and destination country, respectively. Elements $b_{ih}^{k,j}$ of the Leontief inverse of the input-output matrix, $\mathbf{B} = (\mathbf{I} - \mathbf{A})^{-1}$, inform about the value of output that is generated in sector k in country i per unit (value) of final goods production in sector j in country h. **B** takes into account the world-wide fragmentation of the value chain and intermediates trade.

Let \mathbf{C}_n be a column vector collecting sectoral final goods imports of country n from all countries $i = 1, \ldots, N$

$$\mathbf{C}_{n} \equiv \begin{pmatrix} \mathbf{C}_{1n} \\ \vdots \\ \mathbf{C}_{Nn} \end{pmatrix}, \text{ where } \mathbf{C}_{hn} \equiv \begin{pmatrix} C_{hn}^{1} \\ \vdots \\ C_{hn}^{J} \end{pmatrix}$$

Then, $\mathbf{B} \cdot \mathbf{C_n}$ is a $J \cdot N$ column vector that collects the amount of production in country iand sector k for final demand in country n. An element of this vector is $\sum_{h=1}^{N} \sum_{j=1}^{J} b_{ih}^{k,j} C_{hn}^{j}$, which takes into account that sector k's output can reach country n embodied in final goods imports from all sectors j from all countries h.⁷ Value added generated in country i's sector k that is assembled into a final good in country h's sector j and finally consumed in country n is

$$VA_{ihn}^{k,j} = \beta_i^k b_{ih}^{k,j} C_{hn}^j = \beta_i^k b_{ih}^{k,j} \pi_{hn}^j \alpha_n^j I_n.$$
(3.16)

 $^{^7\}mathrm{Note}$ that it is not possible to find an explicit closed-form solution for $b_{ih}^{k,j}.$

By summing over h we obtain the total value added from sector k in country i that reaches country n embodied in final goods from sector j:

$$VA_{in}^{k,j} = \beta_i^k \alpha_n^j I_n \sum_{h=1}^N b_{ih}^{k,j} \pi_{hn}^j.$$

Finally, summation over all final goods sectors yields the total value added from sector k in country i that is consumed in country n:

$$VA_{in}^{k} = \beta_{i}^{k} \sum_{j=1}^{J} \alpha_{n}^{j} I_{n} \sum_{h=1}^{N} b_{ih}^{k,j} \pi_{hn}^{j}$$
(3.17)

To assess how bilateral value added flows change in response to a change in tariffs we proceed as follows: Once the equilibrium trade share changes are determined by (3.9), we can compute the counterfactual Leontief inverse and then the counterfactual bilateral value added flows. The counterfactual input-output coefficients are

$$a_{hi}^{k,j'} = \frac{\hat{\pi}_{hi}^k}{\hat{\kappa}_{hi}^k} a_{hi}^{k,j}.$$
 (3.18)

We collect them in the counterfactual input-output table \mathbf{A}' . The counterfactual Leontief inverse is then just $\mathbf{B}' = (\mathbf{I} - \mathbf{A}')^{-1}$. Final goods trade in the counterfactual experiment is

$$C_{hn}^{j'} = \frac{\hat{\pi}_{hn}^{j} \pi_{hn}^{j}}{(1 + \tau_{hn}^{j'})} \alpha_{n}^{j} I_{n}'.$$
(3.19)

The counterfactual value added flow corresponding to Equation (3.17) results as

$$VA_{in}^{k'} = \beta_i^k I_n' \sum_{j=1}^J \alpha_n^j \sum_{h=1}^N b_{ih}^{k,j'} \hat{\pi}_{hn}^j \pi_{hn}^j.$$
(3.20)

Note that the value added flows in Equations (3.17) and (3.20) are tied to the value added content of final goods consumption. Below in subsection 3.2.6, we look at the value added content of exports. In particular, we show how a connection between value added trade flows as given in Equations (3.17) and (3.20) and exports can be established using the accounting methodology put forward by Koopman et al. (2014). But first we take a closer look at Equation (3.17) to highlight that there is gravity in value added.

3.2.5 Gravity in Value Added

Starting from our expression for value added exports as derived above

$$VA_{i.n}^{k,j} = \beta_i^k \sum_{h=1}^{N} b_{ih}^{k,j} C_{hn}^j$$
(3.21)

we show that value added trade flows between a source sector k in some country i and a final goods sector j in country n obey the law of gravity. That is, after some algebra which we detail below we can rewrite (3.21) as

$$VA_{i.n}^{k,j} = \frac{\beta_i^k Y_i^k I_n^j}{Y_w^k} \frac{\sigma_{in}^{k,j}}{P_n^j \, \Pi_i^k}.$$
(3.22)

Bilateral value added flows on the source sector-demand sector level are proportional to the economic mass of the importing sector I_n^j and the economic mass of the producing sector $\beta_i^k Y_i^k = V A_i^k$, the producer's export price index Π_i^k , the importer's import price index P_n^j and a weighted trade cost term $\sigma_{i,n}^{k,j}$ that summarizes the trade cost associated with all possible travel routes through which value added reaches n.

While Equation (3.22) nicely relates value added trade to the concept of economic gravity, it is of relatively little use empirically. Still, we think that it has something important to say about how not to run gravity-type regressions with value added trade flows. First, the dependent variable on the left-hand side is typically not observed, but rather computed following the very same logic that we used to derive Equation (3.22). Second, the weighted trade cost term $\sigma_{i,n}^{k,j}$ on the right-hand side is not observed either. Constructing it according to its explicit from (derived below) and using constructed value added flows on the left-hand side will lead to a fit that is perfect by construction. Moreover, Equation (3.22) implies that gravity in this simple form—that is, the log-linearity of value added trade flows in economic masses and a trade cost term—is lost as we sum across sectors to get value added flows on the aggregate bilateral level. This implies that gravity-type regressions of aggregate bilateral value added flows on economic size, distance, FTAs and other gravity variables, as it is now done in many studies, do not yield consistent estimates. Except for a few very special cases.⁸ Hence, we advocate a structural approach to

⁸One might argue that this conclusion depends very much on the functional form assumptions that we make in the model, but note that the key assumption used to derive Equation (3.22) (proportionality of source countries' import shares across demanding sectors) is identical to the assumption imposed on the data to generate bilateral input-output tables in the first place.

assessing the impact of fundamentals or policy variables on value added trade as shown in the previous subsection for the case of tariffs.

To derive (3.22), it proves helpful to define modified Leontief coefficients which contain only the output value generated in intermediate goods production. Let $b_{ih}^{k,j}$ be any Leontief coefficient, that is, any element of $\mathbf{B} = (\mathbf{I} - \mathbf{A})^{-1} = \sum_{k=0}^{\infty} \mathbf{A}^k$ and denote with $\tilde{b}_{ih}^{k,j}$ the corresponding element of $\tilde{\mathbf{B}} = \sum_{k=1}^{\infty} \mathbf{A}^k$. Then,

$$b_{ih}^{k,j} = \tilde{b}_{ih}^{k,j} \qquad \text{if} \qquad i \neq h \lor k \neq j$$
$$b_{ih}^{k,j} = \tilde{b}_{ih}^{k,j} + 1 \qquad \text{if} \qquad i = h \land k = j$$

 $\tilde{b}_{ih}^{k,j}$ is the output created through *intermediate* goods production per unit of final goods output. This is identical to the Leontief coefficient if the demanding and supplying sectors are not identical (or not in the same country), because in those cases all output generated in the supplying sector through final goods production of the demanding sector must be through intermediates production. If the two sectors are identical, then the value of the final good itself is included in $b_{ih}^{k,j} = b_{ii}^{k,k}$, given by the 1 that is added to $\tilde{b}_{ih}^{k,j}$.

With the help of those modified Leontief coefficients, the explicit form of b can be rewritten as

$$b_{ih}^{k,j} = \mathcal{I}_{[j=k,h=i]} + a_{ih}^{k,j} + \sum_{\ell_1=1}^{J} \sum_{h_1=1}^{N} a_{ih_1}^{k,\ell_1} a_{h_1h}^{\ell_1,j} + \sum_{\ell_1=1}^{J} \sum_{h_1=1}^{N} \sum_{\ell_2=1}^{J} \sum_{h_2=1}^{N} a_{ih_1}^{k,\ell_1} a_{h_1h_2}^{\ell_1,\ell_2} a_{h_2h}^{\ell_2,j} + \sum_{\ell_1=1}^{J} \sum_{h_1=1}^{N} \sum_{\ell_2=1}^{J} \sum_{h_2=1}^{N} \sum_{h_2=1}^{J} \sum_{h_3=1}^{N} a_{ih_1}^{k,\ell_1} a_{h_1h_2}^{\ell_1,\ell_2} a_{h_2h_3}^{\ell_2,\ell_3} a_{h_3h}^{\ell_3,j} + \dots$$

$$= \mathcal{I}_{[j=k,h=i]} + a_{ih}^{k,j} + \sum_{h_1=1}^{N} \sum_{\ell_1=1}^{J} a_{ih_1}^{k,\ell_1} \cdot \tilde{b}_{h_1,h}^{\ell_1,j}$$

$$(3.23)$$

This expression sheds light on the sources of heterogeneity in the value added content contributed by various source countries by extracting a large part of $b_{ih}^{k,j}$ which is actually common to all of them. Comparing two source countries i, i_2 (within in the same sector k) shows, that sector j in h c.p. uses more value added (output) from i if (i) the direct input coefficient is larger $a_{ih}^{k,j} > a_{i_2h}^{k,j}$, which boils down to i being more competitive than i_2 ($\tilde{\pi}_{ih}^k > \tilde{\pi}_{i_2h}^k$), and (ii) if i has larger trade shares with third countries h_1 that are important intermediate sources for country h (large $\tilde{b}_{h_1,h}^{\ell_1,j}$). While $\tilde{b}_{h_1,h}^{\ell_1,j}$ is of course as much a black box as $b_{i,h}^{k,j}$, here it affects all source countries in the same way (does not depend on i). The intuition is as follows: Once an intermediate good from i has reached the third country h_1 , it is treated in exactly the same way as an intermediate good from

 i_2 as regards the further travel route. $\tilde{b}_{h_1,h}^{\ell_1,j}$ summarizes all the higher order travel routes common to all intermediates (from sector k) once they have reached country h_1 . In other words, how much value added of source i is processed e.g. in China, relative to another source i_2 , depends only on how much i sends to China *directly* and how strong is the *direct* connection of i with other countries that are important sources for China.

Denoting total final goods expenditure on goods j in n by $I_n^j = \alpha_n^j I_n$, we can rewrite (3.21) using (3.23) as

$$VA_{i.n}^{k,j} = \beta_i^k I_n^j \left(\mathcal{I}_{[j=k]} \cdot \tilde{\pi}_{in}^j + \sum_h a_{ih}^{k,j} \tilde{\pi}_{hn}^j + \sum_{h=1}^N \sum_{h_1=1}^N \sum_{\ell_1=1}^J a_{ih_1}^{k,\ell_1} \cdot \tilde{b}_{h_1,h}^{\ell_1,j} \cdot \tilde{\pi}_{hn}^j \right)$$
(3.24)

Using $a_{in}^{k,j} = \tilde{\pi}_{in}^k \tilde{\gamma}_n^{k,j}$ where $\tilde{\gamma}_n^{k,j} = \gamma_n^{k,j} (1 - \beta_n^j)$, $\tilde{\pi}_{in}^k = \frac{\pi_{in}^k}{\tilde{\tau}_{in}^k}$ where $\tilde{\tau}_{in}^k = 1 + \tau_{in}^k$ and $\pi_{in}^k = \frac{\lambda_i^k (c_i^k \kappa_{in}^k)^{-\frac{1}{\theta_k}}}{P_n^k}$ with $P_n^k = 1/A^k (p_n^k)^{-\frac{1}{\theta_k}} = \sum_i \lambda_i^k (c_i^k \kappa_{in}^k)^{-\frac{1}{\theta_k}}$, we can rewrite (3.24) as

$$VA_{i,n}^{k,j} = \frac{\beta_i^k I_n^j}{P_n^j} \lambda_i^k (c_i^k)^{-\frac{1}{\theta_k}} \left(\mathcal{I}_{[j=k]} \cdot (\kappa_{in}^j)^{-\frac{1}{\theta_j}} (\tilde{\tau}_{in}^j)^{-1} + \sum_{h=1}^{\infty} \frac{(\kappa_{ih}^k)^{-\frac{1}{\theta_k}} (\tilde{\tau}_{ih}^k)^{-1} \cdot \tilde{\gamma}_h^{k,j} \cdot (\kappa_{hn}^j)^{-\frac{1}{\theta_j}} (\tilde{\tau}_{hn}^j)^{-1}}{P_h^k} \lambda_h^j (c_h^j)^{-\frac{1}{\theta_j}} + \sum_{h=1}^N \sum_{h_1=1}^N \sum_{\ell_1=1}^J \frac{(\kappa_{ih_1}^k)^{-\frac{1}{\theta_k}} (\tilde{\tau}_{ih_1}^k)^{-1} \cdot \tilde{\gamma}_{h_1}^{k,\ell_1} \cdot \tilde{b}_{h_1h}^{\ell_1,j} \cdot (\kappa_{hn}^j)^{-\frac{1}{\theta_k}} (\tilde{\tau}_{ih_1}^j)^{-\frac{1}{\theta_j}}}{P_{h_1}^k} \lambda_h^j (c_h^j)^{-\frac{1}{\theta_j}} \lambda_h^j (c_h^j)^{-\frac{1}{\theta_j}} \right)$$
(3.25)

Market clearing requires in each country and sector that production equals total sales, that is, $Y_i^k = \sum_{n=1}^N \tilde{\pi}_{in}^k X_n^k = \lambda_i^k (c_i^k)^{-\frac{1}{\theta_k}} \sum_{n=1}^N \frac{(\kappa_{in}^k)^{-\frac{1}{\theta_k}}(\tilde{\tau}_{in}^k)^{-1}}{P_n^k} X_n^k$. Let $Y_w^k = \sum_i Y_i^k$ denote world production of sector k goods. Solving for $\lambda_i^k (c_i^k)^{-\frac{1}{\theta_k}}$ then yields

$$\lambda_{i}^{k}(c_{i}^{k})^{-\frac{1}{\theta_{k}}} = \frac{Y_{i}^{k}}{Y_{w}^{k}} \frac{1}{\Pi_{i}^{k}} \qquad \text{where} \qquad \Pi_{i}^{k} = \sum_{n=1}^{N} \frac{(\kappa_{in}^{k})^{-\frac{1}{\theta_{k}}} (\tilde{\tau}_{in}^{k})^{-1}}{P_{n}^{k}} \frac{X_{n}^{k}}{Y_{w}^{k}} \tag{3.26}$$

(cp. Eaton & Kortum, 2002) and

$$\tilde{\pi}_{in}^{k} = \frac{(\kappa_{in}^{k})^{-\frac{1}{\theta_{k}}} (\tilde{\tau}_{in}^{k})^{-1}}{\Pi_{i}^{k} P_{n}^{k}} \frac{Y_{i}^{k}}{Y_{w}^{k}} \qquad \text{where} \qquad P_{n}^{k} = \sum_{i=1}^{N} \frac{(\kappa_{in}^{k})^{-\frac{1}{\theta_{k}}} (\tilde{\tau}_{in}^{k})^{-1}}{\Pi_{i}^{k}} \frac{Y_{i}^{k}}{Y_{w}^{k}}.$$

Inserting (3.26) into (3.25), we finally arrive at

$$VA_{i,n}^{k,j} = \beta_i^k \frac{I_n^j Y_i^k}{Y_w^k} \frac{1}{P_n^j \Pi_i^k} \left(\mathcal{I}_{[j=k]} \cdot (\kappa_{in}^j)^{-\frac{1}{\theta_j}} (\tilde{\tau}_{in}^j)^{-1} + \sum_h \frac{(\kappa_{ih}^k)^{-\frac{1}{\theta_k}} (\tilde{\tau}_{ih}^k)^{-1} \cdot \tilde{\gamma}_h^{k,j} \cdot (\kappa_{hn}^j)^{-\frac{1}{\theta_j}} (\tilde{\tau}_{hn}^j)^{-1} \frac{Y_h^j}{Y_w^j}}{P_h^k \Pi_h^j} + \sum_{h=1}^N \sum_{h_1=1}^N \sum_{\ell_1=1}^J \frac{(\kappa_{ih_1}^k)^{-\frac{1}{\theta_k}} (\tilde{\tau}_{ih_1}^k)^{-1} \cdot \tilde{\gamma}_{h_1}^{k,\ell_1} \cdot \tilde{b}_{h_1h}^{\ell_1,j} \cdot (\kappa_{hn}^j)^{-\frac{1}{\theta_j}} (\tilde{\tau}_{hn}^j)^{-1} \frac{Y_h^j}{Y_w^j}}{P_{h_1}^k \Pi_h^j} \right)$$
(3.27)

Denoting the trade cost term (the expression in parentheses) with $\sigma_{in}^{k,j}$ and rewriting it slightly yields Equation (3.22) with

$$\begin{aligned} \sigma_{in}^{k,j} &= \mathcal{I}_{[j=k]} \cdot (\kappa_{in}^{j})^{-\frac{1}{\theta_{j}}} (\tilde{\tau}_{in}^{j})^{-1} + \sum_{h} \frac{(\kappa_{hn}^{j})^{-\frac{1}{\theta_{j}}} (\tilde{\tau}_{hn}^{j})^{-1}}{\Pi_{h}^{j}} \frac{Y_{h}^{j}}{Y_{w}^{j}} \times \\ & \times \left(\frac{(\kappa_{ih}^{k})^{-\frac{1}{\theta_{k}}} (\tilde{\tau}_{ih}^{k})^{-1} \cdot \tilde{\gamma}_{h}^{k,j}}{P_{h}^{k}} + \sum_{h_{1}=1}^{N} \sum_{\ell_{1}=1}^{J} \frac{(\kappa_{ih_{1}}^{k})^{-\frac{1}{\theta_{k}}} (\tilde{\tau}_{ih_{1}}^{k})^{-1} \cdot \tilde{\gamma}_{h_{1}}^{k,\ell_{1}} \cdot \tilde{b}_{h_{1}h}^{\ell_{1},j}}{P_{h_{1}}^{k}} \right) \end{aligned}$$

The first term on the right-hand side denotes the effect of the direct trade barrier between the source and the exporter. It matters only for value added generated directly in sector k's production of final goods for n. All other value added from the source sector that reaches n must be embodied in intermediates that enter final goods production for n in a third country h. Note that the set of third countries h = 1, ..., N includes the source country itself, as well as the destination country. Hence, country h's trade cost with nrelative to country h's export price index matter for the source sector in i. The relative importance of h enters through weights given by the relative size of h's sector j. The two terms in parentheses capture the trade barriers that inhibit access to the third country h's final goods producers directly (first term in parentheses) and indirectly via fourth countries h_1 and all other sectors ℓ_1 (second term). As discussed above, all higher order travel routes starting in h_1 are the same for all source countries and are summarized in the $\tilde{b}_{h_1h}^{\ell_1,j}$'s. Trade barriers are considered relative to the importer's import price index and weighted by the cost share of the source sector in the demanding sector's production $\tilde{\gamma}_{h}^{k,j} = (1 - \beta_h^k) \gamma_h^{k,j}$ and $\tilde{\gamma}_{h_1}^{\ell_1,j} = (1 - \beta_{h_1}^j) \gamma_{h_1}^{\ell_1,j}$.

Note that if we shut down intermediate goods linkages (set $\beta_i^k = 1 \forall k, i$), we arrive at the standard sectoral gravity equation that is identical for gross trade and value added trade. $\beta = 1 \forall k, i$ implies that $\tilde{\gamma}_h^{k,j} = 0$ and $\tilde{\gamma}_{h_1}^{\ell_1,j} = 0$. Hence, the only non-zero value added flows are direct flows through final goods imports when source and demanding sectors are identical. That is, $VA_{i,n}^{k,j} = 0$ if $j \neq k$, as can be seen by noting that $\sigma = 0$ for $j \neq k$. For j = k, the only trade costs that matter are direct trade costs $\mathcal{I}_{[j=k]} \cdot (\kappa_{in}^j)^{-\frac{1}{\theta_j}}$.

3.2.6 Decomposition of Exports into Value Added Components

The total value of a country's exports consists of domestic value added, value added generated in other countries that is re-exported, and some double-counting of those values associated with multiple border crossings by the same piece of value added. The value of the latter is a pure statistical artifact. We use the methodology developed by Koopman et al. (2014) to decompose a country's exports as follows.

$$\mathbf{1} \cdot \mathbf{EX}_{i} = \underbrace{\boldsymbol{\beta}_{i} \sum_{n \neq i}^{N} \mathbf{B}_{ii} \mathbf{C}_{in} + \boldsymbol{\beta}_{i} \sum_{n \neq i}^{N} \mathbf{B}_{in} C_{nn} + \boldsymbol{\beta}_{i} \sum_{n \neq i}^{N} \sum_{m \neq i,n}^{N} \mathbf{B}_{in} \mathbf{C}_{nm}}_{i' \text{s VA consumed in } n \neq i \text{ or passed on to } m \neq i,n}}$$

$$+ \underbrace{\boldsymbol{\beta}_{i} \sum_{n \neq i}^{N} \mathbf{B}_{in} \mathbf{C}_{ni} + \boldsymbol{\beta}_{i} \sum_{n \neq i}^{N} \mathbf{B}_{in} \mathbf{A}_{ni} (\mathbf{I} - \mathbf{A}_{ii})^{-1} \mathbf{C}_{ii}}_{i' \text{s VA returning home}}}$$

$$+ \underbrace{\sum_{n \neq i}^{N} \sum_{m \neq i}^{N} \boldsymbol{\beta}_{m} \mathbf{B}_{mi} \mathbf{C}_{in} + \sum_{n \neq i}^{N} \sum_{m \neq i}^{N} \boldsymbol{\beta}_{m} \mathbf{B}_{mi} \mathbf{A}_{in} (\mathbf{I} - \mathbf{A}_{nn})^{-1} \mathbf{C}_{nn}}_{\text{Foreign VA in i's exports}}}$$

$$+ \underbrace{\boldsymbol{\beta}_{i} \sum_{n \neq i}^{N} \mathbf{B}_{in} \mathbf{A}_{ni} (\mathbf{I} - \mathbf{A}_{ii})^{-1} \mathbf{EX}_{i} + \sum_{m \neq i}^{N} \boldsymbol{\beta}_{m} \mathbf{B}_{mi} \sum_{n \neq i}^{N} \mathbf{A}_{in} (\mathbf{I} - \mathbf{A}_{nn})^{-1} \mathbf{EX}_{n},$$
Pure double counting
$$(3.28)$$

where **1** is a unity vector and EX_i is a vector that collects country *i*'s total sectoral exports. $\boldsymbol{\beta}_i$ is a $J \times J$ diagonal matrix with diagonal elements corresponding to country *i*'s sectoral value added coefficients β_i^k .

The first three terms in Equation (3.28) is country *i*'s value added exports to other countries, that is, value added from country *i* that is consumed in other countries $n \neq i$. This is identical to the value added flows in Equations (3.17) and (3.20), when summing over destination countries $n \neq i$. The second line represents value added generated in country *i* that first leaves the country in the form of intermediate goods but is eventually re-imported (as final or intermediate good) and consumed in *i*. These flows show up in country *i*'s export statistic but do not constitute value added exports. The third line shows the part of country i's export value that is foreign value added, embodied either in final or in intermediate goods exports. The last line shows value added (originating either in the home country or in the foreign country) that appears several times in i's export statistic.

This decomposition also helps categorize countries according to their engagement in production fragmentation. For countries heavily involved in the global value chain we expect double-counting to be relatively more important. A country's position in the global value chain is indicated by the importance of final, compared to intermediate, value added exports. The more upstream a country's position in the value chain, the more important are domestic value added exports (the first term in Equation (3.28)) compared to value added re-imports and foreign value added exports (second and third terms in Equation (3.28), respectively). With the help of the model, we are able to do counterfactual analyses of those quantities and their relative importance in order to assess how a country's position in the global value chain is affected by trade liberalization.

3.3 Production Networks

Countries can multiply the gains from specialization in production by relocating production stages across borders. In addition to trade costs, geography, and sectoral productivity differences, which shape the pattern of trade in final goods, intersectoral linkages are the key determinants of trade flows along the value chain. The input-output-based view on interlinkages has advantages and disadvantages, however. Leontief coefficients provide a measure of the depth of a production relationship, taking into account all possible linkages between countries, and thus capture all countries' relative productivity differences and geographical characteristics. However, by summarizing all indirect production relationships, the method does not allow for a step-by-step analysis of all sequential production stages.⁹ Nor can it capture differences in the structure of the value chain, as discussed by Baldwin and Venables (2013).¹⁰ With these limitations in mind, we propose a measure that

⁹As Koopman et al. (2014) and Wang et al. (2013) propose, we can decompose a country's export separately for goods differentiated by their purpose in the destination country. Yet, due to the assumption inherent to the input-output analysis that within each sector the technologies for production of final and intermediate goods are identical, differences between the value added content of final and intermediate goods flows are exclusively due to differences in the demand structure.

¹⁰These authors highlight the importance of engineering details of the production process for the effect of a decrease in trade costs on trade flows and location decisions. They describe two extreme cases, one in which production takes place in a chain of subsequent steps (a "snake" in their terminology), the other in a two-stage process in which a number of intermediate goods are produced independently in a first step and assembled into one final good in the second stage (a "spider"). Our model has features of both

can be used to identify production networks. The measure is based on the relationship between a source sector in one country, which we call the upstream sector, and a final goods producing downstream sector in another country. All the intermediate travel routes, including the second to last location from which the downstream sector imports the upstream sectors' value added, enter through the Leontief coefficients.

The total value added from upstream sector k that is processed into a final good by the downstream sector j in country h and from there exported to the world or consumed in h can be obtained by summing up the expression for value added flows in Equation (3.16) over destination countries n

$$\widetilde{VA}_{ih}^{k,j} = \beta_i^k \widetilde{b}_{ih}^{k,j} \pi_{hW}^j C_W^j, \qquad (3.29)$$

where $\pi_{hW}^{j} = \sum_{n}^{N} \frac{C_{hn}^{j}}{C_{W}}$ is processing country *h*'s share in world demand for final goods from sector *j*. Note that we use the modified Leontief coefficients $\tilde{b}_{ih}^{k,j}$ as defined in Section 1.33 that do not include value added generated in final goods production.

To evaluate the intensity of such a value added trade relationship, we can focus on either the upstream or the downstream industry, which is tied to the source country of value added, or to the final goods producing country. Furthermore, we can look at the value added trade relationship from either the demand side or the supply side by comparing any flow given by Equation (3.29) to the total value from the upstream sector that is processed elsewhere, or to the total value added processed by the downstream sector. We call the former a "demand network" and the latter a "supply network."

3.3.1 Supply Networks

We first look at a supply network and focus on the downstream sector j_d . Sector j_d uses value added from all upstream sectors in country *i* to produce final goods for the world. We define such a value added trade relationship between j_d in *h* and all sectors *k* in country *i* as intense if the share of value added from country *i* processed by j_d relative to the total value added from all sources that j_d processes is large. This measure is given by

$$\frac{\widetilde{VA}_{ih}^{J_d}}{\widetilde{VA}_{.h}^{J_d}} = \sum_{k=1}^J \frac{\beta_i^k \widetilde{b}_{ih}^{k,j_d}}{\sum_i^N \sum_k^J \beta_i^k \widetilde{b}_{ih}^{k,j_d}},\tag{3.30}$$

processes. Varieties are assembled to sectoral composites in a spider-like process, but since composites are used as intermediates for variety production, a change in the range of varieties sourced from one country has a direct impact on the varieties sourced from other countries. A true spider-like process is instead characterized by independent intermediate production processes.

where $\tilde{b}_{ih}^{k,j} = b_{ih}^{k,j} - 1 \times \mathcal{I}[j = k \wedge n = i]$.¹¹ This transformed Leontief coefficient $\tilde{b}_{ih}^{k,j}$ is free of the direct output generated by final goods demand.¹²

We can decompose this measure into two terms, each highlighting a different aspect of such a supply network:

$$\frac{\widetilde{VA}_{ih}^{Jd}}{\widetilde{VA}_{.h}^{jd}} = \sum_{k}^{J} \pi_{ih}^{k,j_d,VA} \cdot \gamma_h^{k,j_d,VA}, \quad \text{where} \tag{3.31}$$

$$\pi_{ih}^{k,j_d,VA} = \frac{\beta_i^k \widetilde{b}_{ih}^{k,j_d}}{\sum_i^N \beta_i^k \widetilde{b}_{ih}^{k,j_d}} \quad \text{and} \quad \gamma_h^{k,j_d,VA} = \frac{\sum_i^N \beta_i^k \widetilde{b}_{ih}^{k,j_d}}{\sum_k^J \sum_i^N \beta_i^k \widetilde{b}_{ih}^{k,j_d}}$$

The first term captures country *i*'s share of value added used by j_d and originating in sector k. We call it $\pi_{ih}^{k,j,VA}$ to highlight the conceptual similarity of this value added-based import share to the import trade share π_{ih}^k . $\pi_{ih}^{k,j,VA}$ is a measure of country *i*'s competitiveness relative to other countries that send value added from sector k to h. Note, however, that due to different production technologies across demand sectors, $\pi_{ih}^{k,j,VA}$ varies across j. The second term, $\gamma_h^{k,j,VA}$, is conceptually similar to the input cost share $\gamma_n^{k,j}$. It denotes the share of value added from sector k (from all source countries) in the total amount of value added from all sectors processed by j_d , and hence measures the importance of sector k for j_d in terms of value added. Using the fact that $\overline{x \cdot y} = \overline{x} \cdot \overline{y} + cov(x, y)$ for $\overline{x} = \frac{1}{J} \sum_{j}^{J} x_j$ we can rewrite Equation (3.31) as

$$\frac{\widetilde{VA}_{ih}^{,j_d}}{\widetilde{VA}_{.h}^{,j_d}} = \frac{1}{J} \sum_{k}^{J} \pi_{ih}^{k,j_d,VA} + J \cdot Cov \left[\pi_{ih}^{k,j_d,VA}, \gamma_h^{k,j_d,VA} \right]$$
(3.32)

to highlight two distinct aspects of a strong supply network as we define it. First, the value added trade relationship is stronger if country i is more competitive, on average, in supplying value added to country h. Second, the relationship will be particularly strong if country i is competitive in those sectors k that are used intensively by sector j_d , as measured by the covariance. Standardization by the product of the standard deviations of π^{VA} and γ^{VA} makes this measure of complementarity comparable across sectors, countries, and time.

Based on the World Input-Output Database we can compute the supply network measure and its components for all countries and sectors at various points in time. Here, we

¹¹Dots in subscripts and superscripts indicate that we have summed up over the respective dimension.

¹²Note that $\sum_k \sum_i \tilde{b}_{ih}^{k,j}$ equals the total output from other sources (including intermediates from sector j in country h) that are used for one unit of sector j's final goods production, while $\sum_k \sum_i b_{ih}^{k,j}$ also includes the direct output value per unit of final goods production.



Figure 3.1: Supply networks with China, 2000

Note: The figure plots the measure of supply networks as given in Equation (3.30) (upper panel) and the correlation coefficient corresponding to the covariance in Equation (3.32) (lower panel). Calculations based on WIOD. Sectors on x-axis in Isic Rev. 3.

focus on China and the period 2000 to 2007, as we will later seek to quantify the contribution of China's WTO entry to observed changes in the production network structure.

Figure 3.1 shows the supply network measure (Equation (3.30)) in the upper panel and the correlation coefficient as implied by Equation (3.32) in the lower panel for a selection of downstream sectors in China. The gray bars capture the maximum size of the network measure of 90% of all sourcing countries; Japan, Korea, and the United States are shown explicitly. In the upper panel, each dot indicates the share of the respective source country in the total value added processed by the respective downstream sector in China. It is apparent that Japan was a major source of value added for almost all sectors in 2000. In fact, with an average share of about 3% across sectors, Japan was the third most important value added source, following China (78%) and the rest-of-the-world aggregate (4%) (not shown). Korea ranked fourth with an average share of 1.5%. The United States is in the middle of the distribution of countries, but tends to have slightly higher shares in the service sectors.

The lower panel presents for each of the networks the degree of complementarity between the relative importance of the source sectors for the downstream sector in China and the competitiveness of the source country in those sectors. As the 90% range indicates, most source countries exhibit a negative correlation. A strongly positive correlation



Figure 3.2: Supply networks with China, change 2000 – 2007

Note: The figure plots changes in the supply networks as given in Equation (3.30) (upper panel) and the correlation coefficient corresponding to the covariance in Equation (3.32) (in units, lower panel). Calculations based on WIOD. Sectors on x-axis in Isic Rev. 3.

exists for China itself.¹³ Some foreign source countries stand out: Korea exhibits strong complementarities with the textiles (Isic 17t18) and leather (19t20) sectors, as well as in manufacturing of optical equipment (30t33) and the service industry supplying business activities (71t74). In the latter two sectors, we find strong complementarities for Japan as well, which otherwise, like the United States, ranges in the middle of the distribution of all source countries.

Figure 3.2 displays the change in the supply networks and the measure of complementarity from 2000 to 2007. As shown in the upper panel, the majority of countries gained shares in the value added processed by China's final goods producing sectors. Generally, this was achieved at the expense of China's own share, which decreased in all sectors except for textiles (17t18) and leather (19t20).¹⁴ We also find that the United States significantly increased its share in almost all sectors, whereas for Korea this was the case only in the sectors producing machinery (29), optical and electronic equipment (30t33),

¹³This pattern of high complementarity of domestic sectors is consistent across all countries in the sample and is chiefly due to the restricted tradability of services, which are intensively used inputs in many downstream sectors.

¹⁴For expositional purposes China is not shown in the upper panel of Figure 3.2. The negative changes range between -3 and -10 percentage points.

and transport equipment (34t35), as well as for a few service sectors. Korea lost a significant share (2 percentage points) in the textiles (17t18) and leather (19t20) industries. Japan, which was a major source of foreign value added in 2000, lost value added shares in almost all sectors, with the exception of transport equipment (34t35) and some of the service sectors, most prominently those associated with transportation (60 – 62).

