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Working Paper

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Cardiff Economics Working Papers, No. E2021/14

Provided in Cooperation with:

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Suggested Citation: Chen, Gang et al. (2021) : Computable general equilibrium models of trade in the modern trade policy debate, Cardiff Economics Working Papers, No. E2021/14, Cardiff University, Cardiff Business School, Cardiff

This Version is available at:

<https://hdl.handle.net/10419/250338>

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*Gang Chen, Xue Dong, Patrick Minford, Guanhua Qiu,
Yongdeng Xu and Zequn Xu*

June 2021

ISSN 1749-6010

Cardiff Business School
Cardiff University
Colum Drive
Cardiff CF10 3EU
United Kingdom
t: +44 (0)29 2087 4000
f: +44 (0)29 2087 4419
business.cardiff.ac.uk

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Computable General Equilibrium Models of Trade in the Modern Trade Policy Debate

Gang Chen^a, Xue Dong^c, Patrick Minford^{a,b}, Guanhua Qiu^a, Yongdeng Xu^a, Zequn Xu^a

^aCardiff Business School, Cardiff University, UK

^bCEPR, UK

^cZhejiang University of Finance and Economics, China

Abstract

We set up two rival Computable General Equilibrium (CGE) models of world trade, one based on classical theories of comparative advantage, the other based on recent gravity theories. We have tested them by indirect inference on the time-series of trade facts for four major countries or country blocs: the UK, the US, China and the EU. The UK is a small enough economy for the rest of the world's behaviour to be treated as exogenous, so we test the UK model with this held constant; the other countries/blocs are large so we test their model by a 'part of model' test in which the other world variables are simulated by a reduced form VAR of the unknown true world model. We show by Monte Carlo experiments that these tests have high power. Our findings are that the Gravity version of the world model is rejected strongly for two of these country cases, but passes the test for the other two. By contrast the Classical model is comfortably accepted in all cases; our power experiment implies that this world model is very likely to be close to the truth and should therefore be used for policy analysis. The policy message of the classical model is that protection is damaging to welfare; this includes protection by customs union, where even though some members may gain, general welfare is reduced.

Keywords: Bootstrap, indirect inference, gravity model, classical trade model, UK trade

JEL classification: F10-14, F16-17

Email addresses: ChenG7@cardiff.ac.uk (Gang Chen), xue.dong6@outlook.com (Xue Dong), patrick.minford@btinternet.com (Patrick Minford), GuanHuaQ@cardiff.ac.uk (Guanhua Qiu), XuY16@cardiff.ac.uk (Yongdeng Xu), XuZ12@cardiff.ac.uk (Zequn Xu)

1. Introduction

The world debate about trade policy is as vigorous as ever, as can be seen from the controversies over Brexit, the US-China tariff wars and the continuing discussions to strengthen the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP). However, in order to evaluate the welfare effects of these trade policies, we require both a general equilibrium model of trade relationships between countries and a means to assess its quantitative accuracy. In recent years a variety of computable general equilibrium models of trade have been built and used for evaluating policy-leading examples are the GTAP model (Corong et al., 2017) and the CESifo model (Felbermayr et al., 2020). These and other CGE models differ in the extent to which the impact of distance, ‘gravity’, affects the CGE model’s relationships. In recent trade theory, some modellers have stressed that distance attenuates trade and substitutability in trade, so that trade occurs more strongly in close neighbours than between distant countries, and substitution is weak, and weaker the more distant the market; furthermore there are links from trade to technology transfer which imply that the stronger trade links with close neighbours are disproportionately important to productivity growth. These ‘gravity effects’ in CGE models considerably change the overall effects of trade policies, as illustrated in the recent Brexit debate in the UK, where opponents of Brexit argued that it would damage relationships forged by these gravity forces with close neighbours, while creating little extra trade with distant partner countries. It is therefore of some importance to find a means to assess these models’ quantitative accuracy- the second desiderandum listed above.

The process of testing general equilibrium trade models, including the today widely-used gravity models, can take and has taken several forms. In recent times the dominant approach has been to find micro relationships across countries, in which trade is found to be related to distance and GDP, as well as other variables regarded as ‘cultural gravity’ such as colonial ties. This is exemplified well in the recent presidential RES speech of Neary and the associated EJ article (Carrere et al., 2020). He and others have then pointed to a general equilibrium model that could

generate these cross-section relationships. Others have argued in a similar way from panel data relationships that include time as well as cross-section variation, and also include price variables (Costinot and Rodriguez-Clare, 2014).

It should be noted however that these relationships are of a reduced form nature between solved-out values of endogenous variables, since trade prices and GDP are all determined by the underlying structural CGE model. While one can reverse engineer a CGE model that generates them, this does not establish identification. Other structural CGE trade models can also generate them. To test the different CGE structural models requires an empirical comparison to be made in terms of the different models' ability to match these regressions on endogenous variables.