The lower panel of Figure 3.2 shows that Japan's and Korea's gains in value added shares in the transport equipment sectors were accompanied by an increase in complementarity. This implies that these countries gained relatively more in sectors that are important inputs for transport equipment producers in China. The figure also reveals that Korea's loss in value added shares in China's textiles and leather industry was accompanied by a strong decline in the degree of complementarity, which initially had been exceptionally high.

3.3.2 Demand Networks

Next, we look at a demand network of the upstream sector k_u with all final goods producing sectors in country h. We define this sort of value added trade relationship as intense if the share of k'_u s value added processed in country h (by any sector) relative to the total value added from k_u processed elsewhere is large. This measure is given by

$$\frac{\widetilde{VA}_{ih}^{k_{u.}}}{\widetilde{VA}_{i.}^{k_{u.}}} = \sum_{j=1}^{J} \frac{\widetilde{b}_{ih}^{k_{u.j}j} \pi_{h,W}^{j} C_{W}^{j}}{\sum_{h}^{N} \sum_{j}^{J} \widetilde{b}_{ih}^{k_{u.j}j} \pi_{h,W}^{j} C_{W}^{j}}.$$
(3.33)

Analogously to the supply network, we can decompose Equation (3.33) into two components

$$\frac{\widetilde{VA}_{ih}^{k_{u.}}}{\widetilde{VA}_{i.}^{k_{u.}}} = \sum_{j=1}^{J} s_{ih}^{k_{u,j}} \cdot r_i^{k_{u,j}}, \quad \text{where} \quad (3.34)$$

$$\widetilde{b}_{ih}^{k_{u,j}} \pi_{h,W}^{j} \qquad \text{and} \quad \sum_{k=1}^{N} \widetilde{b}_{ih}^{k_{u,j}} \pi_{h,W}^{j} C_{W}^{j}$$

$$s_{ih}^{k_{u},j} = \frac{b_{ih}^{k_{u},j}\pi_{h,W}^{J}}{\sum_{h}^{N}\tilde{b}_{ih}^{k_{u},j}\pi_{h,W}^{J}} \quad \text{and} \quad r_{i}^{k_{u},j} = \frac{\sum_{h}^{N}b_{ih}^{k_{u},j}\pi_{h,W}^{J}C_{W}^{J}}{\sum_{j}^{J}\sum_{h}^{N}\tilde{b}_{ih}^{k_{u},j}\pi_{h,W}^{j}C_{W}^{j}}.$$

Here, the first component $s_{ih}^{k_u,j}$ denotes a value added export share, that is, country h's share in total value added from sector k_u that is processed by sector j in any country. This depends on how large a trade share country h has in world final goods consumption and how much output this generates in sector k_u relative to all other final goods producers. The second term captures the importance of sector j for sector k_u from a demand perspective. More specifically, r_{ih}^j is the share of sector j inputs in total value added from sector k_u that



Figure 3.3: Demand networks with China, 2000

Note: The figure plots demand networks as given in Equation (3.33) (upper panel) and the correlation coefficient corresponding to the covariance in Equation (3.35) (lower panel). Calculations based on WIOD. Sectors on x-axis in Isic Rev. 3.

is processed in final goods consumption by all sectors in all countries. As for the supply network, we can distinguish between two determinants of demand network strength based on

$$\frac{\widetilde{VA}_{ih}^{k_u.}}{\widetilde{VA}_{i.}^{k_u.}} = \frac{1}{J} \sum_{j}^{J} s_{ih}^{k_u,j} + J \cdot Cov \left[s_{ih}^{k_u,j}, r_i^{k_u,j} \right].$$
(3.35)

This decomposition shows that the value added trade relationship is strong if country h is an important destination for country i on average, and particularly strong if, on average, country h captures a large share of sector k_u 's value added in sectors that absorb a large share of value added from sector k_u due to either technological reasons or to high demand for this sector's final goods.

We now describe demand networks with China. A demand network, as defined in Equation (3.33), captures the relative importance of a final goods producing country, here China, for an upstream sector in a specific source country. The upper panel of Figure 3.3 shows that in 2000, for most countries, China was an important location for processing value added from the textiles (17t18) and leather (19t20) sectors, as well as from chemical products (24) and electronic and optical equipment (30t33), into final goods. It also shows the remarkable importance of China as a final goods producer for



Figure 3.4: Demand networks with China, change 2000 – 2007

Note: The figure plots changes in supply networks as given in Equation (3.33) (upper panel) and the correlation coefficient corresponding to the covariance in Equation (3.35) (in units, lower panel). Calculations based on WIOD. Sectors on x-axis in Isic Rev. 3.

Korean upstream sectors. With an average share of 5% across sectors, Korea was in fact the country relying most heavily on processing in China, followed by Indonesia and Australia, both having shares of about 2.5%. Japan is found in the middle or at the lower end of the distribution of source countries in most sectors, except for textiles (17t18), metals (27t28) and electrical and optical equipment (30t33), in which sectors its reliance on China as a final goods producer was relatively strong.

The lower panel of Figure 3.3 reveals that the complementarities in demand networks are similar to those found for supply networks. Chinese upstream sectors exhibit strong complementarities with the sourcing structures of its downstream sectors, while for the upstream sectors in foreign countries, the correlation tends to be negative. This suggests that China's reliance on domestic value added from the upstream sectors that are intensively used in important final goods industries was still relatively high. The limited tradability of service sectors plays a crucial role here as well. Figure 3.4 shows the changes in the demand networks and in complementarity. Between 2000 and 2007, China's importance as a processing location grew for almost all countries and in almost all sectors. The electronic and optical equipment sector (30t33), as well as the machinery sector (29), are particularly noteworthy in this regard. Furthermore, we find that for both Japan and Korea, reliance on China increased particularly strongly for most sectors. China lost importance for Korea's value added from the textiles (17t18) and leather (19t20) sectors. The figure's lower panel shows increasing complementarity between foreign source sectors and the demand structure of China's final goods sectors. This means, for example, that for the electrical and optimal equipment sector, stronger reliance on China as a processing location was particularly pronounced in sectors that use relatively more electrical and optical equipment as an input to production.

The deepening of networks with China suggests that China's integration into the global economy brought about a shift toward more foreign value in Chinese final goods and towards all countries processing relatively more value added in China than elsewhere. Moreover, the increase in the complementarity measures indicates a change in the relative supply structure toward more competitive sources and a change in the relative demand structure toward more competitive final goods sectors. These findings highlight the scope for gains achievable from specialization along the global value chain and, furthermore, illustrate that cross-sectoral dependencies play a crucial role in understanding how structural changes affect countries' relative competitiveness and how the effects of trade policy spread across all countries involved in global production sharing.

Before we evaluate China's accession to the WTO by means of a counterfactual experiment, we first describe our data sources and how we identify the parameters of the model.

3.4 Data and Parameter Identification

To simulate the effects of changes in tariffs, we need to identify the model parameters α , β , γ , and θ , and collect data on bilateral trade shares, tariff levels, countries' total value added, and trade surpluses. The expenditure shares α and the cost shares β and γ are obtained from input-output tables. θ is estimated as a trade cost elasticity based on a structural equation that follows from the model. We obtain an alternative set of estimates based on a standard gravity equation.

3.4.1 Data Sources

Our main data source is the World Input-Output Database (WIOD), which provides harmonized international input-output tables as well as production values, final and intermediate goods trade, and consumption by use categories. The database contains data for 40 countries (mainly members of the OECD) and a rest-of-the-world aggregate (RoW) for the years 1995-2011, with a sectoral breakdown at roughtly the two-digit level of ISIC, resulting in 35 industries.¹⁵ The WIOD contains information on trade by sector, including services industries. The WIOD does not have information on actual bilateral input-output coefficients. These coefficients are imputed from national input-output tables based on a proportionality assumption. Accordingly, a sector's usage of a certain intermediate input is split between trade partners according to their respective shares in total intermediate goods imports. See Timmer (2012) for an in-depth description of methods and assumptions used to construct the WIOD.

Data on bilateral tariffs for manufacturing sectors are taken from UNCTAD's TRAINS database.¹⁶ We use effectively applied tariffs at the six-digit level of the Harmonized System goods classification and aggregate them to the WIOD sectoral level using import values as weights. Other trade cost variables for our auxiliary gravity estimation, that is, bilateral distance and a dummy for contiguity, are obtained from the CEPII database. A FTA dummy is constructed based on the RTA database of the WTO.

3.4.2 Identification of Sectoral Productivity Dispersion

The sectoral productivity dispersion parameters are identified with the method proposed by Caliendo and Parro (2015). The estimation equation is based on a structural expression for gross trade flows derived from the model. By dividing a country-pair's trade flow with trade flows of other trade partners, importer, exporter, and pair-specific symmetric effects are canceled out. The corresponding estimation equation is

$$\ln \frac{X_{in}^j X_{hi}^j X_{nh}^j}{X_{ni}^j X_{ih}^j X_{hn}^j} = -\frac{1}{\theta^j} \ln \left(\frac{\tau_{in}^j \tau_{hi}^j \tau_{nh}^j}{\tau_{ni}^j \tau_{ih}^j \tau_{hn}^j} \right) + \varepsilon_{inh}^j, \qquad (3.36)$$

 $^{^{15}\}mathrm{Due}$ to lack of tariff data for Taiwan, we merge it with RoW and are thus left with 39 countries plus the RoW aggregate.

¹⁶The database can be accessed via the World Bank's World Integrated Trade Solution (WITS) project, https://wits.worldbank.org/WITS/WITS/Restricted/Login.aspx?AspxAutoDetectCookieSupport=1.

where ε_{inh}^{j} is an i.i.d. error term. Identification rests on the assumption that unobserved trade costs are exogenous to tariffs after differencing out all importer-sector-, exporter-sector-, and importer-exporter-specific effects.

Alternatively, we can identify θ from a standard gravity equation; the coefficient of tariffs in the gravity equation is $1/\theta^j$ (see Equation (3.4)). Tariff data is directly observable, but iceberg trade costs are not. To estimate Equation (3.4), the gravity literature typically assumes a functional form for iceberg trade costs based on proxies such as bilateral distance and dummies for contiguity and joint membership in a free trade agreement (FTA). We proceed accordingly by assuming that $d_{in}^j = D_{in}^{\rho^j} e^{\delta^j \mathbf{Z}_{in}}$, where D_{in} is bilateral distance and \mathbf{Z}_{in} is a vector collecting dichotomous trade cost proxies (contiguity and FTAs). Plugging this functional form into the trade share equation (3.4) and multiplying by X_n^j , results in the following log-linearized estimable gravity equation for each sector j:

$$\ln(\pi_{in}^j X_n^j) = -\frac{1}{\theta^j} \ln \tau_{in}^j - \frac{\rho^j}{\theta^j} \ln D_{in} - \frac{\delta^j}{\theta^j} \mathbf{Z}_{in} + \nu_i^j + \mu_n^j + \varepsilon_{in}^j, \qquad (3.37)$$

where $\nu_i^j \equiv \ln(\lambda_i^j c_i^j)$ is an exporter fixed effect, $\mu_n^j \equiv \ln(X_n^j / \sum_{i=1}^N \lambda_i^j [c_i^j \kappa_{in}^j]^{\frac{-1}{\theta^j}})$ is an importer fixed effect, and ε_{in}^j an i.i.d. error term.

Table 5.1 displays the results from both estimation strategies. Each row corresponds to a separate estimation. Columns (1) and (2) show the estimates for the (inverse) productivity dispersion, $1/\theta^{j}$, from the Caliendo and Parro (2015) methodology; in column (2) we drop from the sample the 0.5% of observations with the highest tariffs. Column (3) applies a gravity equation where importer and exporter fixed effects control for unobserved country-level heterogeneity and the log of distance and dummies for FTAs and for contiguity proxy trade costs. Sectors are sorted in descending order of the estimated coefficient on tariffs. The higher $1/\theta^{j}$, the smaller the productivity dispersion in the respective sector. The coefficients are fairly stable across the different estimation procedures. Not surprisingly, "basic metals and fabricated metal," "mining and quarrying," and "coke, refined petroleum, and nuclear fuel" are at the top of the list. These sectors are characterized by more homogeneous products. At the lower end of the table are sectors such as "transport equipment" and "manufacturing nec." which tend to produce more heterogeneous goods. All in all, the sorting of sectors seems plausible.¹⁷ Also, the order of magnitude of the estimated coefficients seems plausible, except for three (two) estimates that are smaller than one in Column (1) (Column (2)). For our counterfactual analysis

¹⁷The estimates indicate that the agricultural sector has a rather high productivity dispersion. This is unexpected. However, given that this sector aggregates agriculture, hunting, forestry, and fishing, this result might be due to an aggregation bias.

we use the estimates from Column (2), since Caliendo and Parro (2015)'s methodology relies on weaker identification assumptions. For "manufacturing nec." we use the gravity estimate.

Data on bilateral tariffs are not available for service sectors. Therefore, we cannot apply our estimation strategy for sectors listed in ISIC Chapters E-Q. Instead, we rely on an average value obtained by Egger et al. (2012), who estimate a trade cost elasticity for services of 5.959.

3.4.3 Expenditure and Cost Shares

The remaining parameters, α , β , and γ , and the trade shares π , are obtained from WIOD in conjunction with the tariff data described above. We match production values, the sectoral bilateral trade flows (aggregating intermediate and final goods trade), and the cost shares for intermediates from the WIOD as well as the tariff structure in 2000. We calculate value added, final goods expenditure, and the trade surplus by applying the equilibrium conditions of the model. We show below that deviations from the empirical counterparts are not substantial.

The WIOD data are valued in producer prices; we obtain bilateral imports in purchaser prices by applying the add-valorem tariffs to the reverse export flows so that $X_{in}^k = Z_{in}^k(1 + \tau_{in}^k)$. Trade shares are then computed as

$$\pi_{in}^k = \frac{X_{in}^k}{\sum_{i=1}^N X_{in}^k}$$

Sectoral value added for each country is obtained by subtracting the total cost of intermediate usage from the sector's production value. To that end, we first need to convert sector j's usage of intermediate inputs to purchaser prices by adding the expenses for tariffs to the fob value. Tariff expenses can be calculated as follows:

$$TF_n^j = \sum_i \sum_k \pi_{in}^k \frac{\tau_{in}^k}{\tau_{in}^k + 1} (1 - \beta_n^j) \gamma_n^{k,j} Y_n^j$$

where $(1 - \beta_n^j)\gamma_n^{k,j} = \frac{\sum_i a_{in}^{k,j}}{F_n^k}$ and the value of production observes $Y_n^j = \sum_i^N Z_{ni}^k + \Delta Inv_n^j$, that is, it is given by the sum over exports plus changes in the stock of inventory. Value

		(1)	(2)	(3)
ISIC Rev. 3	Sector	Estimates of $-1/\theta$		
		CP	CP (99.5)	FE
27-28	Basic metals	-12.3572***	-14.5695***	-12.7967***
		(0.2050)	(0.2232)	(0.9444)
С	Mining, quarrying	-12.0365***	-13.7911***	-12.2792***
	0,100	(0.7800)	(0.8951)	(1.8261)
23	Coke, petroleum	-11.0537* ^{***}	-11.4946* ^{***}	-7.5495***
		(1.4409)	(1.6248)	(2.5559)
24	Chemicals	-9.7762* ^{**}	-11.2670***	-9.3409***
		(0.2220)	(0.2416)	(0.8369)
20	Wood	-11.1967***	-10.7237***	-10.7012***
		(0.2924)	(0.3026)	(0.9028)
26	Non-metallic minerals	-2.8295^{***}	-6.1282***	-6.1251^{***}
		(0.2866)	(0.2397)	(1.5628)
19	Leather	-3.9975***	-5.5967***	-5.6334***
		(0.1529)	(0.1798)	(0.7012)
17-18	Textiles	-5.2900***	-5.2978***	-5.1851***
	-	(0.1191)	(0.1205)	(0.5769)
21-22	Paper	-4.4812***	-4.4347***	-5.3701***
2.2		(0.2177)	(0.2333)	(0.7306)
29	Machinery nec.	-4.6152***	-4.2234***	-4.5264***
		(0.2201)	(0.2365)	(0.7764)
15-16	Food	-1.7676***	-2.8780***	-2.0467***
20.22		(0.0600)	(0.0669)	(0.3212)
30-33	Electrical equip.	-3.2876***	-2.5285***	-4.4546***
05		(0.1847)	(0.1910)	(0.7313)
25	Rubber	-1.5353^{+++}	-2.0934^{+++}	-2.0053^{+++}
		(0.2094)	(0.2286)	(0.7344)
A-B	Agriculture	$-0.4081^{-0.40}$	$-1.4012^{+0.01}$	-1.445(
24.25	The second section section	(0.0000)	(0.1043)	(0.3115) 1.0401***
34-33	Transport equip.	-0.8239^{+++}	-0.9790^{+++}	-1.9491
26 27	Manufacturing noo	(0.1001) 0.7070***	(0.2190) 0.6021***	(0.0332) 0.7715***
90-97	manufacturing nec.	-0.1919	-0.0021	-2.1110
		(0.1979)	(0.1021)	(0.0070)
# Observations		$1,\!146,\!618$	$1,\!126,\!494$	$93,\!691$
# Exporters/ $#$ Importers		212/120	212/120	212/120

 Table 3.1: Gravity estimates of sectoral dispersion parameter

Note: The table shows estimates for the (inverse) sectoral productivity dispersion $1/\theta$ as identified by a cross-sectional gravity estimation for the year 2007. Columns (1) and (2) apply the Caliendo-Parro (CP) method as given in Equation (3.36), Column (3) applies the gravity equation with importer and exporter fixed effects (FE) and controls for bilateral trade costs as given in Equation (3.37). Column (2) drops from the sample the 0.5% highest tariffs. Sectors are sorted in descending order of the estimated coefficient in Column (2). Standard errors (in parentheses) are heteroskedasticityrobust. *, ** and *** indicate statistical significance at the 10, 5, and 1% level, respectively.



Figure 3.5: Model fit: Final goods trade

Note: The figure plots bilateral sectoral final goods expenditures in 2000 implied by the model (x-axis) against their counterpart in the data (y-axis, WIOD).

added then results from subtracting the total cost of intermediate usage from the sector's production value, that is,

$$VA_{n}^{j} = Y_{n}^{j} - \sum_{k}^{J} \sum_{i}^{N} a_{in}^{k,j} Y_{n}^{j} - TF_{n}^{j}.$$

Value added shares β follow as $\beta_n^j = \frac{VA_n^j}{Y_n^j}$. The cost shares for intermediate inputs, $\gamma_n^{k,j}$, can be backed out from $(1 - \beta_n^j)\gamma_n^{k,j} = \frac{\sum_i a_{in}^{k,j}}{F_n^k}$ using the β_n^j 's.

The share of expenditure on goods from sector k in total final goods consumption, α_n^k , is derived from the sectoral goods market clearing condition, which requires total expenditure on goods from sector k, $X_n^k = \sum_{i=1}^N X_{in}^k$, to be equal to the sum of expenditure on intermediate and final goods and thus results as

$$\alpha_n^k = \frac{X_n^k - \sum_j^J (1 - \beta_n^j) \gamma_n^{k,j} Y_n^j}{I_n}$$

Finally, income is pinned down by a macroeconomic closure condition that requires income to be equal to final goods expenditure, $I_n = \sum_k X_n^k - \sum_k \sum_j (1 - \beta_n^j) \gamma_n^{k,j} Y_n^j$, and follows as

$$I_n = VA_n + R_n - S_n - \Delta Inv_n,$$

where S_n is the aggregate trade surplus (net exports) $\sum_{i}^{N} Z_{ni}^k - \sum_{i}^{N} Z_{in}^k$ and ΔInv_n is the net change in inventories. Both terms appear as a mere transfer of income in our one-period setting. The trade surplus is valued in producer prices, since tariff income is captured separately in R_n .

To compute final goods consumption and trade we imposed the assumption inherent to the model that bilateral trade shares are the same for final and intermediate goods. Figure 3.5 plots the model-based sectoral bilateral final goods expenditures versus the actual data from WIOD (56,000 observations).¹⁸ The deviations are minor, suggesting that the assumption is not problematic.¹⁹

3.5 Counterfactual Analysis: China's WTO Accession

3.5.1 Developments in China's Export Composition and Bilateral Value Added Trade Relationships in the 2000s

China's accession to the World Trade Organization (WTO) in 2001 was a major trade shock. It is widely believed that it significantly changed global sourcing structures and has spurred formation of production networks with China. Most notable in the latter regard is the evolution of an Asian production network in which Japan and Korea and other Asian countries supply intermediates to China where they are assembled into final goods. China then exports the final goods, predominantly to the United States, but also to the European Union. Between 2000 and 2008, China's real exports increased by a factor of 4.7, which implies an increase in the share in world exports from 4 to almost 10 percent. This surge in exports was accompanied by an almost concurrent decline in the domestic value added content. Figure 3.6 shows China's total exports (right scale) and the value added composition (left scale). The share of value added contributed by China to its own exports decreased steadily. In 2000, foreign value added accounted for 14 percent of the value of Chinese exports; in 2008 its share was 22 percent. The increase

¹⁸The largest .01 percent of observations have been omitted from Figure 3.5 for display purposes.

¹⁹The largest outlier is the U.S. domestic expenditure share for textiles, where the model overestimates the data by 35 percent. The other apparent outliers all involve RoW.



Figure 3.6: China's exports to the world and their value added composition

Note: The figure shows the evolution of China's export (dashed line, right scale) and the cumulated shares of returned domestic value added, double counted value added, and foreign value (left) scale. Shares were computed based on methodology developed by Koopman et al. (2014).

in the share of double-counted trade from 3 to 7.5 percent over the same period is further evidence of China's deepening integration into the global value chain.²⁰

The increase in the foreign value added content of China's exports is reflected in large deviations of bilateral trade balances from net value added trade flows. The left panel of Figure 3.7 shows the U.S. trade balance with China. During the whole period 1995 to 2009, the U.S. ran a trade deficit with China. With China's accession to the WTO, this deficit greatly increased. Starting at about 0.5% of U.S. GDP in 2001, U.S. net imports from China almost quadrupled to 2% of U.S. GDP by 2007. However, the increase in net value added transfers from China to the United States was much smaller. In the same time period, these increased from around 0.5% of U.S. GDP to only 1.5%. This implies that the U.S. trade deficit with China is considerably overstated when measured in gross terms instead of value added terms. In 2007, the trade deficit was overestimated by about 25 percent. Over the same period, Japan's net direct export to the United States decreased,

²⁰We use Koopman et al. (2014)'s methodology (described above) to compute those shares using data from the WIOD. The share of domestic value added in exports that is consumed abroad is given by one minus the cumulated shares of foreign value added, double-counting, and domestic value that returns home.



Figure 3.7: U.S. trade deficit with China and Japan

Note: The figure shows the evolution of U.S. net exports (light gray bars) and net value added exports (dark gray bars) to China (left panel) and Japan (right panel) as a share of U.S. GDP for the period 1995-2009. The figure also shows the adjustment of the deficit from value added terms to nominal exports terms (dashed line, right scale).

while net value added transfers went up (see right panel of Figure 3.7). In value added terms, the U.S. trade deficit with Japan was understated by around 35 percent in 2007.

As shown in our empirical section on networks, China was by far the most important foreign destination for Japan and Korea in terms of processing their value added into final goods and, at the same time, these countries were among the most important sources of foreign value added for China. Korea also experienced disproportionally strong growth in the demand and supply networks, and even though Japan lost in terms of relative importance as a source country for China, the latter's importance as a processing country for Japanese value added increased disproportionately.

3.5.2 China's Accession to the WTO in 2001

To what extent can we attribute these observations to China's accession to the WTO? Can the WTO entry explain the increase in production fragmentation, China's rise as a final goods exporter, and the network formation with its neighboring countries?

To answer these questions, we calibrate the model to the year prior to the accession (2000) and then simulate China's entry by changing China's inward and outward tariff rates with respect to all other countries to the level observed in 2007. Table 3.2 shows the
	Inwar	d	Outwa	ard	Inw	ard	O	utward	
Country	Tariff $\%$	Cut	Tariff $\%$	Cut	Country	Tariff $\%$	Cut	Tariff $\%$	Cut
BRA	13.1	-2.7	35.7	-17.2	NLD	0.9	-0.1	6.0	-3.1
USA	4.1	-0.4	15.4	-7.1	POL	2.5	-0.3	5.9	-3.0
MEX	17.0	-6.4	11.7	-6.7	TUR	7.8	-4.5	10.2	-3.0
IDN	4.7	-1.5	11.8	-6.6	GBR	2.3	-0.2	5.0	-2.8
$_{\rm JPN}$	3.2	0.0	14.1	-6.5	AUT	2.2	-0.2	4.6	-2.5
RoW	8.2	-5.2	11.9	-6.4	ITA	2.9	-0.2	5.0	-2.5
KOR	5.8	-1.6	13.5	-6.0	RUS	11.1	-0.8	5.9	-2.5
CAN	4.8	-0.3	11.3	-5.9	BEL	2.1	-0.2	5.3	-2.5
DNK	2.4	-0.1	10.4	-5.5	CZE	2.9	-0.3	5.1	-2.0
CYP	3.5	-0.2	10.8	-5.0	SVK	2.6	-0.2	4.9	-2.0
LTU	2.8	-0.2	8.3	-4.2	LVA	2.9	-0.2	4.6	-1.9
IND	26.6	-1.3	11.2	-3.9	BGR	1.8	-0.4	4.8	-1.9
FIN	1.7	-0.3	5.8	-3.7	SVN	2.5	-0.3	3.0	-1.4
IRL	1.5	-0.3	5.9	-3.5	ESP	2.8	-0.2	2.6	-1.3
\mathbf{EST}	2.1	-0.4	6.7	-3.3	GRC	2.9	-0.2	3.4	-1.2
FRA	2.5	-0.3	5.9	-3.2	MLT	3.1	-0.2	1.5	-1.0
HUN	1.7	-0.4	5.2	-3.2	ROU	3.1	-0.3	1.9	-0.8
AUS	22.0	-5.1	12.9	-3.2	\mathbf{PRT}	2.4	-0.2	1.2	-0.6
SWE	3.0	-0.3	4.6	-3.1	LUX	1.0	0.0	0.4	-0.2
DEU	2.5	-0.3	5.4	-3.1					

Table 3.2: Inward and outward tariffs with China in 2000 and changes to 2007

Note: The table shows trade-weighted average tariffs and tariff changes for all countries with respect to China

magnitude of the tariff cuts for the countries in our sample. The cuts were substantial, but very heterogeneous across countries; import tariffs on goods from China decreased most for Mexico and Australia, where initial levels were also very high. On the other hand, China had to drastically cut its tariffs on imports from the North American economies (the United States, Mexico, and Canada) and on those from its neighboring countries Japan and Korea, as well as those from the emerging economies of Brazil, Indonesia, and India, and the mostly developing countries grouped in the RoW aggregate.

As regards sectoral heterogeneity, Table 3.3 shows that tariff cuts were particularly deep in the "food, beverages and tobacco" sector and in agriculture, but also for "transport equipment," "manufacturing, nec" and "electrical and optical equipment." For those sectors, the magnitude of tariff cuts also varied substantially across trade partners. Given the large heterogeneity across both sectors and countries, we do not expect all countries to benefit equally from China's WTO entry.

ISIC	Sector	Tariff Cut	Std.Dev.
		(in %)	
15 + 16	Food, beverages and tobacco	-21.1	66.1
A+B	Agriculture, hunting, forestry and fishing	-11.6	25.7
34 + 35	Transport equipment	-6.6	8.5
36 + 37	Manufacturing, nec; recycling	-6.2	6.2
30-33	Electrical and optical equipment	-5.1	3.5
17 + 18	Textiles and textile products	-4.9	5.3
25	Rubber and plastics	-4.6	3.8
21 + 22	Pulp, paper, printing and publishing	-4.4	3.5
24	Chemicals and chemical products	-4.0	4.1
29	Machinery, nec.	-4.0	3.5
23	Coke, refined petroleum and nuclear fuel	-3.8	11.1
20	Wood and products of wood and cork	-3.6	4.2
19	Leather and footwear	-3.3	3.1
26	Other non-metallic mineral	-3.3	3.7
27 + 28	Basic metals and fabricated metal	-3.0	2.9
\mathbf{C}	Mining and quarrying	-0.8	1.1

Table 3.3: Sectoral tariff changes, 2000-2007

Note: The table shows average tariff changes by sector (in %) with respect to China between 2000 and 2007 and the corresponding standard deviation.

3.5.3 Results: The Effect of China's WTO Entry

3.5.3.1 Aggregate Trade and Welfare Effects

Our counterfactual analysis predicts that world real exports increased by 2.1% due to China's WTO entry and that world trade over world production went up by .23 percentage points, as we show in Table 3.4. The driving force behind this overall increase was, of course, China itself, for which we find an increase in total exports of 28 %. A sizeable effect can also be attributed to Australia (19%). Much smaller but still significant increases were experienced by China's neighboring countries Korea, Indonesia, and Japan. We find positive but small trade effects for the United States and negligible or even slightly negative effects for most of the European economies. Furthermore, the results show that China's WTO entry did indeed spur production fragmentation. China's value added exports increased by much less than its total exports. This is indicated by China's value added to export ratio, which decreased by 4 percentage points. On the world level, the VAX ratio decreased by 0.3 percentage points. We find decreasing ratios also for the other countries that had positive export changes. Interestingly, for many countries with negative export effects, value added exports increased by less.

How big are these predicted changes in relation to the actual changes that occurred between 2000 and 2007? The answer to this question depends very strongly on the

	Co	unterfact	tual Cha	nge	Actu	al Chang	e 2000-2007
Country	Rank \widehat{X}	$\widehat{X}_{\%}$	$\widehat{X/Y} \% \text{ pts}$	$\widehat{VAX/X}_{\% \text{ pts}}$	$\widehat{X}_{\%}$	$\widehat{X/Y} \% \text{ pts}$	$\widehat{VAX/X}_{\% \text{ pts}}$
CHN	1	28.35	2.49	-3.87	307	3.55	-9.13
AUS	2	19.28	2.47	-1.92	83	-0.83	-1.69
KOR	3	3.34	0.44	-0.71	87	0.68	-4.04
RoW	4	2.39	0.37	-0.60	100	3.04	-6.08
IDN	5	1.73	0.30	-0.34	62	-4.44	2.93
JPN	6	1.52	0.08	-0.20	28	3.19	-7.19
BRA	7	1.38	0.08	-0.05	140	1.81	-0.37
USA	8	0.42	0.02	0.01	32	0.57	0.32
IND	9	0.39	0.04	-0.12	204	2.87	-5.63
RUS	10	0.17	0.04	-0.04	182	-7.31	1.64
ROU	31	-0.18	-0.01	0.05	257	-0.67	-1.23
\mathbf{EST}	32	-0.19	-0.02	0.02	154	-4.04	5.50
POL	33	-0.19	-0.01	0.01	218	5.87	-7.52
CZE	34	-0.19	-0.02	0.02	236	5.18	-7.66
MLT	35	-0.20	-0.01	0.03	58	-2.71	7.12
ESP	36	-0.20	-0.01	0.00	101	-0.97	-3.03
SVN	37	-0.22	-0.02	0.02	152	5.05	-4.69
ITA	38	-0.23	-0.01	0.01	79	0.93	-4.46
\mathbf{PRT}	39	-0.34	-0.03	0.02	89	1.51	-2.09
LTU	40	-0.58	-0.08	-0.03	237	2.60	1.59
WLD		2.10	0.23	-0.28	86	2.49	-3.81

 Table 3.4:
 Aggregate trade effects

Countries ranking 11-30 in terms of changes in exports not shown.

particular numbers at which we look. On the world level, we find that China's WTO entry explains about 9% of the increase in world exports relative to world GDP and about 7% of the decline in the world VAX ratio. These are sizeable effects if one takes into account that the only difference between the baseline scenario and the counterfactual is the tariff schedule of one country. The scenario does not consider growth in world GDP or growth in China due to anything other than the tariff changes, which explains why the counterfactual changes in total world exports or China's exports explain only a marginal fraction of the actual change (about .25% for the world and 10% for China). As regards China's growth in exports over GDP or value added exports over exports, the contribution of the WTO entry is much larger. About 2.5 percentage points (70%) of the 3.5 percentage point increase in exports over GDP and 4 percentage points (45%) of the 9 percentage points decrease in the VAX ratio can be attributed to the change in the tariff structure.

Exporter	VA Exports	$V\!A \ \widehat{Reimports}$	Foreign VA	Double Counting	$\widehat{Tariffs}$
CHN	-3.87	0.31	1.26	3.08	-0.78
AUS	-1.92	0.11	0.40	1.70	-0.30
KOR	-0.71	0.03	0.52	0.21	-0.05
RoW	-0.60	0.08	0.32	0.29	-0.08
IDN	-0.34	0.00	0.20	0.16	-0.02
JPN	-0.20	0.05	0.10	0.06	-0.01
IND	-0.12	0.00	0.09	0.02	0.01
WLD	-0.28	0.01	0.15	0.18	-0.05

Table 3.5: Changes in export composition (in % pts)

Note: The table shows the changes in the composition for the seven countries with the largest declines in the VAX-ratio.

China's WTO entry also explains a large share of the actual developments in Australia. About one-fourth of Australia's increase in total exports and almost 90% of the decline in its VAX ratio can be explained by the WTO entry, although the fact that exports over GDP actually declined implies that other significant changes were happening in Australia that cannot be explained by China's trade integration. For Japan's and Korea's aggregate statistics we find that the changes implied by our counterfactual point in the same direction as the actual changes, but the share explained by the counterfactual is small, especially for Japan. Not surprisingly, the farther away we move from China, the less of the actual development is explained. However, as we show below, on a more disaggregated level we find that China's WTO entry significantly influenced the bilateral and sectoral pattern of trade in value added.

Next, we use the decomposition method outlined above to analyze how China's WTO entry affected the composition of countries' exports. In Table 3.5 we show the world aggregate for comparison and the countries with the largest declines in their VAX ratios, which are, except for RoW, all countries geographically close to China. We find for China that the largest part of the decline in the domestic value content was due to an increase in the share of double-counted value added, which increased by 3 percentage points. In comparison, the share of foreign value added increased by 1.7 percentage points. Australia's exports experienced similar changes in composition; for the other countries, the increase in the share of foreign value added exceeded the increase in double-counting.

Figure 3.8 shows how the pattern of world wide value added sourcing changed between 2000 and 2007 and what part of this can or cannot be explained by China's WTO accession. The dark gray bars show the actual changes and the light gray bars show the changes to the counterfactual equilibrium. We group the countries that exhibited qual-



Figure 3.8: Changes in world value export shares

Countries are grouped as follows: Asia: IDN, JPN, KOR; BRIT: BRA, RUS, IND, TUR; EEC: Eastern Europe; EU1: AUT, DEU, LUX, IRL, ESP, POR; EU2: BEL, DNK, FIN, FRA, GBR, ITA, NLD, SWE: NA: CAN, USA, MEX

itatively similar changes both in the counterfactual and in the actual data and we find that this scheme is in good accordance with a grouping based solely on geography. Between 2000 and 2007, China gained a significant share in total world value added exports, reaching 9.5% in 2007. Furthermore, Australia, a group of western European countries (EU1), and the central and eastern European countries (EEC), as well as the emerging countries (BRIT) and the primarily developing countries in RoW, were able to increase their shares in world value added exports. This came at the expense of a second set of western European countries and the North American and Asian industrialized economies. We find that China's WTO entry can account for about 20% of its increase in the share of world value added. The country's WTO entry did not significantly affect the shares of the other Asian economies, those of the emerging and eastern European countries, nor those of RoW. Apparently, the dynamics of those regions were due to something else. However, China's WTO accession did contribute to the loss in value added export shares by the northern American and western European countries and the slight gains in Australia's share.

Country	\widehat{W}	$\widehat{(w/P)}$	\hat{P}	\widehat{R}	$\operatorname{Rank} \widehat{W}$
AUS	2.62	3.18	-3.94	-28.23	1
CHN	0.56	1.52	-1.27	-41.12	2
KOR	0.24	0.23	0.31	-0.33	3
IDN	0.13	0.14	-0.09	-1.65	4
RoW	0.07	0.15	-0.08	-5.34	5
JPN	0.04	0.03	0.11	2.71	6
CYP	0.04	0.02	-0.07	-0.10	7
MLT	0.04	0.02	-0.13	0.45	8
BRA	0.03	0.03	0.09	0.39	9
RUS	0.03	0.03	-0.05	0.11	10
USA	0.02	0.02	-0.06	-0.50	13
SVK	0.00	0.00	-0.11	-0.75	31
FRA	0.00	0.01	-0.10	-0.69	32
SVN	0.00	0.00	-0.12	-0.61	33
ITA	0.00	0.00	-0.13	-0.09	34
LUX	-0.01	0.01	-0.09	-0.20	35
BEL	-0.01	0.00	-0.11	-0.66	36
TUR	-0.01	0.00	-0.22	-3.25	37
IRL	-0.01	0.02	-0.14	-1.28	38
MEX	-0.02	0.02	-0.11	-1.04	39
LTU	-0.04	-0.06	-0.20	-0.81	40

Table 3.6: Welfare changes (in %)

Note: The table shows counterfactual changes in welfare \widehat{W} (real income), real wages $\widehat{(w/P)}$, the price level \hat{P} , and tariff revenue \widehat{R} for the 10 most positively and most negatively affected countries in terms of welfare as well as for the U.S..

To assess the welfare implications of China's accession to the WTO we look at changes in real income as given in Equation (3.12). The two determinants of welfare changes are real wages and tariff income. Due to global production linkages, real wages in all countries are much more directly affected than just through the equilibrium price indices, as is the case in the standard gravity model. Even countries that experienced little or no tariff changes with respect to China can witness an increased demand for their labor if they are an important input supplier either for China or for some other country that experienced significant changes in the tariff structure. Similarly, production linkages imply that other countries' production costs show up directly in a country's own price index. Hence, we expect that the welfare consequences are much more complex than in a standard general equilibrium gravity framework without input-output linkages.

China's WTO entry resulted in positive welfare gains in terms of a positive change in aggregate real income for China itself, and also for most other countries. Table 3.6 shows welfare changes for the 10 most and least positively affected countries and for the United States. Remarkably, Australia experienced the largest real income gain – 2.6 percentage

points – more than four times the increase for China. Australia benefited from a strong decrease in the price index, which compensated for the significant 28% decline in tariff revenue. Similarly, China lost 41% of its tariff revenue, but also experienced a significant reduction in prices and higher demand for its labor, resulting in a net real income gain The other countries with sizeable positive effects are China's neighbors and of .6%. the mostly developing countries in the RoW aggregate. We find that in most countries prices decreased, with the noteworthy exceptions of Japan and Korea, where the increased demand for labor drove up nominal wages and prices. Nevertheless, these two countries still experienced real wage gains. The increased demand for labor in Korea and Japan suggests that the relocation of production to China (which we document below for final goods production) was overcompensated by an increase in total demand. We also find positive but small welfare effects for the United States, where the decline in the price index was sufficiently large to make up for the loss in nominal wages and tariff income. We find small negative welfare effects for only six countries, with Lithuania, the most adversely affected country, experiencing a decline in real income of .04%.

A few comments are in order in regard to the welfare effects of our counterfactual experiment. First, in our static framework trade deficits appear as one-time net income transfers that are treated as exogenous and held constant when moving to the counterfactual equilibrium. Second, we assume perfect labor mobility across sectors within a country. Since sectors were affected very differently, owing both to heterogeneous tariff cuts and different sourcing structures, the assumption of labor mobility clearly matters for whether countries could actually realize the real wage gains predicted by the model, and over what time horizon. And lastly, as mentioned before, the consequences of China's WTO accession were much broader than those we discuss here. Our welfare effects reflect only the changes induced by the tariff cuts.

3.5.3.2 Effects on Bilateral Trade in Value Added and Networks

Supply Networks. China's WTO accession facilitated easier access to inputs for Chinese final goods producers. The sectoral and bilateral heterogeneity suggests that input suppliers were differentially affected, yet the sectoral and global interlinkages make it hard to exante predict how value added flows change as a consequence of trade cost changes. We use our measure of supply networks to shed light on the question of which countries and sectors intensified their production linkages with China.

Three features of value added trade relationships, when present, tended to make these relationships particularly affected by China's WTO entry. First, geographical proximity



Figure 3.9: Changes in the intensity of supply networks for selected countries

Note: The figure plots changes in supply network intensity as defined in Equation (3.30) against values (left panel) and against the initial degree of complementarity (right panel), given by covariance term in Equation (3.32) standardized by the product of the standard deviations of $\pi_{ih}^{k,j_d,VA}$ and $\gamma_{h}^{k,j_d,VA}$.

was a major determinant. Following the RoW aggregate, Japan, Korea, Indonesia, and Australia were the countries that on average experienced the strongest increases in their shares of foreign value added processed by final goods sectors in China. Second, the scope and the depth of existing supply networks mattered. Figure 3.9 shows for China's neighboring countries and the United States that the initial value added share was a strong predictor of the change in the share (left panel). Each dot is a supply network between the country as labeled and one downstream sector in China. Likewise, a deeper network facilitated a stronger increase in the value added share (right panel), where the depth of a supply network is measured by the correlation between the source country's relative competitiveness in an upstream sector and the importance of that upstream sector in general for the downstream sector in China.

Table 3.7 presents the correlations for all source countries and all downstream sectors in China and compares the counterfactual changes to the actual changes. Columns (1) and (3) show the relationship of the change in the share with the initial level. Columns (2) and (4) display the relationship with each of the components of the supply network and

Dep. var: $\Delta \frac{VA_{ih}^{Jd}}{VA_{i.}^{Jd}}$	Counter	rfactual Actual Change		
$VA_{ih}^{.j_d}/VA_{i.}^{.j_d}$	26.46^{***} (0.354)		17.72^{***} (0.884)	
$\pi^{k,j_d,VA}_{ih}$		22.60^{***} (0.307)		$\begin{array}{c} 12.25^{***} \\ (1.037) \end{array}$
$\rho(\pi_{ih}^{k,j_d,VA},\gamma_h^{k,j_d,VA})$		$\begin{array}{c} 0.289^{***} \\ (0.0397) \end{array}$		$\begin{array}{c} 0.480^{***} \\ (0.0740) \end{array}$
$\frac{N}{R^2}$	$1287 \\ 0.813$	$1287 \\ 0.819$	$1287 \\ 0.238$	$1287 \\ 0.153$

Table 3.7: Determinants of	changes	in supply	networks
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Note: The table shows OLS regression results for changes in supply network intensity for all source countries with all downstream sectors in China. Standard errors in parentheses. * p < 0.1, ** p < 0.05, *** p < 0.01. ρ denotes the correlation coefficient; the other variables are as defined in Equation (3.35).

confirm that each has a separate effect on intensity of the network. The counterfactual changes strongly resemble the pattern in the data. In terms of magnitudes, we find for the counterfactual that a 1 percentage point higher initial value added share is associated with a .26 percentage point stronger increase. The actual data predict a .18 percentage point increase. An increase in the correlation coefficient by .01 units is associated with a .29 percentage point higher increase in the counterfactual and .48 in the data. It is noteworthy that the initial strength of the network is a remarkably strong predictor of the counterfactual change, as indicated by an R^2 larger than .8, and also has substantial explanatory power for the changes that we observe in the data over a period of seven years.

We find a strong resemblance between the counterfactual changes and the actual data within sectors, too. Figure 3.10 plots for all source countries the changes in supply network intensity with China's manufacturing sectors (29-36) in the counterfactual against the change in the data. The majority of countries are clustered at zero both in our counterfactual and in the data. Countries that repeatedly stand out are Japan, Korea, Australia, the United States, Germany, and RoW. In many cases, the changes in the data are very well explained by our counterfactual, especially so in the case of RoW, Australia, the United States, and Korea. These countries are aligned on or close to the 45-degree line, which is the most challenging benchmark. Apparently, the counterfactual does not do well at explaining the developments in Japan, which lost value added shares in those sectors or gained only a little, whereas our simulation suggests that China's WTO



Figure 3.10: Changes in the intensity of supply networks for selected sectors

Note: The figure plots actual vs. counterfactual changes in supply network intensity as defined in Equation (3.30) for selected sectors.

entry enhanced Japan's supply networks. Also, the significant changes that occurred for Germany, Slovakia, and Russia are at most only partly – as regards the direction of the change – explained by China's WTO entry.

Demand Networks. We next focus on the upstream sectors in the source countries and investigate how China's WTO entry changed the pattern of demand for their value added. We find forces similar to those affecting the supply network to be at work in shaping changes in demand network intensity. That is, geographically close countries had the strongest effects, and initially strong networks were disproportionately intensified. Since service sector networks are very small throughout and do not change by much, we restrict the analysis to the agricultural and manufacturing sectors plus mining (A-36). Figure 3.11 (left panel) shows for China's neighboring countries and for the United States that the increase in the share of value added from a given upstream sector that was processed into final goods in China (rather than elsewhere) was stronger for source



Figure 3.11: Changes in the intensity of demand networks for selected countries

Note: The figure plots changes in supply network intensity as defined in Equation (3.33) against values (left panel) and against the initial degree of complementarity (right panel), given by covariance term in Equation (3.35) standardized by the product of the standard deviations of $s_{ih}^{k_u,j}$ and $r_i^{k_u,j}$.

countries/sectors where China's share was initially high. The right panel shows that a higher complementarity with the demand structure of China's final goods producers was also associated with a stronger effect on China's demand share. Table 3.8, Column (1) confirms that the correlation with the initial value added share holds for the full set of countries. The effect of the complementarity measure on the change in the value added share is small and not significant for the full sample (Column (3)); however, we find a strongly significant and positive coefficient when repeating the regression for the subset of countries displayed in Figure 3.11.

Columns (5) and (6) of Table 3.8 show that the pattern of the counterfactual changes is well aligned with the actual pattern in the data once we exclude the textiles and leather industries (17t20). Comparing Column (4) to Column (5) shows that excluding textiles and leather reverses the coefficient on the initial share, indicating that those two sectors underwent changes that were significantly different from those experienced by the other sectors. We also find that the developments in textiles and leather also cannot be explained by our counterfactual experiment. Excluding these sectors in the regression with the counterfactual changes (Column (2)) hardly affects the coefficient on the initial share. The magnitude of the effect of the initial share on the change is in a range similar to that seen for the supply networks. A 1 percentage point increase in the initial share



Figure 3.12: Changes in the intensity of demand networks for selected sectors

Note: The figure plots actual vs. counterfactual changes in supply network intensity as defined in Equation (3.30) for selected sectors.

implies a .25 and .34 percentage point higher increase in the counterfactual and the data, respectively.

Figure 3.12 zooms in on four manufacturing sectors to show the extent to which China's WTO entry explains the dynamics within sectors between 2000 and 2007. For all sectors it holds that the actual changes exceed the counterfactual predictions, in some cases by a factor of 10. We attribute this to the exceptional growth taking place in China generally, most of which was unrelated to its WTO accession. The benchmark of the 45-degree line is thus out of reach, but we still find that our counterfactual changes do a good job of predicting developments for the countries located close to China as well as for RoW and the United States, which are the countries that most often exhibit significant changes in the data. In the machinery (29) and electrical and optical equipment (30t33) sectors, the relative changes are explained well for all countries except Indonesia and Malta. In transport equipment (34t45) and basic and fabricated metals (27t28), the northern American and European economies exhibit different dynamics, but for China's neighbors and RoW, the counterfactual changes explain a substantial part of the actual developments.

Dep. var: $\Delta \frac{VA_{ih}^{k_u}}{VA_{i.}^{k_u}}$	Coun	terfactual ch	nange	A	ctual change	е
$VA_{ih}^{k_u\cdot}/VA_{i.}^{k_u\cdot}$	25.01^{***} (1.349)	$24.89^{***} \\ (1.584)$		-14.06^{***} (3.784)	33.53^{***} (6.182)	
$\overline{s_{ih}^{k_u.}}$			22.62^{***} (1.425)			27.07^{***} (4.615)
$\rho(s_{ih}^{k_u,j},r_i^{k_u,j})$			$\begin{array}{c} 0.0440 \\ (0.361) \end{array}$			2.762^{*} (1.457)
$\begin{array}{c} \mathrm{N} \\ \mathrm{R}^2 \end{array}$	$622 \\ 0.357$	$545 \\ 0.313$	$545 \\ 0.332$	621 0.0218	$\begin{array}{c} 544 \\ 0.0515 \end{array}$	$\begin{array}{c} 544 \\ 0.0699 \end{array}$

 Table 3.8: Determinants of changes in demand networks

Note: The table shows OLS regression results for changes in demand network intensity for all the agriculteral, mining and manufacturing sectors in the source countries with all downstream sectors in China. Columns 2 and 4 exclude textiles (17t18) and leather (19t20). Standard errors in parentheses. * p < 0.1, ** p < 0.05, *** p < 0.01. ρ denotes the correlation coefficient, the other variables are as defined in Equation (3.34).

3.6 Conclusion

In this paper, we analyze the effects of trade liberalization on production fragmentation and value added trade. To that end, we derive structural expressions for value added trade flows and production networks from a multi-sector multi-country model of the Eaton and Kortum (2002) type. This permits to analyze how the global pattern of value added trade is affected by moving to a counterfactual equilibrium with liberalized trade. Our results strongly suggest that counterfactual analysis in a structural model rather than reduced form gravity-type estimations should be used to assess the impact of trade cost, trade policy, and other variables typically appearing in standard gravity equations on value added trade.

We apply our methodology to the case of China's entry into the WTO which constituted a major shock to global trade in 2001. We estimate the model's structural parameters, calibrate it to the year 2000 using the World Input-Output Database, and then simulate China's WTO entry by changing its inward and outward tariffs to the post entry level of 2007.

We find that China's WTO entry accounts for about 45% of the decrease in China's value added exports to exports ratio and for about 7% of the decline in this figure on the world level. Moreover, we find that China's WTO accession was the driving force behind the strengthening of supply and demand networks with its neighbors and also

significantly shaped its value added trade relationship with the United States. China gained in importance as a location for processing value added into final goods for almost all countries and particularly so for the nearby Asian economies, which could, at the same time, foster their positions as major sources of foreign value added in China's final goods production. China and its neighboring countries experienced significant welfare gains, notwithstanding the substantial decrease in tariff income. We find no evidence for negative welfare consequences for the United States; in fact, only a few countries, primarily European, appear to have been marginally adversely affected.

Going Deep: The Trade and Welfare Effects of TTIP^{*}

4.1 Introduction

In July 2013, the EU and the United States began negotiations on the Transatlantic Trade and Investment Partnership (TTIP). According to the High-Level Working Group on Jobs and Growth, set up by the so called Transatlantic Economic Council, the ambition is to eliminate all tariffs and to create "a comprehensive, ambitious agreement that addresses a broad range of bilateral trade and investment issues, including regulatory issues, and contributes to the development of global rules" that "goes beyond what the United States and the EU have achieved in previous trade agreements." In this paper, we attempt a quantification of the potential effects of this endeavor.

The TTIP is the first big trade agreement that tries to fill the "gap between 21st century trade and the 20th century trade rules" (Baldwin, 2011) that the relative stasis of the World Trade Organization (WTO) has left developed countries in. Our analysis captures important aspects of modern trade, such as globally fragmented production chains, trade in services, and non-tariff barriers to trade (NTBs).

To that end, we augment the quantitative trade model by Caliendo and Parro (2015) with an explicit description of non-tariff barriers to trade. We analyze the effects of reductions in both tariffs and non-tariff barriers to trade between the EU and the United States on the global economy. Our empirical framework covers 38 industries from the

^{*}This chapter is based on joint work with Rahel Aichele and Gabriel Felbermayr and was also published as ifo Working Paper No. 219, 2016

services, manufacturing, and agriculture sectors, and 140 countries or regions. The model features cross-sectoral and international trade in intermediate inputs and thus allows to captures the economic effects on third countries that are integrated into the TTIP countries' value chain. In contrast to the conventional computable general equilibrium (CGE) trade models, the key parameters – the Frechet parameter governing the distribution of productivities within sectors and the coefficients of the trade cost function – are estimated using structural relationships that are implied by the theoretical setup. In contrast to other quantitative studies of trade policy experiments using estimated parameters for model calibration, we explicitly acknowledge the uncertainty associated with our parameter estimates and show how it translates into measures of uncertainty, namely, confidence intervals, for our model-based predictions.

We use data on sectoral trade flows and input-output linkages from the Global Trade Analysis Project (GTAP) and employ an instrumental variables (IV) strategy to obtain estimates of the effects of existing preferential trade agreements (PTAs) on bilateral trade cost. The central assumption we make in the subsequent simulation analysis is that in addition to eliminating all tariffs between the EU and the United States, the TTIP will reduce trade costs by the amount we have estimated as an average effect of existing deep trade agreements. The key results are that the TTIP will yield a long-run increase in the level of real per capita income of 0.4% and 0.5% in the EU and the United States, respectively. It will only marginally lower average real income in the rest of the world, leaving the world as a whole better off with a real income increase of about 0.2%.

We find that the TTIP would bring about a significant amount of trade creation among the insiders. For example, trade between the EU and the United States, as measured at customs, is predicted to increase by more than 50%. At the same time, trade among EU countries and trade within the United States would fall by .4%, respectively .5%, reflecting trade diversion by preference erosion. Similarly, trade with most other countries or regions would decrease. However, imports from suppliers of consumption goods, raw materials, or intermediates can go up due to growth of output and income in the TTIP countries. Also, trade diversion can be attenuated by imported competitiveness: When TTIP partners supply intermediates at lower prices to third countries, changes in relative prices of final goods are dampened. This latter effect, plus the restructuring of production chains, imply that third countries' value added exports to the TTIP parties may go up even if export values decrease. We find such effects, for example, for Mexico and Canada whose value added exports to the EU increase substantially even though direct trade decreases. Similarly, value added exports to the United States increase for non-TTIP countries that are closely integrated into the European production network, such

as Turkey. Moreover, third countries gain competitiveness in each others' markets, as wages in the TTIP countries go up. For example, we find that Mexico's gross exports to China, the ASEAN countries, and Brazil would increase with the TTIP.

The introduction of the TTIP would alter the composition of aggregate value added. It would lead to a slight reindustrialization in the EU and the United States, reflecting the fact that the reduction in NTBs is larger in manufacturing than in services and that manufacturing sectors also benefit from the elimination of tariffs. Service sectors gain shares in total output in all non-TTIP countries, with the exception of a few European economies.

The paper is closely related to three strands of literature. First, it builds on recent work in the field of "New Quantitative Trade Theory" (NQTT). Costinot and Rodriguez-Clare (2014) provide a comprehensive survey of the models and the methodology used in this field. The central element and (one) defining feature of NQTT models is the gravity equation, a parsimonious structural relationship which allows estimation of trade elasiticities with respect to trade cost parameters with the help of relatively simple econometrics. Besides simplicity, the gravity equation derives its popularity from the excellent empirical fit. However, the parsimony of the structure rests on relatively strong functional form assumptions. In our case, the Frechet productivity distribution and CES demand systems. Nonetheless, the NQTT offers important advantages over the more conventional large-scale CGE approach. First, the parsimony allows getting relatively far with analytical descriptions. This feature reduces (but does not undo) the black box nature of large general equilibrium models. Second, the approach allows a tight link between the model and the data. Estimates of unobserved parameters are chosen such as to best fit the data used to calibrate the model's observable moments and the structural relationships used to conduct counterfactual experiments. Moreover, absent knowledge of the precise nature of the policy scenario, in our case, the outcome of the TTIP negotiations, the framework lends itself to letting the data define the scenario. More precisely, the structural relationships, the observable moments, and the data on existing trade agreements together allow us to back out the average effect that trade agreements in the past have had on NTBs. Using this estimated average effect of deep PTAs on trade costs as a plausible guess for the effect of the TTIP on the cost of trade between the EU and the United States, we circumvent the challenge of coming up with bottom-up estimates of the cost equivalents of existing NTBs and we do not need to develop conjectures about potential reductions of these costs. Finally, in contrast to existing work on counterfactual experiments in the NQTT framework, we address the issue that the estimated unobserved parameters used to calibrate the model are surrounded by uncertainty. We conduct a bootstrap to obtain confidence intervals for our simulated effects, reflecting the degree of uncertainty that is introduced by the use of estimated parameters in the calibration.

Second, our work builds on earlier quantitative evaluations of the TTIP. In a study for the European Commission, Francois et al. (2013) employ a large scale CGE framework based on the well-known GTAP model (Hertel, ed, 1997), extended with features of the Francois et al. (2005) model. While their work is at the frontier of classical CGE modeling, it does not utilize the breakthroughs described in Costinot and Rodriguez-Clare (2014). It requires bottom-up estimates of NTBs which are only available for a small set of bilateral trade links, and it defines the scenario on the basis of expert input rather than data. Egger et al. (2015) use the same model, but they rely on a top-down, gravity-based approach to estimating NTBs. However, they do not derive the gravity equation from the model and use ad hoc values to calibrate the model's parameters (such as the trade elasticities). Moreover, these studies work with broad regional aggregates. Felbermayr et al. (2013) and Felbermayr et al. (2015a) apply the model and econometric approach of Egger et al. (2011) to simulate the effects of a TTIP. Their model is a single-sector framework based on the Krugman (1980) model augmented with an extensive margin to capture the prevalence of zero-trade flows. Anderson et al. (2014) use a dynamic single-sector setup with endogenous capital stocks. These latter three approaches all feature a tight link between estimation and simulation. However, they miss out on the sectoral detail and the role of the global value chain. Moreover, none of these papers addresses the issue of parameter uncertainty.

Finally, our paper relates to a large empirical literature on the determinants and effects of PTAs. Much of the earlier work, surveyed, for example, by Cipollina and Salvatici (2010), is based on reduced form equations and does not properly deal with the potential endogeneity of trade agreements. More recent empirical studies provide a tight link between theoretical model and estimation (see Head and Mayer, 2014), and devote much attention to obtaining causal effects of PTAs on trade flows (see Egger et al., 2011, and the discussion of literature therein). The critical step is to find exogenous drivers of PTA formation. Controlling for tariffs, the estimated treatment effect of PTAs can be used to quantify how PTAs have reduced the costs of NTBs. The literature suggests that OLS tends to underestimate the true effects of PTAs and typically finds economically large effects when using IV strategies. In this paper we use the contagion index developed by Baldwin and Jaimovich (2012) as an instrument to obtain IV estimates of the PTA effect for 37 sectors (including services). Moreover, we distinguish between "shallow" and "deep" PTAs, borrowing a classification provided by Dür et al. (2014).

The remainder of this paper is structured as follows. Section 4.2 provides a quick overview of the theoretical model. In Section 4.3 we discuss the data and the identification of parameters. Section 4.4 provides the simulation results and Section 4.5 concludes.

4.2 Methodology

In this section, we briefly summarize the Eaton and Kortum (2002)-type multi-sector, input-output gravity model developed by Caliendo and Parro (2015), which is the basis of our simulations. We discuss the key structural assumptions and then describe the effects of counterfactual changes in trade flows, welfare and other endogeneous variables of the model associated with a change in trade cost. As Caliendo and Parro (2015) discuss in their paper, accounting for input-output linkages allows capturing important additional welfare effects of trade liberalization compared to models without an inputoutput structure; an intermediate goods channel and a sector linkages channel. Since sectoral and international input-output linkages constitute one the important aspects of 21st century trade that modern trade agreements aim to address, Caliendo and Parro (2015)'s model is most suitable for an analysis of the effects of such an agreement. Caliendo and Parro (2015) use the model to analyze the effects of tariff changes attributed to NAFTA. We extend the model by explicitly modeling NTBs, as those are expected to play a major role in the TTIP.

4.2.1 The Gravity Model

In n = 1, ..., N countries, the utility function of the representative household is described by a Cobb-Douglas function over j = 1, ..., J sectoral composite goods, with α_n^j denoting the expenditure share of sector j. The household receives labor income I_n and lump-sum tariff rebates.

Each sector j comprises a continuum of varieties. Labor and the composite goods of each sector k = 1, ..., J are the inputs to j's production process. Let $\beta_n^j \in [0, 1]$ denote the cost share of labor and $\gamma_n^{k,j} \in [0, 1]$ the share of sector k in sector j's intermediate costs, with $\sum_{k=1}^J \gamma_n^{k,j} = 1$. Then the production function for a variety ω^j is given by

$$q_{n}^{j}(\omega^{j}) = x_{n}^{j}(\omega^{j})^{-\theta^{j}} \left[l_{n}^{j}(\omega^{j}) \right]^{\beta_{n}^{j}} \left[\prod_{k=1}^{J} m_{n}^{k,j}(\omega^{j})^{\gamma_{n}^{k,j}} \right]^{(1-\beta_{n}^{j})},$$
(4.1)

where $x_n^j(\omega^j)$ denotes the inverse efficiency of variety producer ω^j . The dispersion of efficiencies across varieties is given by $\theta^j \in (0, 1)$. The higher θ^j , the greater the productivity dispersion in sector j. All varieties ω^j are aggregated with a Dixit-Stiglitz-type CES technology into sector j's composite good. The sectoral composites are used for production and consumption purposes.

A sector's varieties are internationally traded and there is perfect competition among variety producers. Hence, prices equal marginal cost. Producers search across all countries for the lowest-cost supplier of a variety. When importing a variety from sector j in country i, the importer n has to pay the unit costs c_i^j times the trade costs κ_{in}^j which consist of two parts: ad-valorem tariffs $\tau_{in}^j \geq 0$ and iceberg trade costs $d_{in}^j \geq 1$, with $d_{nn}^j = 1$. Following other gravity applications, we model iceberg trade costs as a function of bilateral distance, PTAs, and other observable trade cost proxies such as a common border, a common language or a common colonial history. Accordingly, we assume $d_{in}^j = D_{in}{}^{\rho^j} e^{\delta^j \mathbf{Z}_{in}}$, where D_{in} is bilateral distance, and \mathbf{Z}_{in} is a vector collecting dichotomous trade cost proxies. More explicitly, we allow for two types of PTAs: shallow and deep treaties. The respective dummies are denoted by PTA_{shallow} and PTA_{deep} . Since tariffs are an explicit part of trade costs, the PTA dummies capture trade cost reductions that go beyond the reduction or elimination of tariffs. Thus, the PTA dummies capture the trade-enhancing effect of reducing NTBs like sanitary and phytosanitary trade barriers and other technical barriers to trade like regulatory standards or labeling requirements.

The model gives rise to a gravity equation. Country n's expenditure share π_{in}^{j} for source country *i*'s goods in sector *j* depends on *i*'s price relative to the price index. It can be written as

$$\pi_{in}^{j} = \frac{\lambda_{i}^{j} \left[c_{i}^{j} \kappa_{in}^{j}\right]^{\frac{-1}{\theta^{j}}}}{\sum_{i=1}^{N} \lambda_{i}^{j} \left[c_{i}^{j} \kappa_{in}^{j}\right]^{\frac{-1}{\theta^{j}}}}.$$
(4.2)

This trade share can be interpreted as the probability that, for country n, the lowest cost supplier of a variety in sector j is trade partner i. The model is closed with goods market clearing and an income-equals-expenditure condition for each country n.

Besides "gross" trade flows, that is, the value of trade as measured at customs (to which the trade shares in Equation (4.2) refer), we also consider trade in value added. Following Johnson and Noguera (2012b), we define value added exports as the amount of value added from a source country absorbed (consumed or invested) in a foreign country. Johnson and Noguera (2012b) develop a methodology to compute bilateral sectoral value added trade flows based on trade data, value added shares in production, and international input output tables. Aichele and Heiland (2015) (cp. Chapter 3 of this dissertation) show how a structural equation for so-defined value added trade flows can be derived from

Caliendo and Parro's (2015) model, which facilitates counterfactual analysis of trade in value added. Our value added trade analysis is based on this same methodology.

4.2.2 Comparative Statics in General Equilibrium

In this section, we describe how the model reacts to a trade policy shock. Let $\hat{x} \equiv x'/x$ be the relative change in any variable from its initial level x to the counterfactual level x'. The formation of a PTA implies changes in the tariff schedule and the reduction of NTBs. Hence, changes in trade costs are given by

$$\hat{\kappa}_{in}^{j} = \hat{\tau}_{in}^{j} \exp\left\{\delta_{\text{shallow}}^{j}(PTA_{\text{shallow},in}^{\prime} - PTA_{\text{shallow},in}) + \delta_{\text{deep}}^{j}(PTA_{\text{deep},in}^{\prime} - PTA_{\text{deep},in})\right\}.$$

Since all trade flows between liberalizing countries benefit from the tariff and NTB cost reductions, the approach implicitly assumes that rules of origins, if present, are nonbinding.

As suggested by Dekle et al. (2008), one can solve for equilibrium changes:¹

$$\hat{c}_{n}^{j} = \hat{w}_{n}^{\beta_{n}^{j}} \left(\prod_{k=1}^{J} \left[\hat{p}_{n}^{k} \right]^{\gamma_{n}^{k,j}} \right)^{1-\beta_{n}^{j}}, \qquad (4.3)$$

$$\hat{p}_{n}^{j} = \left(\sum_{i=1}^{N} \pi_{in}^{j} \left[\hat{\kappa}_{in}^{j} \hat{c}_{i}^{j}\right]^{-1/\theta^{j}}\right)^{-\theta^{j}}, \qquad (4.4)$$

$$\hat{\pi}_{in}^{j} = \left(\frac{\hat{c}_{i}^{j}}{\hat{p}_{n}^{j}}\hat{\kappa}_{in}^{j}\right)^{-1/b^{\prime}}, \qquad (4.5)$$

$$X_n^{j'} = \sum_{k=1}^J \gamma_n^{j,k} (1 - \beta_n^k) \left(\sum_{i=1}^N \frac{\pi_{ni}^{k'}}{1 + \tau_{ni}^{k'}} X_i^{k'} \right) + \alpha_n^j I_n', \qquad (4.6)$$

$$\sum_{j=1}^{J} F_n^{j'} X_n^{j'} + S_n = \sum_{j=1}^{J} \sum_{i=1}^{N} \frac{\pi_{ni}^{j'}}{1 + \tau_{ni}^{j'}} X_i^{j'}, \qquad (4.7)$$

where \hat{w}_n denotes the wage change, X_n^j denotes the sectoral expenditure level, $F_n^j \equiv \sum_{i=1}^N \frac{\pi_{in}^j}{(1+\tau_{in}^j)}$, $I'_n = \hat{w}_n w_n L_n + \sum_{j=1}^J X_n^{j'} (1-F_n^{j'}) - S_n$, L_n is country *n*'s labor force², and S_n is the trade surplus. Equation (4.3) shows how unit costs react to input price changes,

¹When solving for the new equilibrium in changes instead of in levels, the set of parameters that have to be estimated is reduced. Information on price levels, iceberg trade costs, or productivity levels are not required.

²Labor can move freely between sectors. However, it cannot cross international borders.

i.e. to wage and intermediate price changes. Trade cost changes affect the sectoral price index p_n^j directly, and also indirectly by affecting unit costs (see Equation (4.4)). Changes in trade shares result from these trade cost, unit cost, and price changes. The strength of the reaction is governed by the productivity dispersion θ^j . A small θ^j implies large trade changes. Equation (4.6) ensures goods market clearing in the new equilibrium and Equation (4.7) corresponds to the counterfactual income-equals-expenditure or balanced trade condition. The change in real income, which is given by

$$\widehat{W}_n = \frac{\widehat{I}_n}{\prod_{j=1}^J (\widehat{p}_n^j)^{\alpha_n^j}},\tag{4.8}$$

serves as our measure for the change in welfare.

Caliendo and Parro (2015) extend the single-sector solution algorithm proposed by Alvarez and Lucas (2007) to solve the system of equations given by (4.3)-(4.7). The algorithm starts with an initial guess of a vector of wage changes. With (4.3) and (4.4), it then computes price and trade share changes and the new expenditure levels based on those wage changes, evaluates the trade balance condition (4.7), and then updates the wage change based on the error in the trade balance.

4.3 Data and Parameter Identification

To simulate the effects of the TTIP based on the model described in the previous section, we need to identify the parameters α , β , γ , θ , and δ_{deep} and δ_{shallow} ,³ and collect data on bilateral trade shares π , tariff levels τ , countries' total value added $w \cdot L$, and trade surpluses S. The expenditure shares α and the cost shares β and γ are obtained from input-output tables. θ , δ_{shallow} and δ_{deep} are estimated based on the gravity equation implied by the model.

4.3.1 Data Sources

Our main data source is the Global Trade Analysis Project (GTAP) 9 database, which provides sectoral production values, sectoral value added information and bilateral final and intermediate goods trade in producer and consumer prices, including service sectors. Based on this information, sectoral expenditures for final and intermediate goods, sectoral

³For the scenario considered later on this paper, we actually do not require estimates of δ_{shallow} . However, $PTA_{shallow}$ is certainly an important control variable in the estimation and will be needed if one defines the scenario differently.

bilateral tariffs, and bilateral input-output tables can be be constructed. The GTAP database was chosen for its rich country detail.⁴ It contains data for 122 countries and 18 aggregate regions (e.g. "Rest of Southeast Asia"). These 140 countries and regions represent the world economy in the year 2011. GTAP distinguishes 57 sectors, which we aggregate to 38 following the sector groupings of GTAP in order to reduce the number of parameters that need to be estimated.⁵

4.3.2 Expenditure and Cost Shares

Expenditure shares α, β , and γ , trade shares π , tariffs τ , and expenditure levels X are obtained from the GTAP database. We perfectly match final goods expenditure, sectoral bilateral trade flows (aggregating intermediate and final goods trade), and cost shares for intermediates and bilateral tariffs. Two adjustments to the data are necessary to align it with the assumptions of the model. The first adjustment regards differences in bilateral trade shares between final and intermediate goods trade. The second adjustment concerns the international transport sector. In the model, the bilateral trade shares are assumed to be identical across use categories. In the GTAP data, however, bilateral trade shares differ across final and intermediate usage. We match sectoral bilateral trade flows, final goods expenditure shares, and the cost shares for intermediates to their empirical counterparts and bilateralize final and intermediate goods trade with the common bilateral trade share. Moreover, GTAP has a separate international transportation sector. To match the iceberg trade cost assumption, we assign the international transport margin and its respective share of intermediate demand to the sectors demanding the international transportation service. This increases the respective sector's production value. Sectoral value added is then calculated as the difference between the so obtained production values and expenditures for intermediate goods, which also implies that we treat production taxes as part of domestic value added.

4.3.3 Identification of Trade Cost Parameters

A key element of our simulation is to distinguish shallow from deep PTAs and estimate their effect on bilateral NTBs. To that end, we classify existing PTAs as shallow or deep

⁴The World Input Output Database (WIOD) constitutes an alternative data source. It provides the same information for a sample of 40 countries and the rest of the world for the years 1995-2011. Since we are interested in trade creation and trade diversion and third country effects, we opted for GTAP in order to maximize country coverage.

⁵An overview of the sectoral breakdown and the aggregation is provided in Table A4.11 in the appendix.



Figure 4.1: Status quo of depth of trade integration

Note: The figure plots the index of depth of PTAs as classified by Dür et al. (2014) for country pairs with a PTA in 2011. The depth index counts the number of provisions and ranges from 0-7. The different provisions are: partial scope agreement, substantive provisions on services, investments, standards, public procurement, competition and intellectual property rights.

based on the number of provisions included in an agreement. Data on the number of provisions is obtained from the Design of Trade Agreements (DESTA) database (see Dür et al., 2014). This database provides an index for the depth of PTAs, which is a count of the number of provisions (partial scope agreement, substantive provisions on services, investments, standards, public procurement, competition and intellectual property rights). The index ranges from 0 to 7, where 0 indicates a partial scope agreement and 7 is the deepest level of integration. We recode this index of depth to obtain two classes of PTAs: shallow and deep agreements. The dummy indicating a shallow PTA switches to one if the index lies between 0 and 3. The dummy for a deep PTA takes the on value one if the index lies between 4 and 7. Figure 4.1 shows the distribution of the depth of existing PTAs for the year 2011. About 16% of the PTAs (i.e., 2,522 bilateral relations out of the 15,700 with a PTA in place) are classified as deep according to our definition; examples include NAFTA, the EU or USA-Korea agreement. The Andean Community, MERCOSUR or ASEAN are examples for shallow agreements.

The vectors of sectoral trade cost parameters $\boldsymbol{\theta}$, $\boldsymbol{\delta}_{deep}$ and $\boldsymbol{\delta}_{shallow}$ can be identified from the gravity equation. Taking the trade share equation (4.2), plugging in the functional

form for trade costs and multiplying by the total expenditure X_n^j yields the following log-linearized estimable gravity equation for each sector j:

$$\ln(\pi_{in}^{j}X_{n}^{j}) = -\frac{1}{\theta^{j}}\ln\tau_{in}^{j} - \frac{\rho^{j}}{\theta^{j}}\ln D_{in} - \frac{\delta_{shallow}^{j}}{\theta^{j}}PTA_{shallow,in} - \frac{\delta_{deep}^{j}}{\theta^{j}}PTA_{deep,in} - \frac{\zeta^{j}}{\theta^{j}}\mathbf{Z}_{in} + \nu_{i}^{j} + \mu_{n}^{j} + \varepsilon_{in}^{j},$$

$$(4.9)$$

where $\nu_i^j \equiv \ln(\lambda_i^j c_i^j)$ and $\mu_n^j \equiv \ln(X_n^j / \sum_{i=1}^N \lambda_i^j [c_i^j \kappa_{in}^j]^{\frac{-1}{\theta^j}})$ are importer and exporter fixed effects, respectively, and ε_{in}^j is an error term.

The coefficient on tariffs directly identifies the productivity dispersion, $1/\theta^j$. The higher $1/\theta^j$, the stronger the response of trade flows to a cost shifter (here, bilateral tariffs). The coefficients of the PTA dummies, $\frac{\delta_{deep}j}{\theta^j}$ and $\frac{\delta_{shallow}j}{\theta^j}$, are expected to be positive, since forming a PTA reduces non-tariff trade barriers, and thus increase bilateral trade. Naturally, we expect $\frac{\delta_{deep}j}{\theta^j} > \frac{\delta_{shallow}j}{\theta^j}$. The change (in percent) in sectoral trade cost due to a deep agreement for countries which previously did not have a shallow agreement implied by the structural equation for trade cost is given by $(e^{\delta_{deep}^j} - 1) * 100$. We estimate Equation (4.9) sector by sector, thus allowing θ^j , $\frac{\delta_{deep}j}{\theta^j}$, and $\frac{\delta_{shallow}j}{\theta^j}$ to be sector-specific.

The importer and exporter fixed effects take care of all, potentially unobserved, countryspecific determinants of bilateral trade flows. However, the estimates of the PTA dummies might still suffer from an endogeneity bias if, for example, countries that trade more with each other are also more likely to sign a PTA. In this case, the PTA dummy would overestimate the trade enhancing effect of a PTA. To account for potential endogeneity, we use an instrumental variables approach. A relevant and valid instrument influences the probability to sign a PTA, but does not affect trade flows through any channel other than the PTA. Baldwin and Jaimovich (2012) propose a contagion index as an instrument. The contagion index rests on the idea that countries are more likely to form a PTA with partners that already have many PTAs with third parties in place. Specifically, the index measures the threat of trade diversion country i faces in a trade partner j's market, by counting j's PTAs with third countries weighted with how important the third country's market is for i (i.e. with the third country's share in i's exports).⁶ We compute separate contagion indices for shallow and deep PTAs.

Our estimations for the agricultural and manufacturing sectors are based on productlevel (HS 6-digit) trade data from UN COMTRADE. The sample is restricted to the GTAP countries. Data on bilateral tariffs for manufacturing sectors are taken from UNCTAD's

⁶This instrument is, for example, also used by Martin et al. (2012).

TRAINS database. We use effectively applied tariffs including estimated ad-valorem equivalents of specific tariffs and quotas. We run separate regressions for our (partly aggregated) GTAP sectors, using product fixed effects to absorb unobserved heterogeneity. Other trade cost proxies, i.e., bilateral distance and a dummy for contiguity, are obtained from the CEPII distance database. We drop 0.5% of observations with the highest tariffs from the sample. Trade and tariff data are 5-year averages centered around 2011. For the service sectors we use sector-level trade flows from the GTAP database.

Table 4.1 displays the IV gravity results for the productivity dispersion and the PTA effects for the 4 agricultural and 18 manufacturing sectors. In general, our estimations can explain between 25 and 55% of the variation in bilateral trade volumes. The coefficients on tariffs satisfy the theoretical restriction $1/\theta^j < -1$ and are highly statistically significant. Except for the "Mining (coal, oil and gas)" sector, where the number of observations is also quite small. The ranking of sectors in terms of their productivity dispersion seems sensible in most cases. Sectors like "Petroleum, coal products," "Chemical, rubber, plastic products," or "Mining," which produce fairly homogenous goods have a low θ , implying that trade flows react relatively strongly to cost changes. Sectors like "Wearing apparel," 'Electronic equipment," or "Metal products," on the other hand, have a relatively high θ which indicates that they provide more differentiated sectoral varieties. We find strong effects of deep PTAs on bilateral trade: Coefficients range between .16 in the "Mineral products nec" industry and .9 in the "Motor vehicles and parts" industry. These estimates imply that deep PTAs increase trade by 17 to 145%, depending on the sector.⁷ We also find some evidence that shallow PTAs increase trade, at least in the manufacturing sectors. In other sectors, mostly the agricultural ones, the shallow PTA effect is not statistically different from zero. For "Cattle, sheep, goats, horses" we actually find a negative effect of shallow PTAs that is significant and in the Mining sector we find an implausible large effect of shallow PTAs. The coefficients on other trade cost proxies (as shown in Table (A4.12)) are as expected. Distance reduces bilateral trade volumes. A common border, common language and a shared colonial past tend to increase trade.

We also estimate the same specification with OLS. The resulting productivity dispersion estimates and their ranking are fairly similar to the IV results, the PTA effects obtained from OLS are smaller; see Table A4.14 in the Appendix. This result is well documented in the literature; For example, Egger et al. (2011) also find that, counterintuitively,

⁷The trade-enhancing effect implied by a coefficient estimate of .16 is calculated as $(e^{.16} - 1) * 100$.

unobservable determinants of PTAs seem to be negatively correlated with bilateral trade volumes. Consequently, OLS estimates of PTA dummies are downward biased.⁸

Table 4.2 provides IV gravity results for PTA effects in service sectors.⁹ In general, our specifications explain between 90 and 97% of the variation in bilateral service trade flows. We find that both shallow and deep PTAs have large and significant effects on trade flows. The magnitudes of the implied effects of deep agreements on trade range between 13 and 79%, for the shallow agreements the range is 14 to 30%. Using OLS instead of IV yields significantly smaller or insignificant effects for the PTA dummies, as shown in Table A4.15 in the Appendix. Since there are no tariffs levied on service trade, we cannot identify θ^{j} in service industries. In the simulations, we use an average value from Egger et al. (2012), who estimate a trade cost elasticity for services of 5.959. Moreover, we do not observe positive trade flows in the service industry "Dwellings;" hence, no PTA effects are estimated for this sector. We set the change in trade cost in this sector to zero in the simulations.

Remember that the structural interpretation of the coefficient for a deep PTA is $-\frac{\delta_{\text{deep}}j}{\theta^j}$, the combined effect of a deep PTA on non-tariff barriers and the effect of trade cost on trade flows. With the estimated θ s, we can thus back out the implied effect of PTAs on trade cost. Figure 4.2 shows the reductions in NTBs implied by our IV estimates. The grey bars show equal-tailed 95% confidence intervals obtained by means of a bootstrap that will be described in more detail below.

There is substantial heterogeneity across sectors: Trade cost reductions tend to be larger in manufacturing sectors, varying between 43% in the "Ferrous metals" industry and 5% in "Machinery nec" and "Minerals." In the agricultural sectors, we find significant trade cost reductions only for "Grains & Crops." In the service sectors, trade cost reductions range between 4 and 9%, being largest in "Business services," "Financial services," and "Trade services."

In our counterfactual analysis we assume that the TTIP will reduce the costs of nontariff measures by the same amount that other PTAs have reduced trade barriers in the past. Hence, we do not need to speculate about the changes in NTBs, and potential sectoral heterogeneity therein, that may result from the implementation of the TTIP.

⁸For a brief survey on the size of existing PTA estimates in the literature see Felbermayr et al. (2015a).

⁹Table A4.13 in the Appendix presents the complete results including the coefficient estimates for the covariates. In stark contrast to goods flows, distance seems to be irrelevant as a trade cost indicator for most service sectors. A shared colonial past and a common border, on the other hand, strongly increase trade in services.

Sect		$\frac{(1)}{\operatorname{Ln} \tan}$	$\operatorname{riff}_{\operatorname{s.e}}^{(2)}$	$\begin{array}{c} (3) \\ \text{Shallow} \\ -\delta/\theta \end{array}$	${ m PTA}_{ m S.P}$	$\begin{array}{c} (5) \\ Deep \end{array} \\ - \delta / \theta \end{array}$	PTA BTA	(7) Obs.	$\mathbf{R}^{(8)}_{2}$	(9) Weak-ID F-stat	(10) Under-ID n-value
200	10	0 / T		0/0	0.0	0/0				n mn cr_ T	h-vanc
	Grains & Crops	-2.310^{***}	0.148	0.249^{**}	0.106	0.401^{***}	0.118	243,624	0.29	346	0.00
2	Cattle, sheep, goats, horses	-2.441^{***}	0.163	-0.261^{**}	0.116	-0.204	0.125	90,274	0.34	458	0.00
က	Forestry	-3.385^{***}	0.553	-0.024	0.156	0.086	0.150	22,304	0.32	347	0.00
4	Fishing	-3.156^{***}	0.657	-0.182	0.210	0.076	0.209	28,274	0.30	148	0.00
ю	Mining (coal, oil, gas)	-6.021	4.199	1.269^{**}	0.591	0.830	0.542	6,669	0.41	98	0.00
9	Minerals nec	-3.695^{***}	0.690	0.357^{**}	0.144	0.364^{***}	0.129	85,350	0.25	244	0.00
7	Livestock & Meat Products	-2.498^{***}	0.093	0.188^{**}	0.082	0.289^{***}	0.091	531,429	0.30	471	0.00
∞	Textiles	-4.913^{***}	0.285	0.079	0.092	0.294^{***}	0.082	801,095	0.32	322	0.00
6	Wearing apparel	-1.613^{***}	0.398	-0.023	0.113	0.502^{***}	0.106	699,145	0.46	282	0.00
10	Leather products	-2.939^{***}	0.299	0.208^{**}	0.095	0.637^{***}	0.093	175,800	0.45	485	0.00
11	Wood products	-2.774^{***}	0.263	0.073	0.075	0.476^{***}	0.077	175,800	0.45	485	0.00
12	Paper products, publishing	-4.697^{***}	0.241	0.146^{*}	0.079	0.526^{***}	0.078	223,734	0.45	672	0.00
13	Petroleum, coal products	-5.463^{***}	1.220	0.807^{***}	0.186	0.672^{***}	0.205	317,824	0.42	636	0.00
14	Chemical, rubber, plastic prods	-4.743^{***}	0.218	0.201^{***}	0.071	0.317^{***}	0.072	22,745	0.39	480	0.00
15	Mineral products nec	-2.804^{***}	0.225	0.081	0.078	0.157^{**}	0.073	1,544,089	0.34	551	0.00
16	Ferrous metals	-1.187^{***}	0.368	0.188^{*}	0.102	0.665^{***}	0.093	337,582	0.37	535	0.00
17	Metals nec	-3.691^{***}	0.452	0.611^{***}	0.121	0.752^{***}	0.102	302, 429	0.32	355	0.00
18	Metal products	-2.167^{***}	0.226	0.247^{***}	0.080	0.307^{***}	0.078	182,487	0.34	256	0.00
19	Motor vehicles and parts	-3.670^{***}	0.239	0.296^{***}	0.091	0.896^{***}	0.101	628,789	0.47	660	0.00
20	Transport equipment nec	-2.315^{***}	0.287	0.136	0.089	0.409^{***}	0.086	157,463	0.54	650	0.00
21	Electronic equipment	-2.184^{***}	0.231	0.467^{***}	0.078	0.242^{***}	0.081	112,560	0.38	466	0.00
22	Machinery and equipment nec	-3.181^{***}	0.166	0.196^{***}	0.066	0.175^{***}	0.062	320, 393	0.53	776	0.00
23	Manufactures nec	-2.275***	0.204	0.169^{**}	0.077	0.251^{***}	0.076	2,212,282	0.46	720	0.00
				-	•	11:				- 17 -	
	Note: Ine table snows gravity controls (not shown) Standard	estimates for errors (in par	agricultur antheses)	are robust to	nacturing A chisterin	sectors with of on country	ı ımporter v-nair level	and exporter PTA dumm	· aummie: iies instru	s and the usu mented with a	al gravity contaoion
	indices a la Martin et al. (2012)	or Baldwin an	d Jaimov	ich (2012) fo	or the resne	ective denth	s. Shea's F	artial R ² is 0	1.19 for sh	allow and 0.2:	3 for deen
	PTAs. *, ** and *** indicate st	atistical signif	ficance at	the $10, 5$ and	d 1% level	, respectivel	y.				

 Table 4.1: IV gravity estimates manufacturing sectors

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		(1)	(2)	(3)	(4)	(5)	(9)	(2)	(8)
		Shallow	PTA	$\tilde{D}eep$]	PTÀ	\hat{Obs} .	$ { {R}}^2$	Weak-ID	Under-ID
		$-\delta/ heta$	s.e.	$-\delta/ heta$	s.e.			F-stat	p-value
25	Gas manufacture, distribution	0.141^{**}	0.062	0.389^{***}	0.089	13,546	0.97	877	0.00
26	Water	0.229^{***}	0.031	0.377^{***}	0.053	11,368	0.95	673	0.00
27	Construction	0.169^{***}	0.064	0.302^{***}	0.081	14,434	0.96	949	0.00
28	Trade	0.129^{***}	0.037	0.580^{***}	0.056	14,518	0.90	927	0.00
29	Transport nec	0.182^{***}	0.032	0.399^{***}	0.050	14,518	0.96	927	0.00
30	Sea transport	0.024	0.055	0.413^{***}	0.075	14,518	0.95	927	0.00
31	Air transport	0.175^{***}	0.040	0.123^{**}	0.055	14,518	0.92	927	0.00
32	Communication	0.221^{***}	0.031	0.294^{***}	0.051	14,518	0.95	927	0.00
33	Financial services nec	0.160^{***}	0.040	0.490^{***}	0.060	14,518	0.95	927	0.00
34	Insurance	0.152^{***}	0.033	0.338^{***}	0.054	14,518	0.95	927	0.00
35	Business services nec	0.267^{***}	0.035	0.559^{***}	0.054	14,518	0.96	927	0.00
36	Recreation and other services	0.142^{***}	0.037	0.238^{***}	0.052	14,518	0.96	927	0.00
37	PubAdmin/Defence/Health/Education	0.178^{***}	0.036	0.367^{***}	0.057	14,518	0.95	927	0.00
Note:	All specifications include importer and exporte	er fixed effect	ts and the	usual gravit	y controls	(not show)	a). Stand	lard errors (ir	parentheses)
are he *** in	teroskedasticity-robust and clustered at the co- dicate statistical significance at the 10, 5 and 1	ountry-pair le 1% level, resj	vel. Shea pectively.	's Partıal K⁴	is 0.114 f	or shallow	and 0.16	5 tor deep P'I	As. *, ** and

 Table 4.2: IV gravity estimates service sectors



Figure 4.2: Implied changes in NTBs

Note: The figure shows sectoral reductions in NTBs implied by the coefficient estimates from the gravity equation (4.9) presented in Tables 4.1 and 4.2. (Equal-tailed) confidence intervals are computed based on 425 bootstrap replications using Hall (1992)'s percentile method.

Moreover, we acknowledge in our simulation the fact that the trade cost changes and the sectoral productivity dispersion parameters are estimated. Uncertainty about parameter estimates θ , $\delta_{shallow}$, δ_{deep} derives from the fact, that the dataset based on which they are estimated is itself just a random draw of the underlying data generating process characterized by the true values of θ_0 , $\rho_{0,shallow}$, $\rho_{0,deep}$. The trade cost changes displayed in Figure 4.2, and, in fact, all outcomes of our simulation, are more or less complicated functions of the estimated parameters and hence, they are random variables as well. To obtain measures of uncertainty, that is, confidence intervals, for the model outcomes, we bootstrap an empirical distribution of the θ , $\delta_{shallow}$, δ_{deep} . That is, we draw 425 bootstrap samples (independently for every sector), estimate θ_b , $\delta_{b,shallow}$, $\delta_{b,deep}$ and collect the 425

sets of estimates.¹⁰ For every set of parameters b = 1, ..., 425, we then simulate the effects of the TTIP and collect the variables of interest, such as changes in trade flows, output, and welfare. Thereby, we obtain a distribution of every model outcome reflecting the uncertainty present in our estimation stage, or, in fact, the uncertainty present in the data. Throughout the analysis, we calculate confidence intervals according to the percentile method proposed by Hall (1992).¹¹

4.4 Simulation Results: Trade and Welfare Effects of the TTIP

We now have paved the way to simulate the effect of the TTIP. Our scenario of a "deep TTIP" assumes that NTBs to trade between EU countries and the United States fall by the amount estimated in the previous section and that all tariffs between the EU and the United States are set to zero. A slight complication regarding the calibration of the model based on data from 2011 is caused by Croatia's entry into EU in July 2013. In our 2011 data, Croatia is not yet an EU member, however, it will be part of the TTIP. In order not to confound the effects of the TTIP with the effects of Croatia's EU accession, we simulate a counterfactual baseline equilibrium describing the world in 2011 if Croatia had been a member already at that time.¹² Based on this counterfactual equilibrium, we then evaluate the effects of the TTIP. Except for Croatia and its neighboring countries, the change from the 2011 equilibrium to the counterfactual baseline with Croatia in the EU has negligible effects on the status quo of the countries in our analysis.¹³

We start our discussion of the effects of the TTIP with a summary of the status quo. Then, we present the simulation results, starting with the effects on global and bilateral trade in terms of gross flow and value added and analyze the role globally fragmented value chains in spreading the TTIP's effects across the globe. Next, we discuss how sectoral value added is affected in different parts of the world. Finally, we investigate the regional and global welfare changes that the TTIP would bring about.

¹⁰Since we expect standard errors to be correlated within country pairs, we conduct a block bootstrap within each sector, drawing country pairs instead of individual observations.

¹¹Hall's percentile method uses the quantiles of the bootstrapped distribution of the $\theta - \theta^b$ rather than just the quantiles θ^b to form confidence bounds, which ensures that the coverage probability is correctly captured if the distribution of the original estimate θ is asymmetric.

¹²2011 is the most recent year for which input-output data for the 140 countries/regions is available. We do not predict baseline values for some future year, as Fontagne et al. (2013) or Francois et al. (2013), since this would introduce additional margins of error.

 $^{^{13}\}mathrm{Details}$ are available from the authors upon request.

4.4.1 Cross-industry facts for the EU and the United States

Tables 4.3 and 4.4 provide information on the status quo of trade between the EU and the United States. All values are in US dollars and relate to the base year of 2011 including the model-based predicted adjustments for Croatia's EU entry. Column (1) of Table 4.3 reports, by sector, the value added generated in the EU. 72% of total value added (GDP) is generated in the service sectors, 25% in manufacturing, and 2% in agriculture. Columns (2) and (5) show that total EU exports to the United States amount to 521 bn. US dollars which equals about 8% of total exports (excluding trade among EU countries). However, in value added terms, exports of 448 bn. US dollars to the United States account for more than 10% of the total.¹⁴ This signals that EU exports to the United States incorporate relatively little reexports of foreign value added (including value added that was previously imported from the United States in the form of intermediates). Column (4) provides trade-weighted sector-level tariff rates that EU exporters face in the United States. These tariffs are low; the trade-weighted average rate (excluding services trade) is just 1.3%. Exports to the world (Column 7) encounter very similar tariff rates; thus, earlier rounds of (multilateral) trade liberalization have not particularly favored EU exports to the United States. Columns (5) and (6) report EU exports to the world. The comparison with Columns (2) and (3) shows that the United States is a particularly important market for EU services exporters: In the majority of service sectors the share of total exports going to the United States exceeds the 10% average (in VA terms) by a wide margin. The opposite is true in the agri-food sectors. The share of exports from manufacturing sectors going to the United States is also below the 10% average in most case.

Table 4.4 provides similar descriptive statistics for the United States. It shows that services industries in the United States account for an even larger share in total value added than in the EU (82%). The share of the agri-food sectors in total value added is comparable to the EU (2%). The United States is slightly smaller in terms of GDP (15,257 bn. vs. 16,186 bn.) and less open; domestic value added embodied in foreign absorption relative to domestic GDP amounts to 9%; in the EU the ratio equals 27%. The EU has a bilateral surplus with the United States of 31 bn. USD in gross terms and of 62 bn. USD in value added terms. This signals that a lot of EU value added reaches the United States via third countries. Moreover, exports to the EU are much more important for the United States (26% of total) than exports to the United States are for the EU (10%). Average tariffs faced by US exporters in the EU are slightly larger than vice versa. The correlation between the two tariff schedules across sectors is relatively high (.3).

 $^{^{14}\}mathrm{Value}$ added exports to the EU reflect European value added embodied in US.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Sector	Value	Èxp	orts to	U.S.	Éxpo	orts to V	Vorld*
	added	Gross	VA	Tariffs	Gross	VA	Tariffs
	(in b	on. USI	D)	(in %)	(in bn.	USD)	(in %)
Grains & Crops	172	1	3	2.97	99	75	0.68
Cattle, sheep, goats, horses	169	1	2	1.20	85	49	1.18
Forestry	32	0	1	0.48	6	17	0.26
Fishing	17	0	0	0.36	8	6	0.06
Mining (coal, oil, gas)	83	1	5	0.10	33	50	0.05
Minerals nec	45	0	3	0.04	42	29	0.02
Livestock & Meat Products	495	20	11	2.51	336	153	2.19
Textiles	92	4	3	5.96	98	48	6.98
Wearing apparel	93	3	1	10.32	71	32	10.37
Leather products	47	3	2	7.30	54	25	12.40
Wood products	89	4	4	0.34	103	50	0.36
Paper products, publishing	284	5	9	0.01	154	115	0.00
Petroleum, coal products	258	16	13	1.61	189	121	0.85
Chemical, rubber, plastic prods	600	100	54	1.33	1,059	440	1.18
Mineral products nec	149	5	4	4.11	80	54	2.93
Ferrous metals	112	8	7	0.19	193	84	0.21
Metals nec	68	8	5	1.73	173	56	0.53
Metal products	285	7	13	1.77	169	146	1.57
Motor vehicles and parts	289	42	16	1.15	676	194	0.56
Transport equipment nec	106	24	9	0.12	184	64	0.46
Electronic equipment	143	10	7	0.30	242	92	0.18
Machinery and equipment nec	701	89	49	0.86	1,043	452	0.79
Manufactures nec	133	14	6	0.92	92	46	1.03
Electricity	294	0	8	0.00	35	95	0.00
Gas manufacture, distribution	21	0	0	0.00	3	6	0.00
Water	45	0	1	0.00	1	8	0.00
Construction	1,053	1	4	0.00	53	62	0.00
Trade services	1,123	7	15	0.00	162	158	0.00
Transport nec	516	17	20	0.00	139	181	0.00
Sea transport	32	1	2	0.00	66	24	0.00
Air transport	84	19	8	0.00	141	53	0.00
Communication	387	5	12	0.00	62	103	0.00
Financial services nec	570	25	25	0.00	144	163	0.00
Insurance	155	25	11	0.00	74	40	0.00
Business services nec	2,421	31	85	0.00	493	830	0.00
Recreation and other services	535	6	8	0.00	87	93	0.00
PubAdmin/Defence/Health/Education	3.359	19	21	0.00	95	138	0.00
Dwellings	$1,\!127$	0	0	0.00	0	2	0.00
Total	16 186	521	448	1 33	6 744	4 351	1 37

 Table 4.3:
 Status quo summary statistics:
 EU28

Note: The table shows aggregate sectoral value added, exports and value added exports to the United States and the world in the baseline equilibrium (2011 with Croatia in the EU), and the respective tariffs for the EU28; Average tariffs in the last row reflect trade-weighted averages of tariffs in manufacturing and agriculture. * EU exports to World exclude intra-EU trade.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Sector	Value	Expo	orts to	EU28	Exp	orts to V	Norld
	added	Gross	VA	Tariffs	Gross	VA	Tariffs (* 07)
	(in	bn. USI	J)	(1n %)	(in bn.	USD)	(1n %)
Grains & Crops	130	6	5	3.38	91	52	2.61
Cattle, sheep, goats, horses	84	1	1	23.78	25	11	27.89
Forestry	13	0	0	1.12	3	2	0.23
Fishing	5	0	0	7.86	1	1	2.76
Mining (coal, oil, gas)	229	6	21	0.00	19	72	0.00
Minerals nec	29	2	3	0.02	12	11	0.01
Livestock & Meat Products	230	6	4	11.09	58	26	7.73
Textiles	62	2	2	6.01	17	10	5.32
Wearing apparel	32	1	0	10.42	4	1	7.28
Leather products	6	1	0	3.68	3	1	7.39
Wood products	121	2	2	0.98	13	10	0.66
Paper products, publishing	245	6	9	0.02	40	40	0.01
Petroleum, coal products	42	35	4	1.78	137	13	0.51
Chemical, rubber, plastic prods	422	75	40	2.13	282	151	1.57
Mineral products nec	77	3	3	3.08	14	13	3.06
Ferrous metals	75	2	5	0.42	30	25	0.18
Metals nec	45	15	6	1.92	52	21	0.88
Metal products	167	6	7	2.08	34	35	1.69
Motor vehicles and parts	143	12	4	7.88	120	29	4.26
Transport equipment nec	117	34	16	1.17	93	46	1.27
Electronic equipment	77	18	5	0.56	97	20	0.94
Machinery and equipment nec	536	63	37	1.29	314	172	1.19
Manufactures nec	48	8	4	.91	25	11	1.20
Electricity	195	0	5	0.00	1	18	0.00
Gas manufacture, distribution	37	1	1	0.00	2	4	0.00
Water	68	0	1	0.00	1	5	0.00
Construction	923	2	6	0.00	8	24	0.00
Trade services	1.971	7	30	0.00	21	122	0.00
Transport nec	289	20	16	0.00	38	49	0.00
Sea transport	32	1	1	0.00	2	5	0.00
Air transport	86	15	6	0.00	34	17	0.00
Communication	326	7	$\tilde{7}$	0.00	14	21	0.00
Financial services nec	1.172	33	35	0.00	$\overline{57}$	$\bar{96}$	0.00
Insurance	322	6	5	0.00	21	$\tilde{20}$	0.00
Business services nec	1.534	60	69	0.00	115	202	0.00
Recreation and other services	501	$\tilde{12}$	7	0.00	35	21	0.00
PubAdmin/Defence/Health/Education	3501	23	20	0.00	$\overline{79}$	69	0.00
Dwellings	1.367	<u> </u>	$\tilde{0}$	0.00	0	0	0.00
	1,001			0.00	1.010		0.00
Total	15.257	490	386	2.17	1.912	1.448	1.87

Table 4.4: Status quo summary statistics: United States

Note: The table shows the United States' sectoral value added, exports and value added exports to the EU28 and the world in the benchmark equilibrium (2011 with Croatia in the EU), and the respective tariffs. Average tariffs in the last row reflect trade-weighted averages of tariffs in manufacturing and agriculture.

	Initial Exports (in bn. USD)	G (in %)	rowth 95% CI	Initial share $(in \%)$	Change (in %pts.)	$e \text{ in share} \\ 95\% \text{ CI}$
Agriculture Manufacturing Services	$725 \\ 16,079 \\ 3,352$	$\begin{array}{c} 0.38 \\ 1.71 \\ 5.06 \end{array}$	$\begin{bmatrix} 0.10, 0.63 \\ 1.32, 1.93 \\ 3.84, 6.08 \end{bmatrix}$	$3.60 \\ 79.77 \\ 16.63$	-0.06 -0.40 0.46	$\begin{matrix} [-0.08, -0.05] \\ [-0.56, -0.23] \\ [0.29, 0.63] \end{matrix}$
Total	20,157	2.22	[1.82, 2.45]	100	0.00	-

Table 4.5: Global trade effects of the TTIP by broad sector

Note: Exports valued in fob-terms. (Equal-tailed) confidence intervals are computed based on 425 bootstrap replications using Hall (1992)'s percentile method.

4.4.2 Global Trade Effects of the TTIP

Reflecting the official ambitions for the TTIP, our counterfactual scenario assumes that all transatlantic tariffs are eliminated. Moreover, we assume that NTBs between the United States and the EU are reduced by the same amount as in existing deep PTAs. Table 4.5 presents the changes in aggregate trade patterns implied by the model. World trade is predicted to increase by about 2.2%.¹⁵ The model also predicts that the TTIP affects the sectoral composition of aggregate trade flows. The strongest trade growth occurs in the service sector, where the predicted increase is 5%. This increases the share of service trade in total trade, which was initially at 17%, by .5 percentage points, at the expense of the shares of manufacturing and agricultural goods. However, trade in manufacturing and agriculture also increases in absolute terms, by 1.7 and .4%, respectively. Irrespective of the considerable amount of uncertainty around the precise trade cost reduction implied by the data as visualized in Figure 4.2, the changes in trade aggregate patterns predicted by the model are all significantly different from zero.

The predicted growth in gross trade, however, is not indicative of the growth in world GDP (or value added) induced by the TTIP. Trade in intermediates – which are used to produce traded goods in consecutive stages of production and might thus cross borders multiple times – drives a wedge between the trade volume registered at customs and the value added content of countries' exports. More specifically, trade in intermediate goods leads to double counting of value added from upstream stages of production. Table 4.6 shows that in the baseline equilibrium value added worth 14.4 tn. US dollars (10% of world GDP) was exported, that is, absorbed (consumed or invested) in a country other than the country of origin. Comparing this number to the recorded trade volume of 20.2 tn. US dollars (Column (1) in Table 4.5), we find a value added export to export (VAX)

¹⁵Note that intra-regional trade in GTAP's "Rest of ..." regions is not included in this number.

	Va	VAX ratio			
	Initial	Share	Growth w. TTIP	Initial	With TTIP
	(in bn. USD)	(in %)	(in %)	(in %)	(in %)
Agriculture	746	5.2	0.2	102.9	102.7
Manufacturing	8,246	57.4	1.3	51.3	51.1
Services	$5,\!374$	37.4	2.8	160.3	156.8
Total	14,366	100.0	1.8	71.3	71.0

Table 4.6: Global value added trade effects of the TTIP by broad sector

ratio of 71.3%. Thus, almost 30% of the trade volume measured at customs is doublecounted value added. With the TTIP, our model predicts value added trade to increase by 1.8%.¹⁶ Hence, growth in world value added trade induced by the TTIP falls behind growth in world gross exports; the VAX ratio declines slightly. Presumably, the TTIP increases the extent of double-counting of value added in trade statistics, because it leads to more back-and-forth trade of intermediates among the TTIP countries.

Decomposing total value added trade into manufacturing, services and agricultural value added reveals that services trade is more important than recorded trade flows would suggest. Even though manufacturing value added accounts for the largest part of exported value added (57%), its share is much smaller than the share in recorded trade flows (80%). The VAX ratio of manufacturing is only 51%, indicating that manufacturing trade partly takes place in the form of intermediates trade and that traded manufacturing goods embody a significant amount of value added from the services industries. Indeed, while the recorded services trade is about 3.4 bn. USD, the value added from the services sectors embodied in global trade amounts to 5.4 bn. USD. Services thus account for 37% of exported value added, but only for 17% of recorded trade volumes. Accordingly, the VAX ratio for services is very large (160%). Under the TTIP, agricultural, manufacturing and services value added trade all grow, but, especially in the case of services, at a much smaller rate than gross trade flows.

4.4.3 Bilateral Trade Effects of the TTIP

Table 4.7 looks into the TTIP's effects on regional trade relationships. Again, we discuss changes in gross trade and trade in value added. Our model predicts a substantial amount of trade creation between the EU and the United States in the long run. EU exports to the United States are expected to increase by 55%, US exports to the EU would go up

¹⁶We do not compute confidence intervals for the value added trade flows because the computational burden is enormous. The computation of value added exports involves inverting a $(140 \times 38) \times (140 \times 38)$ matrix, which would have to be conducted for every bootstrap sample.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)		
Region	$ASEAN^b$	Brazil	Canada	China	EU28	Mexico	$SACU^{a}$	Turkey	USA		
Export gr	owth (in %) from	to								
ASEAN	-0.3	-0.3	-0.7	-0.5	-0.2	-0.9	-0.6	-0.5	-0.7		
Brazil	-0.3	-0.3	-2.0	-0.5	-0.3	-1.9	-0.7	-0.6	-0.5		
Canada	-0.0	-0.1	-0.4	-0.3	-3.8	-1.2	-0.3	-0.4	-1.3		
China	-0.3	-0.2	-0.6	-0.4	-0.2	-0.7	-0.4	-0.4	-1.0		
EU28	-0.7	-0.7	-1.3	-0.7	-0.4	-1.4	-0.8	-0.8	54.5		
Mexico	0.4	0.3	-1.3	0.2	-0.9	-0.6	-0.0	-0.2	-1.5		
SACU	-0.3	-0.1	-1.4	-0.3	-0.4	-0.6	-0.4	-0.6	-2.6		
Turkey	-0.2	-0.2	-1.6	-0.4	-0.3	-1.3	-0.4	-0.3	-1.2		
USA Č	-1.1	-1.0	-1.6	-1.0	58.5	-1.4	-1.1	4.9	-0.5		
Growth of value added transfers (in %) from to											
ASEAN	-0.3	-0.4	-0.1	-0.2	-1.2	0.3	-0.3	-0.4	0.2		
Brazil	-0.4	-0.3	0.2	-0.2	-1.3	0.6	-0.3	-0.5	0.4		
Canada	-0.6	-0.8	-0.3	-0.5	2.1	-0.7	-0.6	-0.2	-1.7		
China	-0.5	-0.5	-0.4	-0.3	-1.2	0.3	-0.3	-0.6	0.4		
EU28	-0.6	-0.4	4.8	-0.2	-0.4	11.9	-1.7	-1.1	46.9		
Mexico	-1.0	-1.0	-1.3	-0.8	3.9	-0.5	-0.7	-0.2	-2.2		
SACU	-0.6	-0.6	-0.0	-0.4	-1.8	0.9	-0.3	-0.9	3.5		
Turkey	-0.6	-0.5	1.5	-0.4	-1.7	3.7	-0.6	-0.3	8.0		
USA Č	0.0	-0.1	-1.8	-0.6	40.5	-1.7	0.4	5.2	-0.3		

 Table 4.7: Aggregate trade effects of the TTIP

Note: Diagonals describes changes in intra-national trade and/or in the trade volume within a region. ^a Southern African Customs Union, ^b Association of Southeast Asian Nations.

by 59%. However, trade statistics exaggerate the actual transfer of value added between the two transatlantic regions. EU value added exports to the United States are predicted to increase only by 47%, US value added exports increase by 41% under the TTIP. This implies that the VAX ratio of EU exports to the United States declines from 86% (as implied by the last row of Table 4.3) to 78%. Similarly, the VAX ratio of US exports to the EU declines from 79 to 61%. This suggests that the TTIP leads to a deepening of transatlantic production chains. Intensified intermediate goods trade between the EU and the United States will lead to a higher foreign value added content of production, increase the extent of double-counting as well as the value added from either of the two partners that is processed by the other and sold to third parties. All these factors contribute to the wedge between recorded trade volumes and actual value added transfers.

The fact that the TTIP countries engage in global production sharing along the value chain implies that the economic consequences of trade diversion are only partially captured by changes in the pattern of bilateral trade flows with non-TTIP countries. Table 4.7 shows that the EU and the United States are predicted to export less to and import less from non-TTIP countries. In value added terms, however, the picture is more nuanced. In particular, the predicted patterns show how the growing transatlantic production network interacts with the existing North American and European production network. Even though the EU exports less to Canada (-1.3%), Canadian absorption of European value added increases by 4.8%. We find a similar pattern for the EU's trade with Mexico. This pattern emerges because, with the TTIP, relatively more value added from the EU enters production in the United States embodied in intermediates, that will then be absorbed in Canada and Mexico who trade intensively with the United States. Vice versa, the EU absorbs more Canadian and Mexican value added, which reaches the EU embodied in US exports. Canadian value added exports to the EU increase by 2.1%; compared to a decrease in Canadian exports of -3.8%.

The EU, on the other hand, has production networks, for example, with Turkey and South Africa. Even though exports from the Southern African Customs Union to the United States fall by 2.6%, the SACU value added exports to the United States increase by 3.5%. Another interesting case is the United States'United States trade relationship with Turkey. Turkey is in a customs union with the EU, and so the Turkish import tariffs on US products would also be eliminated under the TTIP. Thus, US exports to Turkey are stimulated and increase by 4.9%. The asymmetric nature of the Turkish currency union with the EU becomes evident when looking at Turkey's exports to the United States. The United States does not eliminate its import tariffs on Turkish products with the TTIP, and hence, Turkish exporters suffer from trade diversion on the US market. Turkish exports to the United States fall by 1.2%. But indirectly (presumably due to strong input-output linkages with the EU), Turkish value added exports to the United States still grow by 8%.

Table 4.7 also shows that the TTIP will lead to trade diversion within the EU. Intra-EU trade both in gross terms and in terms of value added falls by .4%. The TTIP tends to reduce trade flows between third countries. But in some cases, it stimulates trade among third countries, such as, for example, Mexico's export to Brazil, China, and the ASEAN countries are expected to increase. This ambiguity is due to three potentially opposing effects: first, income in third countries can rise or fall and thus impact imports through a general demand effect; second, trade may rise as exports that went to the EU or the United States in the baseline situation are redirected; and third, wage increases in the TTIP countries enhance the relative competitiveness of other exporters in third markets.

Summarizing, trade and value added trade changes mostly follow similar patterns. However, there are some important exceptions where recorded and value added trade flows change disproportionately or even go in different directions. This is the result of newly forming or existing international production chains. These findings highlight that using a model with input-output relationship that can capture the interconnectedness of countries and sectors in the global value chain is vital for an analysis of structural economic changes such as the integration of regional markets.



Figure 4.3: Sectoral composition of EU exports and value added exports to the United States

Note: Only sectors with shares in total output above 1% are displayed.

4.4.4 Sectoral Trade Effects

Figure 4.3 shows the sectoral composition and evolution of the EU's exports to the United States under the TTIP. Sectors are arranged in descending order of their trade volumes and only sectors with initial trade shares above 1% are shown. The light grey bars depict initial export volumes, the squares show the counterfactual export volume growth with the TTIP. In gross terms, the EU's most important export sector with respect to the United States is "Chemicals," followed by "Machinery," "Motor Vehicles," and "Business services." Exports from all sectors increase with the TTIP, but there is great heterogeneity across sectors. Large growth in exports occurs in the manufacturing sectors "Motor vehicles," "Metals nec," and "Ferrous Metals," and in "Petroleum, Coal." Exports of "Trade services," "Financial services," and "Business services" are also predicted to increase substantially.



Figure 4.4: Sectoral composition of US exports and value added exports to the EU

Note: Only sectors with shares in total output above 1% are displayed.

Figure 4.3 also shows the EU's sectoral value added exports to the United States in the initial situation (dark grey bar) and the counterfactual growth with the TTIP (black dot). Interestingly, in value added terms, the EU's top export sector is no longer "Chemicals," but rather "Business services." As discussed earlier, a lot of service value added is traded indirectly, embodied in the exports and imports of tradable goods. Accordingly, growth in value added exports is significantly smaller compared to growth in gross exports in the manufacturing sectors. In the service sectors the two are commensurate. Nevertheless, the manufacturing sectors "Motor vehicles," "Metals nec," and "Ferrous Metals," as well as "Petroleum, Coal" experience the highest growth rates also in valued added terms.

Figure 4.4 shows a similar graph for US exports to the EU. As for the EU, "Chemicals" is the United States' most important export sector in gross terms, but "Business services" account for the largest part of US value added absorbed in the EU. Export growth is predicted to be extremely large in the "Motor vehicles" sector (250%). Moreover, US exports

are predicted to increase substantially in "Metals nec," "Mining," "Petroleum, Coal," "Meat products," "Trade services," and "Grains & Crops." These sectors also experience the largest growth rates in terms of value added exports.

4.4.5 Effects on Sectoral Value Added

In this section, we investigate the effects of the TTIP on the sectoral production structure. Table 4.8 shows, by region, the share of agriculture, manufacturing and services in total value added, the predicted change in value added due to the TTIP, and the predicted change in the aggregate sector's share in total value added of the region. Both in the EU and the United States, service industries make up by far the largest part of total value added (73% in the EU and 81% in the United States). Manufacturing is thus more important in the EU than in the United States. In Germany, for example, the share of manufacturing is 26.2% and higher than in most developed economies. Agricultural value added plays a minor role for both TTIP countries. Our simulations predict that the TTIP leads to a slight reindustrialization in the EU. The share of manufacturing value added in total value added increases by 0.1 percentage points, on average. Service industries and agriculture lose a small share in total value added. In the United States, the sectoral output structure changes very little.

Table 4.8 also shows that the TTIP leads to deindustrialization in the non-TTIP countries. The share of services in total value added tends to increases to the detriment of manufacturing in all non-TTIP regions with the exception of the countries in the Alianza del Pacifico, who experience a shift away from the manufacturing *and* services towards agriculture, and a few non-TTIP European countries, where both agriculture and manufacturing gain significant output shares. This pattern of deindustrialization versus reindustrialization is also supported by Figure 4.5, which shows distributions of the changes in sectoral shares (manufacturing and services only) across countries, for non-TTIP and TTIP members. The distribution of changes in manufacturing shares for non-TTIP countries (dark grey dashed line) lies to the left of the respective distribution of changes among the TTIP countries (dark grey solid line) and reaches much further into the negative range. The opposite pattern is obtained for the distribution of changes in the service sectors which tend to be positive for the non-TTIP countries (light grey lines).

Within the EU, however, the reindustrialization trend is not universal. Table 4.8 lays out the sectoral changes for the 28 EU countries. The shift towards manufacturing is driven primarily by the Western European economies; Austria, Germany, Belgium, Ireland, Finland, Great Britain, and Sweden. Some Central and Eastern European economies



Figure 4.5: Changes in manufacturing and services shares with the TTIP

Note: The figure shows the density of changes of the share of manufacturing (black lines) and services (grey lines) value added (in percentage points) for the TTIP scenario of deep trade integration distinguished by the TTIP (solid lines) and non-TTIP countries (dashed lines).

like Bulgaria, Cyprus, Slovenia as well as Luxembourg shift production away from manufacturing towards services and, in the case of Bulgaria, towards agriculture.

On the more disagreggated level, sectoral effects are very heterogeneous across countries. Figure 4.6 plots sectoral value added changes for four exemplary countries, the United States, Germany, Canada, and Japan. In every panel, sectors are ordered by their initial shares in total value added of the respective countries, with shares decreasing from left to right. In the United States (upper left panel) all important sectors except for the insurance industry gain. "Mining" value added is predicted to increase strongly, however not significantly so. The large margin of error owes to the fact, that the effect of deep trade agreements on changes in this sector are estimated with low precision (cp. Table 4.1). Germany experiences a huge value added increase in the "Motor vehicles" sector and significant gains in "Metal products," but also small losses in important sectors such as "Transport (equipment) nec" and "Financial services."

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	Υ	griculture		Maı	nufacturing			Services	
		Change	Change		Change	Change		Change	Change
	Initial share	in share	in VA	Initial share	in share	in VA	Initial share	in share	in VA
Region:	(in %)	(in %pts.)	(in %)	(in %)	(in %pts.)	(in %)	(in %)	(in %pts.)	(in %)
TTIP countries EU128	2.4	-0.01*	-0.22	25.1	0.12^{*}	0.77*	72.5	-0.11*	0.14*
$\overrightarrow{\mathrm{USA}}$	1.5	0.00	0.70^{*}	17.7	0.02	0.53^{*}	80.8	-0.02	0.43^{*}
Non-TIP regions				1					
ASEAN	12.2	0.00^{*}	-0.26^{*}	33.5 23.5	-0.05°	-0.45^{*}	54.3	0.05^{*}	-0.20^{*}
AI. del Pacifico	5.3 2.3	0.02*	-0.05	29.8	-0.01	-0.47*	64.9	-0.01	-0.43*
AUS & NZL	0.0 2	0.00	-0.22	19.8	-0.03	-0.47	0.07	0.03	-0.20
Canada	2.4		-0.01	0.22	. JU.U-	-0.08	0.07	0.00	-0.27
Central Asia	11.3	-0.00	-0.34	31.1	-000	-0.01	0.70	0.07	-0.19
China	9.7	0.00	-0.35°	30.3	-0.02	-0.40°	53.9	0.02°	-0.32°
EF IA	1.0	0.00	-0.14°	23.5	-0.09		74.9	0.09	-0.17
East Asia	1.5	0.00^{*}	-0.20^{*}	20.8	-0.04^{*}	-0.58^{*}	$\tilde{51.6}$	0.04^{*}	-0.34^{*}
Eurasian CU	$\frac{4.6}{0}$	0.00	-0.30^{*}	30.4	-0.04°	-0.54^{*}	65.0	0.04^{*}	-0.35°
Central America	9.3	-0.01^{*}	-0.15^{*}	25.5	-0.02*	-0.08	65.2	0.03^{*}	0.04^{*}
MERCOSUR	$\frac{7.3}{2}$	-0.00	-0.29^{*}	21.9	-0.01	-0.30^{*}	10.9	0.01^{*}	-0.26^{*}
Mid.East & N.Africa	8.7	0.00	-0.27^{*}	37.0	-0.06*	-0.45^{*}	54.3	0.06^{*}	-0.17^{*}
Oceania	5.6	-0.00	-0.31°	19.0	-0.10^{*}	-0.80*	75.3	0.11^{*}	-0.11*
Oil exporters	0.9	-0.00	-0.27^{*}	64.3	-0.05*	-0.33*	34.8	0.05^{*}	-0.13^{*}
Rest of Europe	7.7	0.18^{\star}	2.79^{*}	25.0	0.29^{*}	1.57^{*}	67.3	-0.47^{*}	-0.29^{*}
Rest of World	12.1	-0.00	-0.17^{*}	13.6	-0.05*	-0.56^{*}	74.3	0.05^{*}	-0.10^{*}
South Asia	18.5	-0.00*	-0.24^{*}	19.6	-0.04*	-0.42*	61.9	0.04^{*}	-0.17*
South African CU	3.4	0.00^{*}	-0.26*	26.1	-0.05*	-0.53*	70.6	0.04^{*}	-0.30*
Sub-Saharan Africa	28.1	0.00	-0.14^{*}	29.4	-0.01	-0.18	42.6	0.00	-0.14*
Turkey	7.6	0.01^{*}	-0.21*	23.2	-0.03*	-0.42*	69.2	0.02^{*}	-0.26*
Note: * significantly c	lifferent from ze	ero at $\alpha = 5$	% level acc	ording to (equ	al-tailed) cor	ıfidence in	tervals that we	re computed	based on
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	A ₅	griculture		Mar	nufacturing		01	Services	
		Change	Change		Change	Change		Change	Change
	Initial share	in share	in VA	Initial share	in share	in VA	Initial share	in share	in VA
Region:	(in %)	(in % pts.)	(in %)	(in %)	(in $\%$ pts.)	(in %)	(in %)	(in % pts.)	(in %)
AUT	1.8	-0.01^{*}	-0.25^{*}	26.8	0.23^{\star}	1.24^{*}	71.4	-0.21^{*}	0.09^{*}
BEL	1.4	-0.01^{*}	-0.23	24.4	0.22^{*}	1.56^{\star}	74.2	-0.21^{\star}	0.37^{*}
BGR	5.3	0.05^{*}	0.93^{*}	27.7	-0.04*	-0.11	67.1	-0.00	0.05^{*}
CYP	8.3	-0.00	0.03	12.6	-0.07*	-0.45^{*}	79.1	0.07^{*}	0.16^{*}
CZE	3.0	-0.00	-0.03	39.6	0.03^{*}	0.13^{*}	57.4	-0.02*	0.02
DEU	1.4	-0.02^{*}	-0.87*	28.7	0.16^{*}	0.99^{*}	69.8	-0.15^{*}	0.20^{*}
DNK	2.5	-0.01^{*}	-0.32*	24.5	-0.04	0.11	73.0	0.05	0.35^{*}
ESP	3.3	-0.01	-0.45	20.0	0.01	0.02	76.7	0.00	-0.03
\mathbf{EST}	3.6	0.00	0.13	33.3	0.05^{*}	0.28^{*}	63.1	-0.06*	0.02
FIN	2.9	0.00^{*}	0.29^{*}	29.8	0.17^{*}	0.71^{*}	67.4	-0.17^{*}	-0.12^{*}
FRA	2.2	-0.00	0.00	21.6	0.02	0.17^{*}	76.2	-0.02	0.04
GBR	1.0	-0.01*	-0.24^{*}	20.5	0.19^{*}	1.39^{*}	78.5	-0.18^{*}	0.24^{*}
GRC	4.7	-0.00	0.07	21.6	-0.17	-0.65	73.7	0.17	0.37
HUN	5.8	-0.01^{*}	-0.14	38.8	0.02	0.14	55.4	-0.00	0.10
IRL	3.1	-0.07*	-0.41	33.9	1.50^{*}	6.52^{*}	63.0	-1.42^{\star}	-0.29
ITA	2.8	-0.01^{*}	-0.23	26.8	0.09^{*}	0.63^{*}	70.4	-0.07*	0.19^{*}
LTU	9.6	-0.06*	-0.53*	28.7	0.08^{*}	0.33^{*}	61.8	-0.02	0.02
LUX	0.8	-0.02*	-1.83*	17.5	-0.35*	-0.90*	81.7	0.37^{*}	1.57^{*}
LVA	6.3	0.01	0.14	40.4	0.02	0.04	53.3	-0.02	-0.04
MLT	3.3	-0.02*	-0.09	38.8	0.05	0.60	57.9	-0.03	0.40^{*}
NLD	2.6	0.00	0.48^{*}	21.4	0.08^{*}	0.70^{*}	76.0	-0.08*	0.23^{*}
POL	3.6	0.00	0.02	35.2	-0.00	-0.02	61.3	0.00	0.00
PRT	3.2	-0.03*	-0.57	25.3	0.07^{*}	0.49^{*}	71.5	-0.04^{*}	0.16^{*}
ROU	15.8	-0.02^{*}	-0.16^{*}	35.2	-0.01	-0.04	49.0	0.03	0.03
SVK	4.4	-0.01^{*}	0.01	38.2	0.11^{*}	0.42^{*}	57.3	-0.11^{*}	-0.06
SVN	4.3	-0.01*	0.09	31.4	-0.09*	0.01	64.3	0.10^{*}	0.45^{*}
SWE	1.9	-0.00	0.02	23.6	0.21^{*}	1.01^{*}	74.5	-0.21^{*}	-0.17*
Note: * compute	significantly d d based on 425	lifferent from bootstrap re	t zero at e	$\chi = 5\%$ level using Hall (19)	according to 92)'s percent	o (equal-ta bile methoc	uiled) confidenc 1.	ce intervals t	hat were
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Figure 4.6: Sectoral value added: TTIP-induced changes

Note: Equal-tailed confidence intervals based on 425 bootstrap samples and Hall (1992)'s percentile method. Sectors in every panel ordered along shares in total value added, in decreasing order from left to right. Sectors with initial shares in total value added < 1% not shown.

As exemplary TTIP outsiders we show sectoral value added changes for Canada and Japan. In Canada, most of the important sectors experience a decline in value added, most notably in "Motor Vehicles," "Minerals nec," "Machinery nec," and "Metal products." The sectors that gain, "Mining," "Paper products," and "Insurance," tend to be located at early stages of the production chain. This is well in line with the argument laid out above, that third countries gain from the increase in production in the TTIP countries through an increase in the demand for intermediates. In Japan, which is not an important source country of intermediate inputs for the TTIP regions, value added declines in all important sectors.

### 4.4.6 Welfare Effects of the TTIP

Our simulation predicts that the TTIP will bring about significant real income gains for the EU countries and the United States, but also for many other countries. Figure 4.7 presents welfare effects with confidence bands for all countries, Table 4.10 provides numbers for selected individual countries and average effects for the world's regions.¹⁷ In the EU, real income is predicted to go up by .43% on average, in the United States by .49%. Within the EU, Ireland stands out with a predicted real income increase by 3.1%, followed by Luxembourg (1.1%). Moreover, welfare effects within the EU tend to be larger for the Western and Northern European countries and smaller for the Central and Southern European economies. With the exception of Greece, all TTIP countries' predicted gains are significantly different from zero at the 5% level.

Out of the 110 non-TTIP countries, 60 are predicted to gain, and for 50 of them the real income effects are significant at the 5% level. For 33 non-TTIP countries, we find significantly negative predicted welfare effects. Among the non-TTIP winners are many developing countries from Central America, Oceania, South Asia and Sub-Saharan Africa and the primarily developing countries grouped in the "Rest of World." Also, countries close the EU, such as Turkey and the Balkans (collected in the "Rest of Europe") gain from the TTIP. Arguably, the average gains for these regions are small (between .01 and .08), however, these make a strong case against the conjecture that the TTIP would be harmful to the developing world. Increased demand for final and intermediate goods in the TTIP countries counteracts negative trade diversion effects, benefitting countries that are integrated into the TTIP partners production networks or which are important suppliers of raw materials. Trade diversion effects are less problematic for countries whose sectoral

¹⁷Regional effects are weighted averages using real GDP in 2011 as weights.



Figure 4.7: Simulated changes on real income with the TTIP

Note: The figure shows predicted real income changes (in %) for all 140 countries/regions included in our analysis. (Equal-tailed) confidence intervals are computed based on 425 bootstrap replications using Hall (1992)'s percentile method.

		Real income change
	(in %)	95% CI
TTIP Countries	0.46	[0.354,  0.513]
EU28	0.43	[0.313, 0.478]
USA	0.49	[0.396,  0.554]
Non-TTIP Regions	-0.02	[-0.035, -0.004]
ASEAN	-0.01	[-0.021, -0.007]
AUS & NZL	-0.01	[-0.014, 0.001]
Alianza del Pacifico	-0.06	[-0.081, -0.038]
Canada	-0.02	[-0.042,  0.002]
Central America	0.01	[0.001,  0.022]
Central Asia	-0.03	[-0.058,  0.035]
China	-0.03	[-0.033, -0.020]
EFTA	-0.04	[-0.070,  0.018]
East Asia	-0.02	[-0.028, -0.015]
Eurasian CU	-0.11	[-0.195, 0.084]
MERCOSUR	-0.01	[-0.009, 0.002]
Middle East & North Africa	-0.02	[-0.034, 0.023]
Oceania	0.08	[0.064,  0.094]
Oil exporters	-0.10	[-0.149,  0.011]
Rest of Europe	0.06	[0.032,  0.074]
Rest of World	0.05	[0.034,  0.059]
SACU	-0.02	[-0.029, -0.014]
South Asia	0.02	[0.011,  0.031]
Sub-Saharan Africa	0.02	[-0.008, 0.066]
Turkey	0.02	[0.009,  0.033]
World	0.20	[0.155,  0.226]

 Table 4.10:
 Welfare effects by regions

Note: Regional changes are computed as real GDP-weighted averages of country effects. (Equal-tailed) confidence intervals are computed based on 425 bootstrap replications using Hall (1992)'s percentile method.

production structure is complementary to those of TTIP regions, which tends to be true for the less developed economies. This may also explain why welfare effects for Canada are predicted to be negative even though Canada is closely integrated with the United States. The largest losses are expected to occur in the oil-producing countries in the Middle East which compete directly with North American and Central Asian producers in supplying the TTIP regions. Moreover, countries far away from either of the two TTIP regions, such as the East and South East Asian economies including China, Korea, and Japan lose from the TTIP. The industrialized economies in the Far East are likely harmed because their production structure is relatively similar to the TTIP countries. Moreover, because of their remoteness, these countries are of less importance to the TTIP countries as suppliers of intermediate and final goods and hence, benefit less from an increase in demand. Summing up all countries' gains and losses, weighted by their shares in real world GDP, we find that the world as whole gains from the TTIP in terms of an increase in real GDP by .2%.

## 4.5 Conclusion

A number of systemically relevant preferential trade agreements (PTAs) are under negotiation. The largest of these mega-regionals is the proposed Transatlantic Trade and Investment Partnership (TTIP). In this paper, we use the multi-country, multi-industry Ricardian trade model of Caliendo and Parro (2015) extended to include non-tariff barriers to trade and trade in services to assess the potential effects of the TTIP on the global pattern of trade, production, and welfare. The framework features international and cross-sectoral production linkages and therefore allows taking into account globally fragmented value chains and regional production networks. Hence, the model framework combined with rich data on 38 sectors in 140 countries or regions from the GTAP database is well suited to analyze the effects of the TTIP, a deep trade agreement aimed at addressing the important features of 21st century trade: fragmented value chains, trade in services, and non-tariff barriers to trade.

The main assumption of our quantitative experiment is that, in addition to eliminating all tariffs between the EU and the United States, the TTIP will lower the costs of non-tariff measures by the same amount as existing bilateral agreements have, on average, reduced non-tariff barriers. We use the gravity equation implied by the model to estimate the trade cost reductions achieved by existing shallow and deep PTAs, as well as the unobserved parameters of the model. We simulate the model to quantify the trade, production, and welfare effects of the TTIP.

We find that the potential effects of the TTIP are quite substantial: real income is predicted to increase by .43% and .49% in the EU and United States, respectively. We find positive predicted effects for many other countries, including large parts of the developing world, and for the world on average. Positive effects in third countries are driven by the increase in income and demand in the TTIP regions, that benefits suppliers of consumption goods, intermediate goods, and raw materials. Some countries, including the oil producers in the Middle East and the industrialized economies in East Asia, are expected to lose from the TTIP.

Our framework is closely related to the "New Quantitative Trade Theory" literature. This literature (surveyed by Costinot and Rodriguez-Clare, 2014) uses parsimonious trade models combined with structural estimation to conduct counterfactual analyses. For the time being, the methodology has barely been used for the analysis of real trade policy initiatives; most existing work still uses more traditional large-scale computable general equilibrium (CGE) models. While the availability of industry-level trade and output data, the information on existing PTAs, and state-of-the-art of econometric tools has much improved over the last years, there is particular need for further work in at least four areas: First, the unbiased econometric estimation of structural parameters requires quasi-experimental variation and appropriate methods. This remains an important area for future work. Second, top-down approaches to non-tariff trade barriers, as used in this paper, differ from bottom-up assessments based on Francois et al. (2009). Understanding this discrepancy is key if one wants to narrow the interval of welfare predictions found in studies with different approaches to non-tariff barriers to trade. Third, both traditional CGE models as well as the frameworks surveyed by Costinot and Rodriguez-Clare (2014) neglect foreign direct investment. This is particularly important in the transatlantic context. Fourth, estimates presented in this paper may underestimate the true effects as they do not account for effects of trade liberalization on the incentives to develop new products or engineer new processes. A tractable dynamic framework would thus be highly welcome.

# Appendix A.4

# Table A4.11: Overview of sectors and aggregation levels

GT.	AP sectors	Sect	or aggregates used in the analysis	Broad classification
1	Paddy rice	1	Grains & Crops	Agriculture
2	Wheat	1	Grains & Crops	Agriculture
3	Cereal grains nec	1	Grains & Crops	Agriculture
4	Vegetables, fruit, nuts	1	Grains & Crops	Agriculture
5	Oil seeds	1	Grains & Crops	Agriculture
6	Sugar cane, sugar beet	1	Grains & Crops	Agriculture
7	Plant-based fibers	1	Grains & Crops	Agriculture
8	Crops nec	1	Grains & Crops	Agriculture
9	Cattle, sneep, goats, horses	2	Cattle, sneep, goats, horses	Agriculture
10	Animal products nec	2	Livestock & Meat Products	Agriculture
11	Naw milk Wool gill worm accord	2	Livestock & Meat Products	Agriculture
12	Forestry	2	Envestock & Meat Floducts	Agriculture
14	Fishing	3	Fishing	Agriculture
14	Cool	5	Mining (cool oil gos)	Manufacturing
16	Oil	5	Mining (coal, oil, gas)	Manufacturing
10	Oli	5	Mining (coal, oil, gas)	Manufacturing
10	Gas Minerala neo	0 6	Mining (coal, oil, gas)	Manufacturing
10	Monte antile sheep gents hereas	0	Livertals field	Manufacturing
19	Most products poo	2	Livestock & Meat Products	Manufacturing
20	Vogotable oils and fats	7	Livestock & Meat Products	Manufacturing
$\frac{21}{22}$	Dairy products	4	Livestock & Meat Products	Manufacturing
23	Processed rice	i	Grains & Crops	Manufacturing
$\frac{20}{24}$	Sugar	$\frac{1}{7}$	Livestock & Meat Products	Manufacturing
$\frac{2}{25}$	Food products nec	$\frac{1}{7}$	Livestock & Meat Products	Manufacturing
$\bar{26}$	Beverages and tobacco products	$\dot{7}$	Livestock & Meat Products	Manufacturing
$\bar{2}\bar{7}$	Textiles	8	Textiles	Manufacturing
$\frac{1}{28}$	Wearing apparel	ğ	Wearing apparel	Manufacturing
$\overline{29}$	Leather products	10	Leather products	Manufacturing
30	Wood products	11	Wood products	Manufacturing
31	Paper products, publishing	12	Paper products, publishing	Manufacturing
32	Petroleum, coal products	13	Petroleum, coal products	Manufacturing
33	Chemical, rubber, plastic prods	14	Chemical, rubber, plastic prods	Manufacturing
34	Mineral products nec	15	Mineral products nec	Manufacturing
35	Ferrous metals	16	Ferrous metals	Manufacturing
36	Metals nec	17	Metals nec	Manufacturing
37	Metal products	18	Metal products	Manufacturing
38	Motor vehicles and parts	19	Motor vehicles and parts	Manufacturing
39	Transport equipment nec	20	Transport equipment nec	Manufacturing
40	Electronic equipment	21	Electronic equipment	Manufacturing
41	Machinery and equipment nec	22	Machinery and equipment nec	Manufacturing
42	Floatnigity	20	Floatrigity	Somioog
43	Cas manufacture distribution	24 25	Cas manufacture distribution	Services
45	Water	$\frac{20}{26}$	Water	Services
46	Construction	$\frac{20}{27}$	Construction	Services
47	Trade	$\bar{28}$	Trade	Services
48	Transport nec	$\overline{29}$	Transport nec	Services
49	Sea transport	$\overline{30}$	Sea transport	Services
50	Air transport	31	Air transport	Services
51	Communication	32	Communication	Services
52	Financial services nec	33	Financial services nec	Services
53	Insurance	34	Insurance	Services
54	Business services nec	35	Business services nec	Services
55	Recreation and other services	36	Recreation and other services	Services
56	PubAdmin/Defence/Health/Education	37	PubAdmin/Defence/Health/Education	Services
57	Dwellings	38	Dwellings	Services

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Sector:	(1)	(2)	(3)	(4)	(5)	(9)	(2)	(8)	(6)	(10)	(11)	(12)
$\ln  au$ Shallow	$^{-2.310^{***}}_{(0.148)}$	$^{-2.441^{***}}_{(0.163)}$	$-3.385^{***}$ (0.553) -0.024	$-3.156^{***}$ (0.657) -0.182	$^{-6.021}_{(4.199)}$	$-3.695^{***}$ (0.690) 0.357^{**}	$^{-2.498***}_{(0.093)}$	$^{-4.913^{***}}_{(0.285)}$	$-1.613^{***}$ (0.398) -0.023	$^{-2.939^{***}}_{(0.299)}$	$^{-2.774^{***}}_{(0.263)}$	$^{-4.697^{***}}_{0.146*}$
Deep	$(0.106) \\ 0.401^{***} \\ (0.118) $	(0.116) -0.204	$\begin{pmatrix} 0.156 \\ 0.086 \\ 0.150 \end{pmatrix}$	(0.210) 0.076 (0.200)	$\begin{pmatrix} 0.591 \\ 0.830 \\ 0.643 \end{pmatrix}$	$\begin{array}{c} (0.144) \\ 0.364^{***} \\ (0.130) \end{array}$	$(0.082) \\ 0.289^{***} \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ (0.001) \\ $	$(0.092) \\ 0.294^{***} \\ (0.083)$	$\begin{pmatrix} (0.113) \\ 0.502^{***} \\ (0.106) \end{pmatrix}$	(0.095) $0.637^{***}$	$(0.075) \\ 0.476^{***} \\ (0.077)$	(0.079) $0.526^{***}$
$\ln Dist$	$-0.537^{***}$	$-0.561^{***}$	$-0.415^{***}$	(602.0) -0.670***	$-0.592^{***}$	$-0.439^{***}$	$-0.632^{***}$	$-0.562^{***}$	$-0.682^{***}$	$-0.648^{***}$	$-0.719^{***}$	$-0.928^{***}$
Contiguity	$0.831^{***}$ (0.089)	$0.695^{***}$ (0.080)	$0.942^{***}$ (0.101)	$0.725^{***}$ (0.124)	$0.457^{**}$ (0.211)	$0.607^{***}$	$0.762^{***}$ (0.080)	$0.451^{***}$ (0.064)	$0.638^{***}$	$0.786^{***}$	$0.775^{***}$ (0.076)	$0.675^{***}$
ComLang	(0.058)	$0.109^{*}$	-0.086 (0.074)	(0.084)	$-0.552^{***}$ (0.195)	(0.058)	$0.206^{***}$	$0.201^{***}$ (0.044)	$0.375^{***}$ (0.051)	$0.294^{***}$ (0.048)	$0.280^{***}$ (0.044)	$0.422^{***}$ (0.045)
Colony	(0.086)	0.070	$0.343^{***}$	0.046	(0.347)	0.070	$0.296^{***}$	$0.267^{***}$	$0.403^{***}$	$0.467^{***}$	$0.470^{***}$	$0.414^{***}$
CurColony	(0.506)	(0.495)	$1.373^{***}$ (0.390)	(0.363)	(1.296)	(0.275)	(0.583)	(0.503)	(0.698)	(1.083)	(0.906)	(0.564)
ComCol	$0.302^{***}$ (0.081)	$0.435^{***}$ (0.100)	(0.138) (0.116)	$0.339^{***}$ (0.125)	(0.283)	$0.323^{**}$ (0.086)	$0.604^{***}$ (0.070)	$0.162^{**}$ (0.063)	(0.080)	0.335** (0.084)	$0.364^{***}$ (0.067)	$0.630^{***}$ (0.074)
Observations Adjusted $R^2$	$243624 \\ 0.292$	$90274 \\ 0.337$	$22304 \\ 0.318$	$28274 \\ 0.302$	6669 0.413	$85350 \\ 0.251$	$531429 \\ 0.300$	$\begin{array}{c} 801095 \\ 0.325 \end{array}$	$699145 \\ 0.464$	$175800 \\ 0.445$	$223734 \\ 0.450$	$317824 \\ 0.417$
Sector:	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(02)	(31)	(33)	(23)	
ln T	-5.463***	-4.743***	-2.804***	-1.187***	-3.691***	-2.167***	-3.670***	-2.315***	-2.184***	-3.181***	-2.275***	
i e	(1.220)	(0.218)	(0.225)	(0.368)	(0.452)	(0.226)	(0.239)	(0.287)	(0.231)	(0.166)	(0.204)	
Shallow	(0.186)	(120.0)	(0.078)	(0.102)	(0.121)	(0.080)	(0.091)	(0.089)	(0.078)	0.190	0.077) (0.077)	
Deep	$0.672^{***}$	$0.317^{***}$	$0.157^{**}$	$0.665^{***}$	$0.752^{***}$	$0.307^{***}$	$0.896^{***}$	$0.409^{***}$	$0.242^{***}$	$0.175^{***}$	$0.251^{***}$	
$\ln Dist$	$-1.120^{***}$	$-0.765^{***}$	$-0.730^{***}$	$-0.708^{***}$	$-0.529^{***}$	$-0.851^{***}$	$-0.802^{***}$	-0.358***	$-0.748^{***}$	$-0.696^{***}$	$-0.581^{***}$	
Contiguity	$0.717^{***}$	$0.551^{***}$	(nen.u) 0.790***	$0.648^{***}$	$0.422^{***}$	$0.654^{***}$	$0.581^{***}$	$0.531^{***}$	$0.431^{***}$	$0.470^{***}$	$0.662^{***}$	
ComLang	$(0.124) \\ -0.248^{**}$	$(0.068) \\ 0.173^{***}$	$(0.073) \\ 0.231^{***}$	$(0.079) \\ 0.121^{**}$	$(0.076) \\ 0.134^{**}$	$(0.080) \\ 0.383^{***}$	$(0.078) \\ 0.224^{***}$	$(0.066) \\ 0.155^{***}$	$(0.082) \\ 0.299^{***}$	$(0.064) \\ 0.241^{***}$	$(0.076)$ $0.302^{***}$	
Colonu	(0.098) 0.135	(0.044)	(0.045) $0.342^{***}$	(0.055)	(0.055) $0.274^{***}$	(0.046) $0.612^{***}$	$(0.051) \\ 0.335^{***}$	(0.045) $0.305^{***}$	(0.044)	(0.038) $0.466^{***}$	(0.043) $0.383^{***}$	
	(0.139)	(0.065)	(0.071)	(0.073)	(0.079)	(0.080)	(0.088)	(0.066)	(0.077)	(0.064)	(0.074)	
Curvolony	(1.579)	(0.385)	(0.475)	(0.464)	(0.420)	(0.860)	(1.014)	(0.742)	(1.103)	(0.735)	(0.720)	
Com Col	(0.140)	$0.505^{***}$	$0.514^{***}$	$0.264^{***}$	$0.430^{***}$	$0.560^{***}$	$0.974^{***}$	$0.512^{***}$	$0.555^{***}$	$0.633^{***}$	$0.436^{***}$	
Obsemmetions	00745	1544080	337589	309490	189487	698780	157463	119560	320303	9919989	371077	
Adjusted $R^2$	0.385	0.344	0.372	0.318	0.338	0.468	0.536	0.384	0.526	0.458	0.409	
NI						70 		[*;/		14 40 5000		
level. Shea's Pa	s or imported rtial R ² is 0.	c, exporter, a .19 for shallc	ma nd 0.23 f	it product ny or deep PTA	кеа епестs nc As. *, ** and	ot snown. St   *** indicat	andard error e statistical	's (in parenu significance	at the 10, 5 a	istered at the and 1% level	e country-pai, , respectively	ч .
PTA dummies	instrumentec	ł with contag	gion indices a	a la Martin (	et al. (2012)	or Baldwin	and Jaimovi	ch (2012).			1	

Going Deep: The Trade and Welfare Effects of TTIP

Sector:	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)	(35)	(36)	(37)
Shallow	$0.298^{***}$	$0.141^{**}$	$0.229^{***}$	$0.169^{***}$	$0.129^{***}$	$0.182^{***}$	0.024	$0.175^{***}$	$0.221^{***}$	$0.160^{***}$	$0.152^{***}$	$0.267^{***}$	$0.142^{***}$	$0.178^{***}$
Д _{оот} Ц	(0.051)	(0.062)	(0.031)	(0.064)	(0.037)	(0.032)	(0.055)	(0.040)	(0.031)	(0.040)	(0.033)	(0.035)	(0.037)	(0.036)
Deep	(0.076)	(0.080)	(0.053)	(0.081)	(0.056)	(0.050)	(0.075)	(0.055)	(0.051)	(0.060)	(0.054)	(0.054)	(0.052)	(0.057)
$\ln Dist$	$-0.053^{**}$	0.032	0.006	-0.036	-0.019	-0.007	0.012	0.004	-0.002	$-0.036^{**}$	-00.09	-0.017	-0.016	$-0.044^{***}$
:	(0.024)	(0.026)	(0.014)	(0.022)	(0.015)	(0.014)	(0.020)	(0.015)	(0.014)	(0.016)	(0.014)	(0.014)	(0.015)	(0.015)
Contiguity	$2.104^{***}$	$0.573^{***}$	$0.492^{***}$	$0.347^{***}$	$0.414^{***}$	$0.432^{***}$	$0.491^{***}$	$0.319^{***}$	$0.359^{***}$	$0.317^{***}$	$0.418^{***}$	$0.250^{***}$	$0.424^{***}$	$0.407^{***}$
1	(0.158)	(0.095)	(0.067)	0.078)	(0.063)	(0.061)	(0.071)	(0.055)	(0.058)	(0.065)	(0.063)	(0.059)	(0.062)	(0.066)
Compang	0.029	0.005	0.023	0.035)	0.004	-0.022 (0.019)	0.018	-0.033 (0.091)	0.004	-0.014 (0.093)	-0.013 (0.090)	-0.013	0.020	0T0.0-
Colony	$0.345^{***}$	$0.328^{***}$	0.378***	$0.235^{***}$	0.390***	$0.404^{***}$	$0.334^{***}$	$0.347^{***}$	$0.312^{***}$	$0.255^{***}$	$0.246^{***}$	$0.205^{***}$	0.307***	$0.321^{***}$
2	(0.088)	(0.079)	(0.064)	(0.073)	(0.058)	(0.060)	(0.069)	(0.055)	(0.057)	(0.072)	(0.062)	(0.051)	(0.058)	(0.066)
CurColony	-0.258	0.106	-0.059	0.091	0.238	-0.051	-0.289	0.777	0.427	0.943	0.689	0.383	0.443	0.258
	(0.957)	(1.024)	(0.964)	(1.245)	(1.100)	(0.891)	(1.043)	(0.755)	(1.193)	(1.292)	(1.087)	(1.234)	(0.814)	(1.051)
ComCol	-0.007	$-0.107^{**}$	-0.068***	0.024	-0.023	-0.024	$-0.102^{***}$	-0.016	$-0.053^{**}$	$-0.058^{*}$	-0.037	-0.078***	-0.093***	0.012
	(0.045)	(0.053)	(0.024)	(0.039)	(0.027)	(0.024)	(0.036)	(0.027)	(0.025)	(0.030)	(0.024)	(0.027)	(0.028)	(0.026)
Observations	13546	11368	14434	14518	14518	14518	14518	14518	14518	14518	14518	14518	14518	14518
Adjusted $R^2$	0.968	0.952	0.959	0.901	0.956	0.955	0.918	0.948	0.952	0.950	0.956	0.963	0.955	0.939
Note: Estimat	es of import	er and expo	rter fixed eff	fects not sho	wn. Stands	ard errors (i	n parenthes	es) are clust	ered at the	country-pai	r level. She	a's Partial F	$x^2$ is 0.19 for	shallow

ults for Service Sectors
IV Res
A4.13:
Table .

and 0.23 for deep PTAs. *, ** and *** indicate statistical significance at the 10, 5 and 1% level, respectively. PTA dummies instrumented with contagion indices a la Martin et al. (2012) or Baldwin and Jaimovich (2012).

(12)	$\begin{array}{c} -4.783^{***}\\ -4.783^{***}\\ (0.235)\\ 0.068^{*}\\ 0.039)\\ 0.450^{***}\\ (0.047)\\ 0.047)\\ 0.024\\ 0.076)\\ 0.076\\ 0.076\\ 0.045\\ 0.073\\ 0.423^{***}\\ (0.073)\\ 0.423^{***}\\ 0.075\\ 0.045\\ 0.073\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ 0.625^{***}\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)\\ (0.073)$	$318983 \\ 0.417$										
(11)	$\begin{array}{c} -2.899^{***}\\ 0.254)\\ 0.019\\ 0.036)\\ 0.349^{***}\\ 0.349^{****}\\ 0.747^{***}\\ 0.775)\\ 0.748^{****}\\ 0.075)\\ 0.748^{****}\\ 0.075)\\ 0.278^{****}\\ 0.075)\\ 0.0144\\ 0.0143\\ 0.814\\ 0.072\\ 0.814\\ 0.01368^{****}\\ 0.067\\ 0.067\\ \end{array}$	$224570 \\ 0.450$	(23)	$-2.317^{***}$ (0.191) $0.087^{**}$ (0.035)	$\begin{array}{c} 0.278^{***} \\ (0.044) \\ 0.581^{***} \end{array}$	$^{-0.301}_{(0.023)}$ $0.662^{***}_{(0.025)}$	(0.073) (0.043) (0.043)	$0.370^{***}$	(0.717)	$0.430^{***}$ (0.067)	$372259 \\ 0.411$	red at the
(10)	$\begin{array}{c} -3.316^{***}\\ -3.316^{***}\\ (0.280)\\ -0.012\\ (0.042)\\ 0.389^{***}\\ (0.050)\\ -0.706^{***}\\ (0.054)\\ 0.706^{*}\\ 0.706^{*}\\ 0.706^{*}\\ 0.706^{*}\\ 0.7084\\ 0.764^{***}\\ 0.084\\ 0.087\\ 0.087\\ 0.087\\ 0.083\\ 0.335^{***}\\ (0.083)\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083\\ 0.083$	$176517 \\ 0.446$	(22)	$-3.142^{***}$ (0.157) 0.169^{***} (0.033)	$\begin{array}{c} 0.302^{***}\\ (0.037)\\ 671^{***}\end{array}$	$\begin{array}{c} -0.011 \\ (0.019) \\ 0.486^{***} \\ 0.6.064 \end{array}$	$\begin{array}{c} (0.004) \\ 0.247^{***} \\ (0.038) \end{array}$	$0.463^{***}$	(0.725)	$0.629^{***}$ (0.068)	$\begin{array}{c} 2221122 \\ 0.458 \end{array}$	) are cluster
(6)	$\begin{array}{c} -1.727^{***}\\ (0.312)\\ 0.067\\ (0.042)\\ 0.372^{***}\\ (0.054)\\ 0.372^{****}\\ (0.054)\\ 0.610^{****}\\ (0.088)\\ 0.510^{****}\\ (0.088)\\ 0.378^{****}\\ (0.088)\\ 0.349^{****}\\ (0.095)\\ 0.732\\ (1.273)\\ 0.1732\\ (0.080)\\ (0.080)\end{array}$	701957 0.465	(21)	$-2.180^{***}$ (0.227) $0.249^{***}$ (0.039)	$\begin{array}{c} 0.397^{***} \\ (0.043) \\ 725^{****} \end{array}$	$\begin{array}{c} -0.130\\ (0.023)\\ 0.462^{***} \end{array}$	$\begin{array}{c} (0.000)\\ 0.311^{***}\\ (0.044) \end{array}$	$0.485^{***}$	$2.006^{*}$ (1.082)	$0.530^{***}$ (0.081)	$321309 \\ 0.527$	parentheses
(8)	-5.000*** (0.234) (0.037) (0.037) (0.037) (0.037) (0.044) (0.044) (0.044) (0.044) (0.044) (0.064) (0.064) (0.065) (0.065) (0.065) (0.065) (0.065) (0.063) (0.063)	$802975 \\ 0.326$	(20)	$\begin{array}{c} -2.352^{***} \\ (0.283) \\ 0.123^{***} \\ (0.043) \end{array}$	$\begin{array}{c} 0.297^{***} \\ (0.047) \\ 0.270^{***} \end{array}$	$\begin{array}{c} -0.379 \\ (0.023) \\ 0.517^{***} \\ 0.6025 \end{array}$	$\binom{0.000}{0.155^{***}}{(0.045)}$	$0.282^{***}$	(0.744)	$0.515^{***}$ (0.080)	$112875 \\ 0.384$	d errors (in ely.
(2)	$\begin{array}{c} -2.439^{***}\\ (0.085)\\ 0.113^{***}\\ (0.039)\\ 0.423^{***}\\ (0.050)\\ 0.7218^{****}\\ (0.078)\\ 0.780^{****}\\ (0.078)\\ 0.748^{*}\\ (0.074)\\ 0.306^{****}\\ (0.074)\\ 0.647\\ (0.074)\\ 0.647\\ (0.079)\\ 0.592^{****}\\ (0.070)\end{array}$	533495 $0.300$	(19)	$-3.796^{***}$ (0.225) $0.253^{***}$ (0.047)	(0.053)	$\begin{array}{c} -0.030 \\ (0.027) \\ 0.550^{***} \end{array}$	(0.051) (0.051)	$0.313^{***}$	(0.460)	$0.980^{***}$ (0.090)	$158267 \\ 0.536$	vn. Standar el, respectiv
(9)	$-4.254^{***}$ (0.643) (0.034 (0.052) 0.422^{***} (0.060) (0.050) 0.610^{***} (0.086) 0.610^{***} (0.086) 0.057 0.057 0.057 0.057 0.057 0.057 0.0166 0.030 0.0166 0.030 0.0166 0.030 0.0106 0.030 0.0106 0.030 0.030 0.030 0.030 0.030 0.030 0.030 0.052 0.052 0.052 0.052 0.052 0.052 0.052 0.052 0.052 0.052 0.052 0.052 0.052 0.052 0.052 0.052 0.052 0.052 0.052 0.052 0.052 0.052 0.052 0.052 0.052 0.052 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.055 0.0550 0.0550 0.0550 0.0550 0.0550 0.05500000000	$85510 \\ 0.252$	(18)	$^{-2.266***}_{(0.207)}$ $^{0.119^{***}}_{(0.039)}$	$\begin{array}{c} 0.333^{***}\\ (0.046)\\ 0.854^{***}\end{array}$	$\begin{array}{c} -0.004 \\ (0.024) \\ 0.656^{***} \\ (0.070) \end{array}$	(0.018) $0.391^{***}$ (0.046)	$0.598^{***}$	(0.853)	$0.557^{***}$ (0.077)	$631455 \\ 0.468$	ects not show 5 and 1% lev
(5)	$\begin{array}{c} -11.126^{****}\\ (3.834)\\ (.3.844)\\ (.1.84)\\ (.0.191)\\ (.0.191)\\ (.0.191)\\ (.0.191)\\ (.0.191)\\ (.0.191)\\ (.0.191)\\ (.0.191)\\ (.0.191)\\ (.0.186)\\ (.0.204)\\ (.0.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.228)\\ (.2$	$6684 \\ 0.421$	(17)	$-4.742^{***}$ (0.415) 0.084* (0.045)	$\begin{array}{c} 0.371^{***} \\ (0.054) \\ 0.644^{***} \end{array}$	$^{-0.044}_{(0.028)}$ $^{(0.028)}_{0.397^{***}}$	$\begin{array}{c} (0.073) \\ 0.154^{***} \\ (0.053) \end{array}$	$0.265^{***}$	(0.422)	$0.408^{***}$ (0.078)	$182827 \\ 0.341$	ict fixed effe e at the 10, 5
(4)	$\begin{array}{c} -2.907^{***}\\ 0.586)\\ -0.033\\ 0.072)\\ 0.0213^{***}\\ 0.0213^{***}\\ 0.043)\\ 0.043\\ 0.043\\ 0.019\\ 0.019\\ 0.019\\ 0.049\\ 0.049\\ 0.049\\ 0.049\\ 0.0183\\ 0.049\\ 0.0121\\ 0.0121\\ 0.121\end{array}$	$28326 \\ 0.304$	(16)	$-1.527^{***}$ (0.356) -0.056 (0.048)	$0.504^{***}$ (0.056) $750^{***}$	$\begin{array}{c} -0.109\\ (0.029)\\ 0.632^{***}\\ (0.078)\end{array}$	(0.05) (0.054)	$0.241^{***}$	$0.975^{**}$ (0.461)	$0.272^{***}$ (0.087)	$303154 \\ 0.319$	3-digit prodι al significance
(3)	$\begin{array}{c} -3.452^{***}\\ 0.540\\ -0.085\\ 0.067\\ 0.073\\ 0.073\\ 0.074\\ 0.037\\ 0.037\\ 0.037\\ 0.037\\ 0.096\\ 0.100\\ 0.344^{***}\\ 0.096\\ 0.344^{****}\\ 0.096\\ 0.116\\ 0.116\\ 0.116\end{array}$	$22337 \\ 0.318$	(15)	$-2.760^{***}$ $(0.205)$ $0.058$ $(0.039)$	$\begin{array}{c} 0.278^{***}\\ (0.045)\\ 0.700^{***}\end{array}$	$\begin{array}{c} -0.109 \\ (0.024) \\ 0.799^{***} \end{array}$	(0.045) (0.045) (0.045)	$0.343^{***}$	$0.921^{-4}$	$0.513^{***}$ (0.070)	$338654 \\ 0.373$	er, and HS ( ate statistice
(2)	$\begin{array}{c} -2.203^{***}\\ (0.154)\\ -0.019\\ (0.054)\\ 0.277^{***}\\ (0.063)\\ -0.456^{****}\\ (0.078)\\ 0.754^{****}\\ (0.078)\\ 0.078\\ 0.078\\ 0.078\\ 0.078\\ 0.078\\ 0.078\\ 0.078\\ 0.095\\ 0.095\\ 0.099\\ 0.498\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.099\\ 0.009\\ 0.009\\ 0.009\\ 0.009\\ 0.009\\ 0.009\\ 0.009\\ 0.009\\ 0.009\\ 0.009\\ 0.009\\ 0.009\\ 0.009\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000\\ 0.000$	$90501 \\ 0.339$	(14)	$-4.815^{***}$ (0.205) 0.064 [*] (0.036)	$\begin{array}{c} 0.354^{***} \\ (0.046) \\ 760^{***} \end{array}$	$\begin{array}{c} -0.103 \\ (0.024) \\ 0.556^{***} \\ 0.67 \end{array}$	$0.181^{***}$	$0.279^{***}$	$1.235^{***}$ (0.380)	$0.498^{***}$ (0.069)	$1548959 \\ 0.344$	rter, exporte nd *** indic
(1)	$\begin{array}{c} -2.329^{***}\\ (0.143)\\ (0.033^{**})\\ (0.042)\\ 0.384^{***},\\ (0.053)\\ 0.053)\\ 0.057^{**},\\ (0.087)\\ 0.027\\ 0.087\\ 0.087\\ 0.087\\ 0.084\\ 0.084\\ 0.084\\ 0.084\\ 0.084\\ 0.084\\ 0.084\\ 0.084\\ 0.084\\ 0.084\\ 0.084\\ 0.084\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0.080\\ 0$	$244386 \\ 0.292$	(13)	$-7.003^{***}$ (1.156) -0.018 (0.084)	$\begin{array}{c} 0.250^{***}\\ (0.095) \end{array}$	$\begin{array}{c} -1.200\\ (0.051)\\ 0.707^{***} \end{array}$	$-0.207^{**}$	(0.133)	(1.571)	(0.146)	$22815 \\ 0.389$	ttes of impo evel. *, ** a
Sector:	ln τ Shallow Deep In Dist Contiguity ConLang Colony CurColony ComCol	Observations Adjusted $R^2$	Sector:	$\ln  au$ Shallow	Deep	m Dist Contiguity	ComLang	Colony	CurColony	Com Col	Observations Adjusted $R^2$	Note: Estime country-pair l

 Table A4.14: OLS Results for Agriculteral and Manufacturing Sectors

																	ance
(37)	$-0.069^{***}$	0.085***	(0.026)	-0.109	$0.412^{***}$	(0.064)	-0.005	(0.021)	$0.306^{***}$	(0.063)	0.271	(1.055)	0.003	(0.025)	14760	0.940	stical signific
(36)	$-0.028^{*}$	(0.014) 0.026	(0.026)	-0.064 (0.012)	$0.423^{***}$	(0.060)	0.031	(0.020)	$0.295^{***}$	(0.056)	0.448	(0.817)	-0.097***	(0.028)	14760	0.955	idicate statis
(35)	0.007	$0.188^{***}$	(0.024)	-0.097	$0.242^{***}$	(0.057)	-0.005	(0.020)	$0.196^{***}$	(0.047)	0.393	(1.251)	-0.083***	(0.026)	14760	0.964	** and *** ir
(34)	$-0.032^{**}$	$0.122^{***}$	(0.026)	-0.039	$0.420^{***}$	(0.062)	-0.005	(0.020)	$0.239^{***}$	(0.060)	0.690	(1.089)	$-0.043^{*}$	(0.024)	14760	0.956	air level. *, *
(33)	-0.027	$0.127^{***}$	(0.029)	-0.104 (0.013)	$0.312^{***}$	(0.063)	-0.013	(0.023)	$0.240^{***}$	(0.070)	0.958	(1.321)	$-0.061^{**}$	(0.030)	14760	0.951	le country-pa
(32)	-0.016	(0.015)	(0.025)	-0.005	$0.362^{***}$	(0.056)	0.016	(0.018)	$0.302^{***}$	(0.054)	0.434	(1.197)	$-0.060^{**}$	(0.024)	14760	0.953	ustered at th
(31)	-0.008	-0.013	(0.026)	-0.034 (0.011)	$0.327^{***}$	(0.054)	-0.023	(0.020)	$0.345^{***}$	(0.052)	0.783	(0.748)	-0.021	(0.027)	14760	0.949	heses) are ch
(30)	-0.010	$0.208^{***}$	(0.036)	-0.021	$0.476^{***}$	(0.070)	0.016	(0.029)	$0.322^{***}$	(0.067)	-0.274	(1.076)	$-0.101^{***}$	(0.036)	14760	0.918	cs (in parent)
(29)	-0.018	$0.060^{**}$	(0.024)	-0.0/9	$0.425^{***}$	(0.059)	-0.016	(0.019)	$0.386^{***}$	(0.057)	-0.032	(0.910)	-0.028	(0.024)	14760	0.956	andard erro
(28)	-0.003	$0.222^{***}$	(0.026)	-0.086 (0.012)	$0.391^{***}$	(0.062)	0.009	(0.021)	$0.359^{***}$	(0.056)	0.258	(1.138)	-0.028	(0.027)	14760	0.956	ot shown. St
(27)	-0.034	0.003	(0.037)	-0.101	$0.342^{***}$	(0.076)	$0.069^{**}$	(0.032)	$0.224^{***}$	(0.071)	0.091	(1.260)	0.015	(0.038)	14760	0.902	ted effects no
(26)	$-0.032^{**}$	0.029	(0.026)	-0.071	$0.489^{***}$	(0.065)	$0.035^{*}$	(0.018)	$0.362^{***}$	(0.060)	-0.050	(0.975)	$-0.074^{***}$	(0.023)	14674	0.960	l exporter fi
(25)	-0.040	0.055	(0.043)	-0.033	$0.573^{***}$	(0.094)	0.060	(0.038)	$0.312^{***}$	(0.076)	0.128	(1.046)	$-0.109^{**}$	(0.053)	11523	0.952	mporter and
(24)	-0.022	0.017	(0.035)	-0.148 (0.019)	$2.110^{***}$	(0.156)	0.040	(0.031)	$0.327^{***}$	(0.085)	-0.244	(0.968)	-0.016	(0.045)	13780	0.969	stimates of i
Sector:	Shallow	Deep		$\ln Dist$	Contiquity	2	ComLang	2	Colony	5	CurColony	5	ComCol		Observations	Adjusted $R^2$	Note: E

 Table A4.15: OLS Results for Service Sectors

lgn ry-pa se) e (in par at the 10, 5 and 1% level, respectively.

# Parameter Uncertainty in NQTT Models^{*}

# 5.1 Introduction

One defining feature of the New Quantitative Trade Theory (NQTT) is the tight link between theory and empirics. This link is created by structural estimation of unobserved model parameters based on the same model that is used for the counterfactual analysis and based on the same data that is used for calibration of the model's observable moments. Hence, unobserved structural parameters are chosen in a way that is consistent with both the model and the observable moments used in the subsequent analysis. However, the estimated parameters depend on the particular dataset we have at hand and, depending on the precision of the estimation, provide only a more or less noisy measure of the true parameters guiding the structural model. The estimates are random variables and so are the model predictions based on these estimates. Moreover, expected values of non-linear functions of random variables, such as trade and welfare effects in NQTT models, diverge from values at estimated means of parameters. Ignoring the random nature of estimated parameters leads to biased predictions of model outcomes, with the bias depending on the degree of non-linearity of the model and the degree of uncertainty surrounding the estimates.

The aim of this chapter is to draw attention to the issues of uncertainty and bias in simulation outcomes of models calibrated with estimated parameters. We propose that

^{*}This chapter is based on joint work with Rahel Aichele and Gabriel Felbermayr.

acknowledging uncertainty of model predictions caused by uncertainty about the model's parameters is a natural step forward for counterfactual analyses based on NQTT models.

With few exceptions, the issue of parameter uncertainty has been overseen by this literature. Lai and Trefler (2002), Anderson and Yotov (2016), and Shapiro (2015) are noteworthy exceptions. Lai and Trefler (2002) compute analytical standard errors for gains from trade estimates based on a structural gravity model, which is feasible only for very parsimonious model structures. Anderson and Yotov (2016) bootstrap regression coefficients from a structural gravity equation to obtain standard errors for inference on the general equilibrium effects of a gravity model. Shapiro (2015) conducts a bootstrap to obtain confidence intervals for model predictions based on the structural parameter estimates' asymptotic normal distribution. We aim to contribute to this recent literature by showing how the bootstrap can be used to estimate the bias caused by the nonlinearity of the model. Moreover, we discuss different concepts of confidence intervals for model outcomes that can be obtained from the bootstrap exercise. We also take a first step towards understanding the relationship between the degree of parameter uncertainty and the quantitative importance of the bias and the uncertainty surrounding the model predictions.

To that end, we conduct a bootstrap to quantify the bias and the extent of uncertainty of the simulated effects of the policy scenario analyzed in the previous chapter, that is, the implementation of the Transatlantic Trade and Investment Partnership (TTIP). Based on 425 bootstrap samples drawn from our original dataset underlying the estimation of the structural parameters, we find an average bias of 7% for the welfare effects predicted by the model. The bias tends to be positive for positive welfare changes and negative otherwise, implying that the simulation results overestimate the true effects in absolute terms. Since our simulation outcomes were small to begin with, the estimated bias in absolute terms (for example, .013 percentage points for the EU, .017 percentage points for the US) is rather small. In accordance with the theory, we find that the bias increases in the degree of uncertainty surrounding the parameter estimates. We repeat the bootstrap and the simulation exercise based on only 50% of the observations from the original sample, and find that the average bias increases to 11%.

Our results show that even in an application characterized by very precisely estimated parameters, accounting for uncertainty is important to tell apart model outcomes that are not statistically significant from those that are. Our counterfactual analysis of the TTIP predicts negative welfare effects for 50 out of 140 countries or regions, however, only in two thirds of these cases are the effects significantly different from zero at the 95% level. Some of the largest losses, predicted for the oil exporting countries from the Middle East and

the countries forming the Eurasian Customs Union, turn out to be insignificant. On the winning side, we find that 12% of the predicted positive effects fall victim to accounting for uncertainty. The predicted positive effect for the TTIP countries, except for Greece, and for the world average are strongly significant. Hence, in the case of our application, accounting for parameter uncertainty does not impair the validity of the main results of the counterfactual analysis.

# 5.2 A Bootstrap of the Standard Error, Confidence Interval, and Bias of Model Predictions

In the previous chapter, we conducted a counterfactual experiment based on a general equilibrium trade model to analyze the effects of the introduction of the TTIP. We used observable and estimated unobservable parameters to calibrate the model and then solved the model for the changes in endogenous outcomes, such as prices, wages, trade patterns, and welfare. From a more general point of view we may characterize the outcomes of such a counterfactual analysis by a structural relationship  $W := W(\boldsymbol{\mathcal{X}}_t, \mathcal{O}, \kappa)$ , relating the change in some endogeneous variable of interest W to the change in a policy variable  $\kappa$  for a given set of observable moments  $\boldsymbol{\mathcal{X}}_t$  describing the current state of the economy. The functional relationship  $W(\cdot)$  depends on the particular model structure chosen to describe production and consumption relationships in the economy, characterized by structural parameters  $\mathcal{O}$ .

In the TTIP scenario discussed in the previous chapter,  $W_i$  may denote, for example, the real income change of country *i* following the reduction of trade costs between the United States and the EU28 countries, captured by changes in the respective elements of the bilateral trade cost matrix  $\kappa$ .¹ The functional relationship  $W(\cdot)$  is determined by the set of equilibrium conditions and the functional form assumptions governing demand and supply. The set of observable moments  $\mathcal{X}_t$  is given by the matrix of trade shares  $\pi_t$ , expenditure levels  $\mathbf{X}_t$ , and value added  $\mathbf{wL}_t$ . The structural parameters comprise the elasticities of the utility and production functions,  $\alpha, \beta$ , and  $\gamma$ , the dispersion parameters of the sectoral productivity distributions  $\boldsymbol{\theta}$ , and the sectoral elasticities of the trade cost

¹Note that for simplicity's sake, we do not use the hat notation here to differentiate changes in variables from their levels as we did in the previous chapter, but rather define symbols as levels or changes in the text.

function  $\rho_{deep}$  with respect to deep trade agreements.² In this particular setup, some of the elements of  $\mathcal{O}$ , namely,  $\alpha, \beta$ , and  $\gamma$ , are observable. More precisely, they may be replaced by observable moments, since according to the model's agents' first order conditions, in equilibrium the elasticities of the utility and production functions are equal to expenditure shares for final goods and cost shares of inputs, respectively.

The remaining elements of  $\mathcal{O}$ , which we collect in the vector  $\Theta := [\theta, \rho_{deep}]$  need to be estimated. We use  $\Theta_N$  to denote a consistent estimate of  $\Theta$  obtained from one particular sample of size N. Since the dataset is only one draw of the underlying data generating process characterized by the population moments  $\Theta$ ,  $\Theta_N$  is a random variable. Abstracting from other sources of uncertainty, for example uncertainty about the functional relationships summarized in  $W(\cdot)$  or measurement error in the observable moments  $\mathcal{X}_t$ , our outcome variable of interest from the simulation,  $W(\Theta_N)$  (as well as all other endogenous variables of the model) can be viewed as a measurable function of the random variables  $\Theta_N$ . Therefore, our model-based predictions of the effects of the TTIP inherit the uncertainty present in the data used to estimate the model's parameters.

For many problems of this type, in particular for cases where the derivative of  $W(\Theta)$ with respect to  $\Theta$  is simple to obtain, the Delta method can be used to approximate the variance of a function of random variables. In our case, however,  $W(\Theta)$  is the solution to a complicated system of equations rendering analytical derivation of its derivatives infeasible. For problems of this type, the bootstrap theory provides us with a computationally burdensome but feasible alternative to estimate the standard error of a function of random variables. In the following subsections we briefly discuss some results from econometrics theory on the estimation of standard errors, confidence intervals, and the bias of non-linear estimators by means of a bootstrap. This discussion follows Cameron and Trivedi (2005) and Horowitz (2001) to whom we refer the reader for details.

### 5.2.1 Some Results from the Bootstrapping Literature

The theory of the bootstrap builds on the fact that every independently drawn sample from the dataset used to estimate  $\Theta_N$  inherits some of the properties of the underlying data generating process and that we can draw any desired number *B* of such samples. For every sample b = 1, ..., B (of size *N*), we can calculate parameter estimates  $\Theta_N^b$  to obtain an empirical distribution of  $\Theta_N^b$ s that approximates the distribution of  $\Theta_N$ . Moreover, for

²Note that  $\mathcal{X}_t$  and  $\mathcal{O}$  are only subsets of the complete sets of observable moments and structural parameters of the model. Which subsets are needed depends on the variable of interest W and the structure of the model.

each of the  $B \Theta_N^b$ s, we can compute the corresponding value of  $W(\Theta_N^b)$  and thereby obtain an empirical distribution of  $W(\Theta_N^b)$ , which approximates the distribution of  $W(\Theta_N)$ . The bootstrap works under mild conditions regarding the underlying data generating process, which we assume to be fulfilled.

### 5.2.1.1 Bootstrapping Standard Error

Based on *B* bootstrap samples (of size *N*) and the corresponding values of our model outcomes  $\{W(\Theta_N^1), ..., W(\Theta_N^b), ..., W(\Theta_N^B)\}$ , it is straightforward to compute an estimate of the sampling variance as

$$s_W^2 = \frac{1}{B-1} \sum_{b=1}^B \left( W(\Theta_N^b) - \overline{W}(\Theta_N^b) \right)^2 \quad \text{with} \quad \overline{W}(\Theta_N^b) = \frac{1}{B} \sum_{b=1}^B W(\Theta_N^b), \quad (5.1)$$

which consistently estimates  $\sigma_W^2$ , the variance of  $W(\Theta_N)$ .

### 5.2.1.2 Confidence Intervals

A confidence interval (CI)  $[W_{low}, W_{high}]$  of significance level  $\alpha$  for  $W := W(\Theta)$  is defined by

$$Prob \left[ W_{low} < W < W_{high} \right] = 1 - \alpha. \tag{5.2}$$

Let  $W_N := W(\Theta_N)$  and let  $G_N(\cdot)$  denote the distribution of the sampling error  $W_N - W$ conditional on N, the size of the original sample. Then, for any  $\alpha_1, \alpha_2$  satisfying  $\alpha_1, \alpha_2 > 0$ and  $\alpha_1 + \alpha_2 = \alpha$ , the confidence bounds  $[W_{low}, W_{high}]$  are given by

CI: 
$$[W_N - w_{1-\alpha_2}, W_N - w_{\alpha_1}],$$
 (5.3)

where  $w_x$  denotes the *x*th percentile of  $G_N(\cdot)$ , that is,  $G_N(w_{\alpha_1}) = \alpha_1$  and  $G_N(w_{1-\alpha_2}) = 1-\alpha_2$ . The interpretation of the CI is as follows. Suppose a large number of samples of size N could be drawn from the true data generating process characterized by  $E[W(\Theta_N)] = W$ . Then, in  $(1-\alpha) \times 100$  percent of all cases, confidence intervals computed in accordance with Equation (5.3) above would contain the true value. In other words, the chance that a so-defined confidence interval includes the true parameter is  $(1-\alpha) \times 100$  percent.

To compute the confidence bounds, one needs to know the sampling distribution  $G_N(\cdot)$ and choose  $\alpha_1, \alpha_2$  subject to  $\alpha_1 + \alpha_2 = \alpha$ . Typically,  $\alpha_1, \alpha_2$  are chosen such as to obtain either equal-tailed CIs by setting  $\alpha_1 = \alpha_2 = \alpha/2$  or symmetric CIs for which  $\alpha_1, \alpha_2$  are chosen to yield bounds which are centered around the estimate  $W_N$ , so that  $|-w_{1-\alpha_2}| = |-w_{\alpha_2}|$ . If the sampling distribution is symmetric, equal-tailed and symmetric confidence intervals for a given significance level are identical.

In general, the sampling distribution  $G_N$  is neither symmetric nor known. Standard asymptotic theory, however, implies that  $G_N$  converges to a normal distribution with mean zero and variance  $\sigma_W^2$  as N goes to infinity.³  $\sigma_W^2$  may be replaced by a consistent estimator such as  $s_W^2$  (cp. Equation 5.1). Hence, for large enough values of N, the standard CI

$$CI_S: \qquad [W_N - \sigma^W z_{1-\alpha_2}, W_N - \sigma^W z_{\alpha_1}], \qquad (5.4)$$

where  $z_x$  denotes the *x*th percentile of the standard normal distribution, well approximates the CI as defined in Equation (5.3).

An alternative estimate of the confidence bounds proposed by Efron (1981) can be obtained from the bootstrapping exercise. It uses the fact that the sampling distribution of the bootstrap estimates,  $W_N^b - W_N$ , converges to the distribution of  $W_N - W$ , the sampling distribution of our original estimate, and hence, the percentiles of the distribution of the bootstrapped  $W_N^b$ 's are consistent estimates of the percentiles of the (unobserved) distribution of  $W_N$ . This so-called *bootstrap percentile method* yields the confidence interval

$$CI_{BP1}: \qquad [W^b_{\alpha_1}, W^b_{1-\alpha_2}] \quad \Leftrightarrow \quad [W_N + w^b_{\alpha_1}, W_N + w^b_{1-\alpha_2}], \tag{5.5}$$

where  $w_x^b$  is the *x*th percentile of the bootstrap distribution of  $W_N^b - W_N$ . As discussed by Hall (1992),  $CI_{BP1}$  is problematic if the distribution  $W_N - W$  is asymmetric since the implied coverage probability as defined in Equation (5.2) generally does not equal  $\alpha = \alpha_1 + \alpha_2$ , unless  $G_N(\cdot)$  is symmetric.⁴ To address this concern, Hall (1992) proposes another bootstrap percentile method based CI

CI_{BP2}:  $[W_N - w_{1-\alpha_2}^b, W_N - w_{\alpha_1}^b],$  (5.6)

³To be precise, we are considering the normal asymptotic distribution of  $\sqrt{N}(W_N - W)$  with mean 0 and asymptotic variance  $N\sigma_W^2$ , since the distribution of  $W_N - W$  degenerates in the limit of N.

⁴CI_{BPI} approximates  $W + w_{\alpha_1}$ ,  $W + w_{1-\alpha_2}$ . Hence, the coverage probability implied by CI_{BP1} is  $Prob[W + w_{\alpha_1} < W < W + w_{1-\alpha_2}] = G_N(-w_{\alpha_1}) - G_N(-w_{1-\alpha_2}) \leq (1 - \alpha_1 - \alpha_2)$ .  $G_N(-w_{\alpha_1}) - G_N(-w_{1-\alpha_2}) = (1 - \alpha)$  holds for symmetric distributions  $G_N(\cdot)$ , but generally not in asymmetric cases.

which is not quite as intuitive as  $\operatorname{CI}_{BP1}$ , but more appealing from a theoretical perspective and equally simple to obtain from the bootstrap replications of W. The reason is that the confidence bounds given in Equation (5.3) depend on the distribution of  $-(W_N - W) =$  $(W - W_N)$  which has the opposite skewness of the distribution of  $(W_N - W)$ . Therefore, being based on the quantiles of the distribution of  $W_N^b - W_N$  which converges to the distribution of  $W_N - W$ ,  $\operatorname{CI}_{BP1}$  gets the skewness wrong.  $\operatorname{CI}_{BP2}$ , instead, is based on the quantiles of the distribution of  $-(W_N^b - W_N)$  which converges to the distribution of  $W - W_N$  and, therefore, gets the skewness right.

Neither of the percentile method based CIs, however, achieves asymptotic refinement. The validity of  $CI_{BP1}$  and  $CI_{BP2}$ , alike the validity of  $CI_S$ , relies on a sufficiently large sample size N (in addition to a sufficiently large number of bootstrap replications) since only then do the bootstrapped percentiles  $w_x^b$  provide a good approximation to  $w_x$ , the percentiles of  $G_N(\cdot)$ . CIs offering asymptotic refinement can be obtained with the *percentile-t method* or with adjustments for *bias* and *acceleration* as proposed by Efron (1987). In our framework, however, both approaches are technically feasible but computationally burdensome due to the fact that every bootstrap of  $W_N^b$  requires numerically solving a complex system of non-linear equations. To apply the percentile-t method, we would need a bootstrap within each bootstrap to obtain a standard error estimate for every replication b, since an analytical solution even with the help of the delta method is not within reach. In fact, we mainly resorted to bootstrapping in the first place exactly because of the difficulty to obtain a standard error for  $W_N$  by conventional methods. Likewise, for the bias-corrected and accelerated CIs, a non-parametric estimate of the acceleration constant would be equally burdensome to obtain.

#### 5.2.1.3 The Bias

The non-linearity of  $W(\cdot)$  implies that the expected value of W differs from the function evaluated at the expected value of  $\Theta_N$ . The bias,  $E[W(\Theta_N) - W(\Theta)]$ , can be approximated by a second-order Taylor expansion of W around the true value  $\Theta$ . To convey the intuition, we consider first the case where  $W(\cdot)$  is a scalar-valued function. The bias is then approximated by

$$B_N = \frac{\partial W}{\partial \theta} \operatorname{E} \left[\theta_N - \theta\right] + \frac{1}{2} \frac{\partial^2 W}{\partial \theta^2} \operatorname{E} \left[\theta_N - \theta\right]^2 = \frac{1}{2} \frac{\partial^2 W}{\partial \theta^2} \sigma_{\theta}^2, \tag{5.7}$$

where we have used the fact that  $E[\theta_N - \theta] = 0$  if  $\theta_N$  is a consistent estimator of  $\theta$ . The bias is larger the stronger the curvature of W and, in accordance with Jensen's inequality, positive if W is convex and negative otherwise. Moreover, the bias increases in the variance of the estimate,  $\sigma_{\theta}^2$ . It vanishes as  $\sigma_{\theta}^2$  goes to zero; hence,  $W(\theta_N)$  is a *consistent* estimator for  $W(\theta)$ .

Naturally, these results carry over to the case of our vector-valued function  $W(\Theta)$ , for which we obtain

$$B_N = \frac{1}{2} \mathbb{E} \left[ (\Theta_N - \Theta)' \frac{\partial^2 W}{\partial \Theta \Theta'} (\Theta_N - \Theta) \right]$$
(5.8)

as a second-order approximation to the bias  $E[W(\Theta_N)] - W(\Theta)$ . In practice, the magnitude of  $B_N$  is unknown since it depends on the matrix of second derivatives of  $W(\cdot)$ evaluated at the unknown population moments  $\Theta$ . However, it can be estimated by means of a bootstrap that makes use of the fact that the average of the bootstrapped quantities  $W(\Theta_N^b)$ , b = 1, ..., B provides an estimator for  $W(\Theta_N)$  whose behaviour mimicks the behaviour of  $W(\Theta_N)$  as an estimator for  $W(\Theta)$ . In other words, the bootstrap uses the deviation of the  $E[W(\Theta_N^b)]$  from  $W(\Theta_N)$  to approximate the deviation of  $E[W(\Theta_N)]$  from  $W(\Theta)$ . A second-order approximation of  $E[W(\Theta_N^b)] - W(\Theta_N)$ , the bias of the bootstrap estimate of  $W(\Theta_N)$ , yields

$$B_N^B = \frac{1}{2} \mathbb{E} \left[ (\Theta_N^b - \Theta_N)' \frac{\partial^2 W}{\partial \Theta_N \Theta_N'} (\Theta_N^b - \Theta_N) \right].$$
(5.9)

Importantly,  $E\left[W(\Theta_N^b)\right] - W(\Theta_N)$  can be approximated by  $\frac{1}{B}\sum_{b=1}^B W(\Theta_N^b) - W(\Theta_N)$  with arbitrary precision by increasing the number of bootstrapped samples. Hence, the bootstrap provides us with a feasible estimate of  $B_N$ , the bias caused by the non-linearity of  $W(\cdot)$  Moreover, as detailed in Horowitz (2001),  $B_N^b$  converges to  $B_N$  faster than  $B_N$  approaches zero; hence, we can use  $B_N^b$  to obtain a *bias-corrected* estimate of our quantity of interest as

$$W_{bc}^B(\Theta_N) = W(\Theta_N) - B_N^B.$$
(5.10)

# 5.3 Application: Predicted Welfare Effects of the TTIP

We now apply the insights from the bootstrapping literature summarized in the previous section to a simulation study of the welfare effects of the TTIP. The application is based on the same model and the same dataset as the analysis in Chapter 4. Our model outcome of interest is the welfare effect (change in real income, by country) as defined in Equation (4.8) in Chapter 4. We bootstrap 425 replications of the country-specific welfare effects

to calculate confidence intervals and assess the magnitude of the bias for this particular application.

The dataset used to estimate the structural parameters consists of bilateral trade flows for 140 countries and 38 sectors in the year 2011 and proxies for bilateral trade costs typically used in the gravity literature. In the agricultural and manufacturing sectors (sectors 1-23) trade flows are disaggregated at the product level. The coefficients of interest are the sectoral productivity dispersions  $\theta$ , which equals the inverse of the elasticity of trade with respect to trade costs and can be obtained as the coefficient on tariffs, and the elasticity of trade costs with respect to the incidence of a deep or shallow preferential trade agreement (PTA),  $\rho_{deep}$ ,  $\rho_{shallow}$ .⁵ Since the latter are likely endogeneous to the level of trade cost or other unobserved determinants of bilateral trade, we instrument the deep and shallow PTA dummies with a contagion index. Country-fixed effects control for the country-level determinants implied by the theory and potentially unobserved confounding factors. We run separate regressions for 37 sectors to obtain sector-specific estimates of  $\theta^{j}, \rho^{j}_{deep}, \rho^{j}_{shallow}$  which we collect in the vectors  $\theta$ ,  $\rho_{deep}$ , and  $\rho_{shallow}$ .⁶ By running regressions sector by sector, we implicitly assume independence of errors across sectors. However, standard errors are expected to be correlated within country pairs. To account for clustering within country pairs in the bootstrap-based inference, we sample country pairs rather that country-pair (-product) observations. That is, the bootstrap sampling randomly chooses country pairs from the original dataset using all available product-level observations within the pair. The sampling is done with replacement to ensure independence of individual draws. Throughout this chapter we present results based on 425 bootstrap replications of parameter estimates  $\theta^b$ ,  $\rho^b_{deep}$  and the corresponding simulation outcomes  $W^b$ .

To shed some light on the relationship between the degree of parameter uncertainty and the degree of uncertainty surrounding the model outcomes, we repeat the whole exercise starting out with a smaller sample, where we randomly dropped 50% of all observations in the estimation stage. Moreover, we consider the case where in the simulation stage only uncertainty of the estimates of  $\boldsymbol{\theta}$  is taken into account, holding fixed the values of  $\boldsymbol{\rho}_{deep}$  at the level of the original estimates.

⁵Note that our particular definition of the TTIP scenario does not need the estimates of  $\rho_{shallow}$ , however, they are clearly important as control variables in the estimation and would be needed in the simulation if alternative scenarios were considered.

⁶As detailed in Chapter 4, we set the PTA effect to zero in sector 38 ("Dwellings"), where we do not observe positive trade flows, and we use  $\theta = 5.9$  for the services sector, where  $\theta$  cannot be estimated since we do not observe tariffs.

		(1)	(2)	(3)	(4)	(5)	(6)
			Full sar	nple	Ē	50% sam	ple
Sector name	Sector	1/ heta	t-stat	$\overline{N}$	1/ heta	t-stat	N
Grains & Crops	1	-2.310***	-15.85	243,624	-2.232***	-12.99	122,027
Livestock farming	2	-2.441***	-13.99	90,274	-2.434***	-13.25	45,114
Forestry	3	-3.385***	-6.42	$22,\!304$	$-2.889^{***}$	-3.79	11,140
Fishing	4	-3.156***	-4.70	28,274	-3.369***	-3.99	14,218
Mining	5	$-6.021^{*}$	-1.72	$6,\!669$	$-10.275^{*}$	-1.94	3,292
Minerals nec	6	-3.695***	-5.26	$85,\!350$	-4.082***	-4.86	$42,\!669$
Meat products	7	$-2.498^{***}$	-29.48	$531,\!429$	$-2.542^{***}$	-24.09	265,841
Textiles	8	-4.913***	-16.89	801,095	-4.826***	-15.83	400,672
Wearing apparel	9	$-1.613^{***}$	-4.95	699,145	$-1.514^{***}$	-4.77	349,963
Leather products	10	-2.939***	-9.80	175,800	-2.635***	-8.03	87,824
Wood products	11	$-2.774^{***}$	-10.35	175,800	$-2.784^{***}$	-9.29	87,824
Paper products	12	$-4.697^{***}$	-20.50	223,734	-4.633***	-17.29	111,859
Petroleum, Coal	13	$-5.463^{***}$	-4.65	317,824	$-5.163^{***}$	-3.24	158,986
Chemicals	14	$-4.743^{***}$	-22.18	22,745	$-4.753^{***}$	-21.22	11,281
Minerals	15	$-2.804^{***}$	-12.81	1,544,089	$-2.875^{***}$	-11.35	$772,\!538$
Ferrous metals	16	$-1.187^{***}$	-4.40	337,582	-1.000***	-4.35	$168,\!691$
Metals nec	17	-3.691***	-8.30	302,429	-3.787***	-7.24	151,291
Metal products	18	$-2.167^{***}$	-9.59	182,487	-2.309***	-9.53	91,364
Motor vehicles	19	-3.670***	-15.97	628,789	-3.892***	-13.87	$314,\!373$
Transport eqpm. nec	20	$-2.315^{***}$	-7.76	157,463	$-2.434^{***}$	-6.95	78,827
Electronics	21	$-2.184^{***}$	-9.74	112,560	-2.235***	-8.62	56,295
Machinery nec	22	-3.181***	-19.90	320,393	$-3.176^{***}$	-19.25	160,523
Manufactures nec	23	$-2.275^{***}$	-11.03	$2,\!212,\!282$	$-2.197^{***}$	-9.78	$1,\!106,\!528$

**Table 5.1:** Parameter estimates: Sectoral productivity dispersion  $\theta$ 

Note: Estimates of  $\rho_{deep}$  ( $\rho_{shallow}$ ) are reported in Table 5.2 (A5.6). Estimates of importer, exporter, and HS 6-digit product fixed effects and the standard gravity controls (ln *Dist, Contiguity, Common Language, Former Colony, Current Colony, Common Colonizer*) not shown. Standard errors obtained from 425 bootstrap replication accounting for clustering at countrypair level. *, ** and *** indicate statistical significance at the 10, 5 and 1% level, respectively. PTA dummies instrumented with contagion indices a la Martin et al. (2012) or Baldwin and Jaimovich (2012).

### 5.3.1 Data and Estimation Results

Tables 5.1 and 5.2 show the estimated parameters of interest obtained from the gravity specification with instrumental variables as described in the previous chapter.⁷ Columns (1)-(3) display the result from the full sample (equaling the estimates used for the simulations in the previous chapter), Columns (4)-(6) show the results for the same specification based on a dataset where we have randomly dropped 50% of observations in every sector.⁸ With few exceptions, the loss of information leads to less precise estimates (smaller *t*-values). Generally, however,  $\rho_{deep}$  and  $\theta$  are very precisely estimated also with only half of the data and their magnitudes are remarkably stable.

⁷For the sake of completeness, Table A5.6 reports the estimates for the shallow PTA effects, which do not feature in our simulations.

⁸The number of observations in Column (6) is some times more or less than half the number of observations in Column (3) because a few observations are not used in the regressions because of missing data or collinearity with fixed effects.

		(1)	(2)	(3)	(4)	(5)	(6)
			Full sa	mple	Ę	50% sam	nple
Sector name	Sector	$oldsymbol{ ho}_{deep}$	<i>t</i> -stat	N	$oldsymbol{ ho}_{deep}$ )	t-stat	N
Grains & Crops	1	0.401***	3.09	243,624	0.456***	3.64	122,027
Livestock farming	2	-0.204	-1.51	90,274	-0.240	-1.63	45,114
Forestry	3	0.086	0.55	22,304	-0.028	-0.13	11,140
Fishing	4	0.076	0.35	28,274	0.087	0.36	14,218
Mining	5	0.830	1.52	$6,\!669$	-0.102	-0.12	3,292
Minerals nec	6	$0.364^{***}$	2.67	85,350	$0.300^{*}$	1.94	42,669
Meat products	7	$0.289^{***}$	3.05	$531,\!429$	$0.311^{***}$	3.22	265,841
Textiles	8	$0.294^{***}$	3.37	801,095	$0.317^{***}$	3.55	400,672
Wearing apparel	9	$0.502^{***}$	4.79	699,145	$0.533^{***}$	4.97	349,963
Leather products	10	$0.637^{***}$	6.44	175,800	$0.686^{***}$	6.45	87,824
Wood products	11	$0.476^{***}$	6.16	175,800	$0.476^{***}$	6.06	87,824
Paper products	12	$0.526^{***}$	6.90	223,734	$0.503^{***}$	5.68	111,859
Petroleum, Coal	13	$0.672^{***}$	3.18	317.824	$0.653^{**}$	2.32	158.986
Chemicals	14	$0.317^{***}$	4.26	22,745	$0.347^{***}$	4.52	11,281
Minerals	15	$0.157^{**}$	2.12	1.544.089	$0.169^{**}$	2.04	772.538
Ferrous metals	16	$0.665^{***}$	7.00	337,582	$0.656^{***}$	6.66	168,691
Metals nec	17	$0.752^{***}$	7.18	302,429	$0.735^{***}$	6.46	151,291
Metal products	18	$0.307^{***}$	3.71	182,487	$0.346^{***}$	4.20	91,364
Motor vehicles	19	$0.896^{***}$	8.98	628,789	$0.866^{***}$	8.11	314.373
Transport eqpm. nec	20	$0.409^{***}$	4.37	157.463	$0.431^{***}$	4.32	78,827
Electronics	21	$0.242^{***}$	2.85	112,560	$0.191^{**}$	2.13	56,295
Machinery nec	22	$0.175^{***}$	2.83	320,393	$0.174^{***}$	2.71	160,523
Manufactures nec	23	$0.251^{***}$	3.24	2,212,282	$0.279^{***}$	3.15	1.106.528
Electricity	24	$0.438^{***}$	5.88	371.077	$0.530^{***}$	5.13	185.957
Gas	25	$0.389^{***}$	4.47	13,546	$0.497^{***}$	3.92	6,789
Water	26	$0.377^{***}$	7.12	11,368	$0.438^{***}$	5.88	5,726
Construction	27	$0.302^{***}$	3.68	14,434	0.179	1.60	7.215
Trade services	28	$0.580^{***}$	10.23	14,518	$0.542^{***}$	6.73	7,271
Transport nec	29	$0.399^{***}$	7.67	14,518	$0.330^{***}$	4.52	7,261
Sea transport	30	$0.413^{***}$	5.35	14,518	$0.436^{***}$	3.93	7.265
Air transport	31	$0.123^{**}$	2.20	14,518	0.067	0.90	7,244
Communication	32	$0.294^{***}$	5.35	14,518	$0.360^{***}$	4.97	7.269
Financial services	33	$0.490^{***}$	8.30	14,518	$0.444^{***}$	5.35	7.251
Insurance	34	$0.338^{***}$	6.09	14,518	$0.366^{***}$	4.50	7,263
Business services	35	$0.559^{***}$	10.04	14,518	$0.580^{***}$	7.90	7,262
Recreation	36	$0.238^{***}$	4.43	14,518	$0.240^{***}$	2.82	7,259
Public services	37	$0.367^{***}$	6.50	14,518	$0.508^{***}$	5.90	7,250

Table 5.2: Parameter estimates: Deep PTA effect

Note: Estimates of  $\theta$  ( $\rho_{shallow}$ ) are reported in Table 5.1 (A5.6). Estimates of importer, exporter, and HS 6digit product fixed effects (sectors 1-23 only) and standard gravity controls (ln Dist, Contiguity, Common Language, Former Colony, Current Colony, Common Colonizer) not shown. Standard errors obtained from 425 bootstrap replication accounting for clustering at country-pair level. *, ** and *** indicate statistical significance at the 10, 5 and 1% level, respectively. PTA dummies instrumented with contagion indices a la Martin et al. (2012) or Baldwin and Jaimovich (2012).

### 5.3.2 Confidence Bounds for Welfare Effects

The main results from our bootstrapping exercise are summarized in Table 5.3 for 22 countries or regions and the world. Table 5.4 presents disaggregated results for the 28 EU countries, Table A5.7 has detailed results for the non-TTIP countries. Column (1) of Tables 5.3 and 5.4 shows the welfare effects obtained from solving the model for the original parameter estimates  $\Theta_N$ .⁹ Columns (2)-(5) present the four different confidence intervals described in Section 5.2.1.2. The first result we want to highlight is that irrespective of the confidence interval we are looking, at most of the predicted welfare effects are significantly different from zero at the level of  $\alpha = .05$ .¹⁰ With the exception of Greece, the predicted gains for all individual TTIP countries are strongly significant, and so is the predicted gain for the world as a whole. Hence, in this particular application, accounting for parameter uncertainty does not bring into question the qualitative results obtained from the simulation study.

However, accounting for uncertainty allows to single out quantitative predictions, which, from a statistical point of view, cannot be differentiated from zero. Consider, for example, the welfare effect predicted for the Eurasian Customs Union (CU) in Table 5.3, which is the largest negative effect among the 22 regions. According to three of the four estimated confidence intervals, the effect is not statistically different from zero for  $\alpha = .05$ . Similarly, the negative welfare effects for Central Asia and the EFTA are surrounded by a large degree of uncertainty, rendering the predictions insignificant. On the winning side, we find that welfare gains predicted for Sub-Saharan Africa and Central America are not significant. In total, we find that the welfare effects for 17 out of 50 countries who are predicted to lose from TTIP, and for 11 out of 90 countries who are predicted to win, can, statistically, not be differentiated from zero.

Table 5.3 also shows that different concepts of confidence intervals may lead to different conclusions regarding significance. Only in three cases do the four concepts considered unanimously agree on insignificance for a given level of  $\alpha$  (Sub-Saharan Africa, Central America, and Middle East & North Africa). The two symmetric confidence intervals,  $(CI_S \text{ in Column (2)}, \text{ which relies on the normal approximation, and CI_{BP1} in Column$ (4), which uses the quantiles of the bootstrapped distribution of the welfare effects) arevery similar.

 $^{^{9}}$ The estimated welfare effects in Column (1) are equal to the results presented in Chapter 4.

¹⁰Note that due to the fact that the choice of  $\alpha = \alpha_1 + \alpha_2$  does not always reflect a coverage probability of  $(1 - \alpha) * 100$ , as discussed in Section 5.2.1.2, we do not generally refer to  $\alpha$  as the significance level.

	(1)	(2)	(3)	(4)	(5)	(9)	(2)	(8)
Region/Country	$W_N$ (in %)	$\begin{array}{c} \mathrm{CI}_S\\ \mathrm{symm.} \begin{array}{l} (\mathrm{eqt.})\\ (\mathrm{in} \ \%) \end{array}$	$\begin{array}{c} \operatorname{CI}_{BP1} \\ \operatorname{equal-tailed} \\ (\operatorname{in} \ \%) \end{array}$	$\begin{array}{c} \operatorname{CI}_{BP1} \\ \operatorname{symm.} \\ (\operatorname{in} \%) \end{array}$	$\begin{array}{c} \operatorname{CI}_{BP2} \\ \operatorname{equal-tailed} \\ (\operatorname{in} \%) \end{array}$	Biaabsolute(in %pts.)	s relative (in %)	$\begin{array}{c} pwd \\ (425,.05) \\ (\mathrm{in}  \%) \end{array}$
USA	0.493	[0.416, 0.571]	$\begin{bmatrix} 0.433, \ 0.592 \end{bmatrix}$	[0.408, 0.579]	[0.395, 0.553]	0.013	0.026	0.042
EU28 Occania	0.426	0.344, 0.508	0.372, 0.537	0.333, 0.519	0.314, 0.479	0.017	0.040	0.075
Cecama Rest of Europe	0.056	0.035, 0.077	0.044, 0.086	0.033, 0.080	0.026, 0.032	0.003	0.050	0.064
Rest of World	0.044	[0.031, 0.056]	[0.031,  0.056]	[0.031, 0.056]	[0.031, 0.057]	-0.001	0.016	0.013
South Asia	0.023	[0.013, 0.034]	[0.015, 0.035]	[0.014, 0.033]	[0.012, 0.032]	0.000	0.020	0.022
Sub-Saharan Africa	0.023	[-0.011, 0.057]	[-0.019, 0.054]	[-0.011, 0.057]	[-0.008, 0.065]	-0.001	0.063	0.371
Turkey	0.023	[0.010, 0.035]	[0.014, 0.038]	[0.010, 0.035]	[0.007, 0.032]	0.001	0.047	0.051
Central America	0.009	-0.002, 0.020 0.011 0.000	[-0.003, 0.019]	-0.002, 0.019 0.011 0.000	-0.001, 0.020	0.000	0.002	0.047
MERCOSUR AUS & NZL	-0.010 -010	-0.011, -0.000	-0.012, -0.002 -0.019 -0.004	-0.011, -0.000	-0.009, 0.002 -0.017 -0.001	-0.000	0.002	0.043 0.023
ASEAN	-0.014	-0.021, -0.006	-0.021, $-0.006$	-0.021, -0.006	-0.021, -0.007	-0.000	0.008	0.013
Mid.East & N.Africa	-0.016	[-0.045, 0.012]	[-0.056, 0.001]	[-0.043, 0.010]	[-0.034, 0.023]	-0.002	0.101	0.380
East Asia	-0.019	[-0.026, -0.012]	[-0.025, -0.012]	[-0.026, -0.012]	[-0.026, -0.013]	0.000	0.003	0.010
SACU	-0.021	[-0.029, -0.014]	[-0.028, -0.013]	[-0.029, -0.013]	[-0.029, -0.014]	0.001	0.034	0.009
Canada	-0.024	[-0.046, -0.002]	[-0.044, -0.000]	[-0.046, -0.002]	[-0.048, -0.004]	0.001	0.058	0.069
China	-0.027	[-0.034, -0.021]	[-0.034, -0.022]	[-0.034, -0.021]	[-0.033, -0.021]	-0.000	0.009	0.006
Central Asia	-0.030	-0.078, 0.017	[-0.095, -0.001]	[-0.078, 0.017]	-0.060, 0.034	-0.003	0.106	0.534
EFTA	-0.040	[-0.086, 0.006]	[-0.097, -0.010]	[-0.083, 0.004]	[-0.070, 0.018]	-0.002	0.052	0.354
Al. del Pacifico	-0.064	[-0.086, -0.042]	[-0.084, -0.042]	-0.086, -0.042	[-0.086, -0.044]	0.001	0.016	0.025
Oil exporters	-0.102	[-0.186, -0.018]	[-0.216, -0.056]	[-0.195, -0.008]	-0.148, 0.013	-0.007	0.065	0.626
Eurasian CU	-0.104	[-0.245, 0.038]	-0.297, -0.018	[-0.237, 0.030]	[-0.189, 0.090]	-0.008	0.077	1.484
World	0.202	[0.168,  0.236]	[0.178, 0.249]	[0.164,  0.240]	[0.156,  0.226]	0.007	0.033	0.022
Note: $pwd(B,t)$ denotes impusing the approximate method bias in percent of $W_N$ .	lied percents od proposed	age deviation of bias e by Cameron and Trive	timate not exceed wi di (2005), Ch. 11. Cc	th probability $(1-t)$ onfidence intervals in 0	* 100 = 95% given B Columns (2)-(5) and b	= 425 bootstrap s ias estimate as de	samples. <i>pwd</i> is fined in the tex	s calculated ct. Relative

**Table 5.3:** Welfare change, confidence intervals ( $\alpha = .05$ ), and bias: by regions

Chapter 5

countries
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Welfare
Table 5.4:

51	QT	5			
$\begin{array}{c} \mathrm{CI}_{BP1} \\ \mathrm{equal-tailed} \\ \mathrm{(in \%)} \end{array}$	$\begin{array}{c} {\rm CI}_{BP1} \\ {\rm symm.} \\ ({\rm in} \ \%) \end{array}$	$\begin{array}{c} \mathrm{CI}_{BP2}\\ \mathrm{equal-tailed}\\ (\mathrm{in}\ \%) \end{array}$	Bias absolute (in %pts.)	relative (in %)	pwd(425,.05)(in %)
$\begin{bmatrix} 2.593, 3.785 \\ 0.000 \end{bmatrix}$	$\begin{bmatrix} 2.515, 3.715 \end{bmatrix}$	$\begin{bmatrix} 2.445, 3.637 \end{bmatrix}$	0.068	2.182	0.405
0.890, 1.356	0.857, 1.317	0.819, 1.284	0.025	2.328	0.177 0.096
0.613, 1.014	0.543, 0.970	0.499, 0.920	0.034	4.557	0.203
[0.570, 0.845]	[0.511, 0.813]	[0.480, 0.755]	0.025	3.719	0.101
[0.482, 0.667]	[0.440, 0.658]	[0.432, 0.617]	0.018	3.227	0.057
0.445, 0.672	$\begin{bmatrix} 0.382, \ 0.639 \end{bmatrix}$	[0.349, 0.576]	0.024	4.692	0.207
0.289, 0.791		0.094, 0.595	0.030	6.691 7 887	0.985
0.300, 0.040	0.339, 0.324	[0.340, 0.496] -0.006_0.578]	0.034	2.002	1.567
0.315, 0.449	0.301, 0.438	[0.291, 0.425]	0.008	2.218	0.043
.308, 0.478	[0.264, 0.447]	[0.233, 0.403]	0.016	4.635	0.196
289, 0.434	[0.262, 0.421]	[0.249, 0.395]	0.013	3.808	0.053
293, 0.401	[0.272, 0.394]	[0.266, 0.374]	0.011	3.191	0.034
266, 0.385	[0.249, 0.368]	[0.232, 0.352]	0.010	3.195	0.036
231, 0.513	[0.154,  0.431]	[0.072, 0.354]	0.021	7.081	0.783
238, 0.380	[0.214,  0.360]	[0.194, 0.337]	0.012	4.237	0.062
244, 0.368	[0.223, 0.342]	[0.197, 0.322]	0.011	3.968	0.069
229, 0.386	[0.195, 0.368]	[0.178, 0.334]	0.015	5.359	0.098
234, 0.348	[0.221,  0.334]	[0.208, 0.322]	0.007	2.651	0.049
215, 0.391	[0.176, 0.362]	[0.147, 0.324]	0.015	5.636	0.165
203, 0.373	[0.163, 0.342]	[0.132, 0.302]	0.014	5.520	0.180
211, 0.314	[0.186, 0.303]	[0.175, 0.278]	0.009	3.803	0.054
197, 0.348	[0.163, 0.317]	[0.133, 0.283]	0.012	4.920	0.281
178, 0.276	[0.161, 0.261]	[0.147, 0.244]	0.008	3.594	0.052
168, 0.267	[0.145,  0.245]	[0.123, 0.222]	0.009	4.548	0.126
135, 0.277	[0.104, 0.243]	[0.070, 0.212]	0.011	6.272	0.181
.137,  0.228	[0.122,  0.219]	[0.113, 0.203]	0.009	5.110	0.047

Parameter Uncertainty in NQTT Models



Figure 5.1: Distribution of bootstrap estimates and confidence bounds

Note: Bootstrap distribution of welfare effects for based on 425 bootstrap samples.

However, they differ vastly from the equal-tailed confidence intervals (CI_{BP1} in Column (3), which uses the quantiles of the bootstrapped distribution of the welfare effects, and CI_{BP2} (Column 4), which uses the reversed quantiles of the bootstrapped distribution). This suggests that the distribution of the original estimate,  $G_N(\Theta_N)$  is skewed, and hence, neither the symmetric confidence intervals nor the equal-tailed confidence interval based on the "raw" distribution of the bootstrapped welfare effects (CI_{BP1}) lead to correct coverage probability  $(1 - \alpha)$  (except for special cases). Hence, CI_{BP2} (or a symmetric version thereof) emerges as the most reliable interval to test for a given significance level. Note that (CI_{BP1}) tends to yield smaller lower bounds for positive values of W and larger upper bounds for negative values of W than the other concepts, implying for the distribution of  $W(\Theta_N)$  that large deviations into the negative range are less likely for winners and vice versa for losers.

Figure 5.1 plots the distribution of the bootstrapped welfare effects and the three different confidence intervals for Greece and Canada. For the case of Greece (right panel), the bootstrap distribution is strongly positively skewed, implying that the different concepts for confidence intervals lead to vastly different bounds. Likewise but to a smaller extent also for Canada (left panel), where the (negative) skewness is less extreme. Moreover,



Figure 5.2: Distribution of bootstrap estimates and confidence bounds

Note: Bootstrap distribution of welfare effects based on 425 bootstrap samples.

it implies that in the case of Greece large positive deviations are likely.¹¹ Accordingly, the  $CI_{BP2}$  (light grey dashed line) sets the lower bound far to the left, because observing a large estimate  $W(\Theta_N)$  is likely even if the true value is close to zero. Note that the other two confidence intervals do not capture this implication of the skewness, in fact, the bounds of the equal-tailed  $CI_{BP1}$ , which simply uses the percentiles of the bootstrap distribution (dark grey dashed lines), gets the effect of the skewness exactly wrong. Arguably, as Column (4) of Table 5.4 reveals, Greece is an extreme case. Nevertheless, it serves as a good example to highlight the importance of accounting for the skewness of the distribution of W.

To understand how the uncertainty surrounding our parameter estimates translates into uncertainty about the predicted welfare effects, we also computed confidence bounds based on 425 bootstrap parameter estimates obtained from the small sample that contains only 50% of the observations from the original dataset. Moreover, we computed confidence

¹¹Remember that the distribution of the bootstrap estimates' sampling error  $W_N^b - W_N$  mimicks the distribution of the original estimates sampling error,  $W_N - W$ .
		Median	Mean	Std. Dev.	Min	Max
Absolute bias (in %pts.)	100% sample 50% sample	.001 .001	.003 .004	$.01 \\ .015$	018 037	.068 .107
Relative bias (in $\%$ of $W_N$ )	100% sample 50% sample	$\begin{array}{c} 3.71 \\ 4.64 \end{array}$	$7.39 \\ 11.9$	$\begin{array}{c} 25.2\\ 30.9 \end{array}$	.09 .259	$287 \\ 237$
pdw(B,t) (in %) B=425,t=.05	100% sample 50% sample	$.066 \\ .055$	$.387 \\ .319$	$1.599 \\ .907$	.003 $.003$	$\begin{array}{c} 17.0 \\ 7.28 \end{array}$

Table 5.5: Summary statistics of bias estimates for 140 countries

Note: Bias estimate of welfare effects as defined in the text. Estimates based on B = 425 bootstrap samples.

bounds for the hypothetical case that there is no uncertainty about the value of  $\rho_{deep}$ . To obtain the corresponding distribution of welfare effects, we repeated the simulation exercise for 425 bootstrap replications of  $\theta$ , holding fixed the values of  $\rho_{deep}$  at the level of the original parameter estimates. Figure 5.2 shows the different distributions and confidence bounds for the United States.

Comparing the bootstrap distributions based on 100% (black solid curve) and 50% (grey solid curve) of the data shows that the distribution obtained from the small sample has a slightly larger dispersion and negative skewness, as it is indicated by the confidence interval extending much further to the left than to the right. However, in comparison to the distribution of welfare effects obtained for the hypothetical case where  $\theta$  is the only source of randomness (dashed grey line), these differences are marginal.

### 5.3.3 Estimated Bias of Predicted Welfare Effects

As described in Section 5.2.1.3, we can also use the bootstrap to obtain an estimate of the bias of  $W_N = W(\Theta_N)$ , that derives from the non-linearity of  $W(\cdot)$ ; see Equation (5.8). The bias estimate is given by the difference between the mean of the bootstrapped quantities  $W_N^b$  for b = 1, ..., B and  $W_N$ , the original estimate. We compute the *absolute* bias for every country i as

$$\widehat{Bias_i} = \frac{1}{B} \sum_{b=1}^{B} \left( W_{N,i}^b - W_{N,i} \right)$$

Moreover, we report the estimated *relative* bias which we define as

$$\widehat{rBias}_i = \frac{|\widehat{Bias}_i|}{|W_{N,i}|}.$$

Figure 5.3: Distribution of absolute bias estimates: Negative vs. positive welfare effects



Note: Bootstrap distribution of estimated biases across 140 countries/regions. Estimates based on 425 bootstrap samples.

Columns (6) and (7) of Tables 5.3 and 5.4 present the results for individual countries and regions, Table 5.5 provides summary statistics of the distribution across the 140 countries and regions.¹²

We find that the bias is small in absolute terms, ranging between -.018 and .068 percentage points. However, since the welfare changes were small to begin with, the relative estimated biases range between .1 and 287.3% of the estimated welfare effect  $W_N$ . The average relative bias is 7.4%, the median equals 3.7%. Moreover, as Figure 5.3 shows, the bias tends to be positive for positive predicted welfare changes, and negative for negative predictions. In accordance with Jensen's inquality, this suggests that  $W(\Theta_N)$  is convex around  $\Theta$  and hence, we tend to overpredict the absolute magnitude of the welfare changes by not accounting for parameter uncertainty.

The comparison with our analysis based on the 50% sample shows that the degree of parameter uncertainty matters for the bias, notwithstanding the fact that the parameters are still very precisely estimated with the smaller sample. Table 5.5 shows summary

 $^{^{12}}$  Table A5.7 has the details for those individual countries that do not appear in Tables 5.3 and 5.4.

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Figure 5.4: Distribution of relative bias estimates: Large vs. small sample

Note: Bootstrap distribution of estimated biases across 140 countries/regions. Estimates based on 425 bootstrap samples.

statistics of the distribution of bias estimates also for the 50% sample, Figure 5.4 plots kernel densities of the distribution of estimated relative biases (across countries) obtained with the small sample (grey line) and the large sample (black line). The figure shows that the distribution of bias estimates based on the small dataset has more mass in the right tail, that is, large biases occur more often. Table 5.5 shows that the median, the mean, and the standard deviation of the relative bias estimates all increase as we lose precision in the estimation stage. The range of absolute bias estimates based on the small sample is -.037 to .107 percentage points, which is almost twice as large as the range we obtained with the full sample.

As regards the number of bootstrap samples used in the analysis, we use the approximation to Andrews and Buchinsky (2000)'s three step algorithm suggested by Cameron and Trivedi (2005) to calculate the implied percentage deviation of the bias corrected estimate (5.10) from its ideal quantity (the limit for  $B \to \infty$ ). Cameron and Trivedi (2005) suggest using  $(s_W/W_N)^2$  to approximate the ideal quantity  $(se_{\infty}/W_N^{\infty})^2$ , where  $W_N^{\infty}$  is the limit of the bias-corrected estimate (5.10) and  $se_{\infty}$  is the limit of the bootstrap standard error (5.1) for  $B \to \infty$ . For a given number of bootstraps, we can then calculate the percentage deviation from the ideal quantity

$$pdw(B,t) = z_{1-t/2}\sqrt{\frac{s_W}{W_N}\frac{1}{B}}$$

which will not be exceed with probability (1 - t).  $z_x$  denotes the *x*th percentile of the standard normal distribution. We calculate the (approximate) pdw implied by B = 425 and t = .05 for every country. Results are presented in Column (8) of Tables 5.3, 5.4, and A5.7, Table 5.5 provides summary statistics of the distribution across countries. The implied pwd's range between .003 and 17%, the median values is below .1%. Hence, with 425 bootstraps, we achieve a fair degree of precision of the bootstrapped quantities.

### 5.4 Conclusion

In this chapter we have discussed the implications of parameter uncertainty for simulation results obtained from non-linear quantitative models calibrated with estimated parameters, as it is typical for studies applying the methodology summarized as "New Quantitative Trade Theory" (Costinot and Rodriguez-Clare, 2014). Building on well established results from the econometrics literature, we discuss the issues of bias and uncertainty of model predictions that arise in these frameworks once we acknowledge that the parameters used to calibrate the model are estimated with uncertainty. We show how a bootstrap can be used to translate parameter uncertainty, deriving from the fact that we observe only one realization of the data generating process, into measurable uncertainty of model predictions. Moreover, we show the bootstrap replications of model predictions can be used to estimate the bias deriving from the combination of parameter uncertainty and of non-linearity of the model.

We apply the methodology to a counterfactual analysis of the simulated welfare effects of the "Transatlantic Trade and Investment Partnership" (TTIP), which was the subject of Chapter 4. Our application shows, that even in a case of very precisely estimated parameters, accounting for parameter uncertainty in the simulation stage is important to tell apart predictions that are not statistically significant from those that are. Moreover, we find that the interaction of uncertainty with the non-linearity of the model leads to a systematic bias of model predictions, equaling 7% on average in our application. In line with the theoretical results, we find that the degree of uncertainty matters: Using estimates based on a dataset including only 50% of the observations from the original sample increases the average bias to 11%. Quantitatively, our bias estimates are small.

### Chapter 5

For example, we find an overestimation of the welfare gains for the EU countries of .013 percentage points and .017 percentage points for the United States. However, the simulation outcomes were small to begin with. Moreover, our particular application is characterized by high precision in the estimation stage, even after dropping 50% of the observations. We leave a more systematic analysis of the relationship between the degree of uncertainty and the degree of non-linearity of model structures for future research.

Moreover, estimated structural parameters are certainly only one source of uncertainty surrounding the simulated welfare effects of a policy change. In this study, we have taken as given the data used to calibrate the model's observable moments, which might be subject to measurement error. More importantly, we have assumed a particular structural model, implicitly shutting down uncertainty with regard to exact production and consumption relationships in the economy. Therefore, we view our analysis of parameter uncertainty as a first step of a greater endeavour into the issue of uncertainty in counterfactual analysis.

## Appendix A.5

Table A5.6: Parameter estimates full sample and 50% sample: Shallow PTA effect

		Full sample			50% sample		
Sector name	Sector	$oldsymbol{ ho}_{shallow}$	t-stat	Ň	$ ho_{shallow}$	<i>t</i> -stat	N
Grains & Crops	1	$0.249^{**}$	2.14	243,624	$0.272^{**}$	2.33	122,027
Livestock farming	2	$-0.261^{**}$	-2.08	90,274	-0.209	-1.53	45,114
Forestry	3	-0.024	-0.15	22,304	-0.148	-0.66	11,140
Fishing	4	-0.182	-0.80	28,274	-0.214	-0.78	14,218
Mining	5	$1.269^{**}$	2.07	$6,\!669$	0.936	0.98	3,292
Minerals nec	6	$0.357^{**}$	2.34	85,350	0.282	1.58	42,669
Meat products	7	$0.188^{**}$	2.33	531,429	$0.203^{**}$	2.33	265,841
Textiles	8	0.079	0.84	801,095	0.087	0.92	400,672
Wearing apparel	9	-0.023	-0.21	699,145	-0.017	-0.15	349,963
Leather products	10	$0.208^{**}$	2.06	175,800	$0.224^{**}$	2.10	87,824
Wood products	11	0.073	1.00	175,800	0.063	0.73	87,824
Paper products	12	$0.146^{*}$	1.88	223,734	$0.183^{**}$	2.01	111,859
Petroleum, Coal	13	$0.807^{***}$	4.02	317,824	$0.530^{**}$	2.17	158,986
Chemicals	14	$0.201^{***}$	2.60	22,745	$0.201^{***}$	2.72	11,281
Minerals	15	0.081	1.00	1,544,089	0.067	0.76	772,538
Ferrous metals	16	$0.188^{*}$	1.94	337,582	$0.189^{*}$	1.79	168,691
Metals nec	17	$0.611^{***}$	4.68	302,429	$0.629^{***}$	4.65	$151,\!291$
Metal products	18	$0.247^{***}$	2.95	182,487	$0.266^{***}$	3.14	91,364
Motor vehicles	19	$0.296^{***}$	3.04	628,789	$0.278^{***}$	2.91	314,373
Transport eqpm. nec	20	0.136	1.49	157,463	$0.204^{**}$	1.99	78,827
Electronics	21	$0.467^{***}$	6.12	112,560	$0.436^{***}$	4.90	56,295
Machinery nec	22	$0.196^{***}$	3.00	320,393	$0.198^{***}$	2.91	160,523
Manufactures nec	23	$0.169^{**}$	2.10	2,212,282	$0.219^{**}$	2.57	1,106,528
Electricity	24	$0.298^{***}$	5.96	371,077	$0.245^{***}$	3.37	185,957
Gas	25	$0.141^{**}$	2.25	13,546	$0.274^{***}$	3.19	6,789
Water	26	$0.229^{***}$	7.60	11,368	$0.196^{***}$	4.33	5,726
Construction	27	$0.169^{***}$	2.67	$14,\!434$	$0.168^{*}$	1.76	7,215
Trade services	28	$0.129^{***}$	3.55	14,518	$0.174^{***}$	3.23	7,271
Transport nec	29	$0.182^{***}$	5.94	14,518	$0.201^{***}$	4.50	7,261
Sea transport	30	0.024	0.44	14,518	0.030	0.36	7,265
Air transport	31	$0.175^{***}$	4.35	14,518	$0.224^{***}$	3.67	7,244
Communication	32	$0.221^{***}$	7.20	14,518	$0.226^{***}$	4.93	7,269
Financial services	33	$0.160^{***}$	4.04	14,518	0.202***	3.62	7,251
Insurance	34	$0.152^{***}$	4.86	14,518	0.201***	4.10	7.263
Business services	35	$0.267^{***}$	7.58	14,518	0.309***	6.22	7,262
Recreation	36	$0.142^{***}$	4.02	14,518	$0.129^{**}$	2.50	7,259
Public services	37	$0.178^{***}$	5.12	$14,\!518$	$0.179^{***}$	3.20	$7,\!250$

Note: Estimates of  $\theta$  ( $\rho_{deep}$ ) are reported in Table 5.1 (5.2). Estimates of importer, exporter, and HS 6-digit product fixed effects (sectors 1-23 only) and standard gravity controls (ln *Dist, Contiguity, Common Language, Former Colony, Current Colony, Common Colonizer*) not shown. Standard errors obtained from 425 bootstrap replication accounting for clustering at country-pair level. *, ** and *** indicate statistical significance at the 10, 5 and 1% level, respectively. PTA dummies instrumented with contagion indices a la Martin et al. (2012) or Baldwin and Jaimovich (2012).

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	$W_N$	$CI_S$	$CI_{BP1}$	$CI_{BP1}$	$CI_{BP2}$	$\widehat{\operatorname{Bia}}$	ŝ	pwd(425, .05)
Country	(in %)	$ \begin{array}{c} \text{symm. (eqt.)} \\ \text{(in \%)} \end{array} $	equal-tailed (in %)	(in %)	equal-tailed (in %)	abs. (in %pts.)	rel. (in %)	(in %)
BEN	0.187	[0.133, 0.242]	[0.154, 0.266]	[0.125, 0.250]	[0.108, 0.221]	0.008	4.230	0.132
KGZ	0.177	[0.125, 0.230]	[0.140, 0.250]	[0.123, 0.231]	[0.105, 0.214]	0.006	3.463	0.102
TGO	0.130	[0.128, 0.184] [0.097, 0.200]	0.134, 0.190 0.116, 0.215	0.093, 0.205	[0.122, 0.178] [0.083, 0.181]	0.007	4.922	0.140
ZWE	0.140	[0.115, 0.165]	[0.119, 0.168]	[0.115, 0.164]	[0.111, 0.160]	0.002	1.203	0.016
MDA	0.134	[0.069, 0.199]	[0.094, 0.221]	[0.065, 0.203]	[0.047, 0.174]	0.008	5.854	0.256
XSA CIN	0.124	[0.102, 0.145]	[0.107, 0.149]	[0.102, 0.146]	[0.099, 0.141]	0.002	1.282	0.013
GEO	0.097	[0.050, 0.144]	[0.073, 0.152]	[0.057, 0.136]	[0.042, 0.121]	0.004	4.207	0.115
KEN	0.093	[0.072, 0.114]	[0.077, 0.119]	[0.072, 0.114]	0.067, 0.109	0.002	2.534	0.019
ECU	0.092	[0.045, 0.140]	[0.056, 0.149]	[0.045, 0.140]	[0.036, 0.129]	0.002	1.714	0.118
PAN	0.091	[0.065, 0.117]	[0.070, 0.122]	[0.067, 0.115]	[0.060, 0.112]	0.002	1.974	0.041
JOB	0.090	[0.024, 0.157] [0.054, 0.114]	[0.027, 0.137] [0.064, 0.124]	[0.025, 0.155] [0.054, 0.114]	[0.025, 0.154] [0.044, 0.104]	0.001	1.230 4.586	0.172 0.094
XOC	0.080	0.064, 0.096	0.068, 0.098	0.063, 0.097	[0.062, 0.092]	0.002	2.030	0.010
SEN	0.074	[0.046, 0.103]	[0.058, 0.115]	[0.043,  0.105]	[0.034, 0.091]	0.004	5.894	0.109
XNA	0.072	[0.040, 0.105]	[0.045, 0.108]	0.039, 0.105	[0.036, 0.100]	0.003	4.474	0.052
HKG MUS	0.065	[0.047, 0.083]	[0.050, 0.086] [0.051, 0.087]	[0.047, 0.083]	[0.043, 0.080]	0.002	2.725 3 115	0.021
TZA	0.064	[0.047, 0.081]	[0.052, 0.087]	[0.048, 0.080]	[0.043, 0.077]	0.002	2.979	0.022
NPL	0.064	[0.049, 0.078]	0.053, 0.084	0.049, 0.079	[0.043, 0.074]	0.002	3.017	0.017
ARM	0.059	[0.034, 0.084]	[0.042, 0.091]	[0.033, 0.084]	[0.027, 0.076]	0.003	4.623	0.070
GHA	0.058	[0.042, 0.074]	[0.045, 0.078]	[0.042, 0.074]	[0.038, 0.071]	0.002	2.851	0.020
ETH	0.057	[0.030, 0.083] [0.041, 0.070]	[0.042, 0.094] [0.045, 0.075]	[0.028, 0.080]	[0.020, 0.072]	0.003	3.382	$0.114 \\ 0.021$
MAR	0.054	[0.030, 0.078]	[0.040, 0.086]	[0.028, 0.080]	0.022, 0.069	0.003	5.530	0.094
XER	0.050	[0.033,  0.066]	[0.039,  0.073]	[0.031,  0.068]	[0.026,  0.060]	0.002	4.789	0.044
LKA	0.047	[0.035, 0.059]	[0.038, 0.062]	[0.035, 0.059]	[0.032, 0.056]	0.001	2.313	0.020
NGA	0.042 0.041	[0.032, 0.052]	[0.031, 0.051]	[0.032, 0.053] [-0.010_0.092]	[0.034, 0.054]	-0.000	$0.000 \\ 4 470$	0.009
UKR	0.039	[0.015, 0.064]	[0.025, 0.072]	[0.012, 0.066]	[0.006, 0.054]	0.002	5.078	0.136
PAK	0.039	[0.028, 0.050]	[0.031, 0.052]	[0.028, 0.050]	[0.025, 0.047]	0.001	2.639	0.021
XCB	0.037	[0.025, 0.049]	[0.026, 0.049]	[0.026, 0.049]	[0.025, 0.048]	-0.000	0.193	0.013
LAO VNM	0.036	[0.023, 0.048]	[0.026, 0.051] [0.021, 0.056]	[0.023, 0.048]	[0.020, 0.045]	0.001	3.359	0.017
BLR	0.033 0.034	[-0.002, 0.070]	[0.008, 0.082]	[-0.000, 0.067]	[-0.015, 0.049]	0.002	5.515	0.311
JAM	0.032	[0.016, 0.048]	[0.018, 0.050]	[0.016, 0.048]	[0.014, 0.046]	0.001	3.375	0.032
BGD	0.030	[0.016, 0.043]	[0.018, 0.047]	[0.017, 0.043]	[0.013, 0.042]	0.001	1.908	0.032
TUN	0.029	[0.015, 0.042]	[0.018, 0.047]	[0.015, 0.042]	[0.010, 0.039]	0.001	3.719	0.037
COL	0.028 0.028	[0.012, 0.044] [0.011, 0.045]	[0.010, 0.044] [0.007, 0.041]	[0.011, 0.044] [0.010, 0.045]	0.012, 0.040 0.014, 0.048	-0.000	1.108	$0.034 \\ 0.067$
PHL	0.027	0.019, 0.035	[0.021, 0.038]	0.019, 0.035	0.016, 0.033	0.001	3.462	0.017
ARE	0.026	[0.004,  0.048]	[0.001, 0.047]	[0.004,  0.049]	[0.005, 0.051]	0.000	1.473	0.080
GTM	0.026	[0.015, 0.037]	[0.017, 0.040]	[0.014, 0.037]	[0.012, 0.034]	0.001	3.962	0.026
SIN	0.025 0.024	[0.005, 0.046] [0.013, 0.036]	[-0.000, 0.041] [0.016, 0.038]	[0.000, 0.045] [0.013, 0.036]	[0.010, 0.051]	-0.000	1.801 4.237	0.091
TUR	0.023	[0.010, 0.035]	[0.014, 0.038]	[0.010, 0.035]	[0.007, 0.032]	0.001	4.745	0.051
XSE	0.022	[0.018, 0.026]	[0.018, 0.027]	[0.018, 0.026]	[0.017, 0.025]	0.000	1.373	0.003
KHM	0.021	[-0.011, 0.053]	[-0.012, 0.054]	[-0.012, 0.054]	[-0.012, 0.054]	-0.001	5.034	0.186
IND XFF	0.020	[0.009, 0.031]	[0.011, 0.032]	[0.010, 0.031]	[0.008, 0.029]	0.000	1.837	0.026
URY	0.013 0.017	[0.012, 0.022]	[0.013, 0.023]	[0.012, 0.022]	[0.021, 0.030]	0.004	1.965	0.204
MWI	0.017	[-0.016, 0.049]	[-0.025, 0.041]	[-0.015, 0.049]	[-0.007, 0.059]	-0.001	5.422	0.364
RWA	0.016	[0.003, 0.030]	[-0.002, 0.025]	[0.003, 0.030]	[0.007, 0.035]	-0.001	3.347	0.067
MDG ISB	0.015	[-0.003, 0.032]	[-0.009, 0.027]	[-0.003, 0.033]	[0.003, 0.038]	-0.001	5.083	0.130 0.150
CMR	0.011	-0.006 0.025	[-0.003, 0.034] [-0.009, 0.023]	-0.006, 0.031	-0.001, 0.020	-0.001	8.065	0.109
VEN	0.008	-0.028, 0.045	-0.043, 0.025	-0.030, 0.047	-0.009, 0.060	-0.004	45.613	1.773
DOM	0.004	[-0.006, 0.014]	[-0.006, 0.014]	[-0.006, 0.014]	[-0.006, 0.014]	-0.000	10.833	0.103
NZL	0.000	[-0.004, 0.005]	[-0.004, 0.005]	[-0.004, 0.005]	[-0.005, 0.005]	-0.000	28.479	0.253
AWS XEC	-0.001	[-0.042, 0.040]	[-0.053, 0.022] [-0.014 _0.002]	[-0.041, 0.039]	[-0.024, 0.052]	-0.003	287.308	17.011
BLZ	-0.006	[-0.048, 0.035]	[-0.051, 0.034]	[-0.049, 0.036]	[-0.047, 0.039]	-0.003	41.156	0.967

**Table A5.7:** Welfare change, confidence intervals ( $\alpha = .05$ ), and bias: Non-TTIP countries

Note: pwd(B,t) denotes implied percentage deviation of bias estimate not exceed with probability (1-t)*100 = 95% given B = 425 bootstrap samples. pwd is calculated using the approximate method proposed by Cameron and Trivedi (2005), Ch. 11. Confidence intervals in Columns (2)-(5) and bias estimate as defined in the text. Relative bias in percent of  $W_N$ .

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	$W_N$	$CI_S$	$CI_{BP1}$	CI _{BP1}	$CI_{BP2}$	$\widehat{\operatorname{Bias}}$	rol	pwd(425,.05)
Country	(in %)	(in %)	(in %)	(in %)	(in %)	(in %pts.)	(in %)	(in %)
BRA	-0.007	[-0.009, -0.004]	[-0.009, -0.004]	[-0.009, -0.004]	[-0.010, -0.004]	0.000	2.133	0.004
AUF VEA	-0.008	[-0.091, 0.075]	[-0.120, 0.047]	[-0.069, 0.074]	[-0.002, 0.100]	-0.005	09.940	7.000
ALA MOZ	-0.008	[-0.020, 0.010]	[-0.035, 0.004]	[-0.026, 0.012]	[-0.020, 0.010]	-0.003	32.470	0.202
AUS	-0.011	[-0.030, 0.012]	[-0.035, 0.011]	[-0.035, 0.012]	[-0.034, 0.012]	-0.002	0 1 25	0.184
ABG	-0.012	-0.020, -0.003	-0.021, -0.004	-0.020, -0.003	-0.015, $-0.002$	-0.000	2.234	0.023
BOL	-0.012	[-0.026, -0.001]	[-0.029, -0.000]	[-0.026, -0.001]	[-0.024, 0.003]	-0.000	1.396	0.048
XTW	-0.014	-0.023, -0.005	-0.025, -0.006	-0.023, -0.005	[-0.023, -0.004]	-0.000	1.035	0.025
SGP	-0.015	[-0.035, 0.005]	[-0.035, 0.007]	[-0.035, 0.005]	[-0.036, 0.006]	-0.000	1.263	0.099
JPN	-0.015	[-0.021, -0.009]	[-0.021, -0.009]	[-0.021, -0.010]	[-0.021, -0.010]	0.000	0.243	0.010
IDN	-0.018	[-0.025, -0.010]	[-0.026, -0.010]	[-0.025, -0.010]	[-0.025, -0.009]	0.000	0.255	0.011
THA	-0.022	-0.031, -0.014	-0.032, -0.015	-0.031, -0.014	-0.030, -0.013	-0.001	3.994	0.011
CAN	-0.024	[-0.046, -0.002]	[-0.044, -0.000]	[-0.046, -0.002]	[-0.048, -0.004]	0.001	5.760	0.069
NAM	-0.025	[-0.045, -0.004]	[-0.043, -0.004]	[-0.044, -0.006]	[-0.045, -0.006]	0.001	3.477	0.067
ZAF	-0.025	[-0.033, -0.017]	[-0.032, -0.017]	[-0.032, -0.018]	[-0.033, -0.018]	0.001	2.897	0.008
HND	-0.030	[-0.048, -0.012]	[-0.046, -0.009]	[-0.048, -0.013]	[-0.052, -0.014]	-0.000	0.090	0.065
CHN	-0.031	[-0.038, -0.024]	[-0.038, -0.024]	[-0.037, -0.024]	[-0.037, -0.023]	-0.000	1.073	0.006
CRI	-0.032	[-0.051, -0.013]	[-0.052, -0.015]	-0.051, -0.012	[-0.049, -0.011]	-0.001	3.707	0.043
XSC	-0.033	[-0.057, -0.010]	[-0.065, -0.016]	-0.057, -0.009	[-0.051, -0.002]	-0.002	4.750	0.084
CHE	-0.033	[-0.051, -0.016]	[-0.048, -0.015]	[-0.049, -0.017]	[-0.051, -0.018]	0.001	1.677	0.050
KOR	-0.038	[-0.050, -0.025]	[-0.049, -0.025]	[-0.050, -0.026]	[-0.051, -0.026]	0.000	0.338	0.016
NIC	-0.041	[-0.066, -0.016]	[-0.065, -0.016]	[-0.065, -0.016]	[-0.066, -0.016]	-0.001	1.586	0.079
DUD	-0.042	[-0.058, -0.025]	[-0.059, -0.027]		[-0.056, -0.024]	-0.001	1.920	0.023
DIL	-0.045	[-0.063, -0.007]	[-0.095, -0.017]	[-0.062, -0.009]	[-0.074, 0.000]	-0.002	3.809	0.159
NOP	-0.047	$\begin{bmatrix} -0.001, -0.033 \end{bmatrix}$	[-0.003, -0.034]	[-0.002, -0.033]	$\begin{bmatrix} -0.001, -0.031 \end{bmatrix}$	0.001	11 510	0.015
NUL	-0.050	-0.170, 0.070	[-0.204, 0.020]	[-0.109, 0.009]	[-0.120, 0.104]	-0.000	12.019	2.102
XAC	-0.052	-0.148, 0.045	[-0.164, 0.004]	[-0.140, 0.042]	-0.107, 0.080	-0.000	12.134	1.029
XSU	-0.057	[-0.106, -0.009]	-0.104, -0.002	[-0.104, 0.027]	-0.091 0.006	-0.004	7,130	0.269
CIV	-0.058	[-0.086, -0.029]	[-0.092, -0.036]	[-0.086, -0.030]	[-0.080, -0.023]	-0.002	2.718	0.063
IRN	-0.071	-0.113, -0.030	-0.124, $-0.042$	-0.115, -0.028	-0.100, -0.018	-0.003	3.759	0.156
XSM	-0.075	-0.106, -0.045	-0.113, -0.048	-0.106, -0.045	-0.103, -0.038	0.000	0.104	0.049
PER	-0.076	-0.095, -0.056	-0.097, -0.058	-0.095, -0.057	-0.094, -0.054	-0.000	0.133	0.018
CHL	-0.078	[-0.096, -0.059]	[-0.098, -0.062]	[-0.097, -0.059]	-0.094, -0.058	-0.000	0.168	0.016
MEX	-0.087	-0.120, -0.053	[-0.120, -0.052]	-0.120, -0.053	-0.122, -0.054	0.002	2.129	0.043
SAU	-0.097	[-0.191, -0.003]	[-0.228, -0.051]	[-0.195, 0.001]	[-0.142, 0.034]	-0.008	7.789	0.879
BFA	-0.097	[-0.140, -0.054]	[-0.147, -0.062]	[-0.137, -0.057]	[-0.132, -0.047]	0.001	0.908	0.074
RUS	-0.102	[-0.250, 0.046]	[-0.303, -0.013]	[-0.236, 0.032]	[-0.191, 0.099]	-0.008	8.154	1.654
TWN	-0.104	-0.126, -0.083	[-0.128, -0.085]	[-0.125, -0.083]	[-0.124, -0.081]	-0.002	1.705	0.016
BRN	-0.122	[-0.189, -0.056]	[-0.215, -0.081]	[-0.195, -0.049]	[-0.163, -0.030]	-0.006	4.705	0.261
OMN	-0.127	[-0.195, -0.058]	[-0.217, -0.087]	[-0.204, -0.050]	[-0.166, -0.036]	-0.006	4.941	0.296
ZMB	-0.162	[-0.204, -0.120]	[-0.210, -0.126]	[-0.205, -0.119]	[-0.198, -0.113]	-0.001	0.851	0.037
KAZ AZE	-0.174	[-0.320, -0.027]	[-0.371, -0.081]	[-0.324, -0.023]	[-0.200, 0.024]	-0.009	4.961	0.874
AZE	-0.215	[-0.470, 0.039]	[-0.580, -0.072]	[-0.470, 0.039]	[-0.359, 0.150]	-0.018	8.403	2.411
	-0.220		[-0.400, -0.100]		[-0.200, -0.040]	-0.013	0.448	0.709
UA1 TTO	-0.200 -0.248	-0.434, -0.098 -0.693 -0.204	[-0.400, -0.100]	[-0.441, -0.092]	-0.373, -0.043	-0.011	2.052	0.755 0.619
110	-0.440	[-0.030, -0.204]	[-0.100, -0.210]	[-0.102, -0.190]	[-0.021, -0.129]	-0.003	2.002	0.012

Welfare change, confidence intervals ( $\alpha = .05$ ), and bias: Non-TTIP countries, continued

Note: pwd(B,t) denotes implied percentage deviation of bias estimate not exceed with probability (1-t)*100 = 95% given B = 425 bootstrap samples. pwd is calculated using the approximate method proposed by Cameron and Trivedi (2005), Ch. 11. Confidence intervals in Columns (2)-(5) and bias estimate as defined in the text. Relative bias in percent of  $W_N$ .

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