Minford and Xu(2018)- hereafter MX- suggested a way to carry out such testing. They set up two rival CGE models, 'classical' and 'gravity', designed to capture the trade time-series developments for major trading countries or country blocs across major product categories. The classical CGE model is recognisable as largely the Hecksher-Ohlin-Samuelson model of goods and factor markets under perfect competition; the gravity model adopts the same general market structure but imposes gravity assumptions on it, including typically imperfect competition, limited substitutability across country-source of products, and a link from trade intensity to productivity. They tested this model by indirect inference on UK data, treating world prices and other country behaviour as exogenous, an appropriate assumption given the small size of the UK economy relative to the world (about 4% of world GDP). In this paper our contribution is to extend the indirect inference test to other countries/country blocs, which are too large for this assumption to be appropriate; for this we use a new 'part-of-model test' in which the country or bloc model is simulated together with simulations of the world and other country/bloc variables from a VAR model representing the reduced form of the full unknown true world model. We also take the opportunity to update the UK results for the latest data and model version¹.

These tests on time series are relevant for policymakers whose policies change over time.

¹The MX model approximated current account equilibrium in the gravity model by equating the volumes of exports and imports. The current version more accurately equates the values of imports and exports.

Our structural trade models, to be useful to them, should predict the effects of variables' change over time in such a way that the parameters are constant across regime change, so satisfying Lucas' critique (Lucas, 1976). Our test therefore establishes whether the models can be used reliably to assess policy changes.

For this purpose we use a small World Trade Model of a few country-groups and commodity groups: 4 products \times 5 country-groups \times 4 factors of production. This is still a highly complex construction, especially when we embed in it gravity elements, to be discussed below. The model is a comparative static one, in which exogenous shocks have an immediate effect on the endogenous variables. Consequently the observed shocks in this model are to be interpreted as accumulated effects of current and lagged real-time shocks, capturing the process of adjustment over time; they are therefore either trend-stationary or non-stationary (as with productivity and other permanent shocks) and autocorrelated, and their autocorrelation processes are included in the model as parameters. The linear-approximation reduced form of the model will therefore be a VAR. This interpretation allows us to retain the CGE structure of the trade model on which we are primarily focused in our test. In effect we are comparing the features of trended trade behaviour with those of simulated equilibrium models driven by the current equilibrium effects of largely trended exogenous variables such as productivity, transport technology and trade policies.

We test the rival models by indirect inference, a method whose most familiar form until recently was the method of simulated moments. There is by now a substantial body of work using this method to test macroeconomic models (Le et al., 2016; Meenagh et al., 2019). It involves first estimating an 'auxiliary' model whose role is to describe the data behaviour; this can take the form of moments or Impulse Response Functions or, as here, regression equations, to be described shortly. In the second stage, the structural model being tested is simulated by bootstrapping its shock innovations to generate a large number of parallel 'histories', on which the same auxiliary model is estimated. This creates a distribution of the auxiliary model parameters with which the data-based values can be compared; if these reach a sufficient likelihood level,

the model is not rejected.

A convenient variant of the test- the ‘part-of-model’ variant (Minford et al., 2019)- can focus on a subset of the model’s equations. Here these equations are simulated by bootstrap simulations, with the variables entering them but determined by other equations being simulated by bootstrapping a reduced form, such as a VAR, of the unknown true model. We use this variant to test the equations of each country-group on its own.

We look at five country/groups (hereafter just ‘countries’), the UK, US, the EU, China, and ROW; we test all five countries except ROW separately. For our auxiliary model we compute a series of regressions relating different data series of the country related to trade. These series are all non-stationary, so they are related to each other via common trends in cointegrating regressions. We can think of these as being formed from reduced form relationships between endogenous and exogenous variables that are cointegrated because the latter cause the former.

So suppose $ax+bz = 0$ is one such; and $cy+dz = 0$ is another, where x and y are endogenous, and z is exogenous. We can then create a weighted average of the two: $wax + wbz + (1 - w)cy + (1 - w)dz = 0 = ax + cy + bz$.

This last is a cointegrating regression between two endogenous variables and one exogenous variable. We can generalise this result by treating all the coefficients and variables as vectors. We can therefore produce descriptive cointegrating relationships linking the main endogenous and exogenous variables, including between endogenous variables alone. Thus in the above we can have: $ax + bz = ax + b(-c/d)y = ex + fy = 0$.

We use a series of cointegrating relationships between key trade variables as our auxiliary model.

To test a model’s simulation performance against the data behaviour requires careful selection of the data features to be matched. Indirect inference tests tend towards unlimited power as the number of features is increased: as one tries to match all features of behaviour one ultimately requires to have the real world itself as the model. Hence to give the test a reasonable level of power, that on the one hand will reject tractable models of some moderate falsity but on the other

will not reject all models that are even slightly false, a small number of relevant data behaviour features need to be selected; experience suggests close to a dozen.

The main data movement we want to explain is in output shares by sector and trade (export+import or total trade) shares by country bloc. These two sets of shares summarise the economy's output structure and direction of trade. Accompanying these trends are: a) world relative prices and relative productivity of manufactures and services, treating raw materials as the numeraire; b) UK relative factor supplies of land, unskilled and skilled labour.

To construct these relationships we relate the trade shares and the output shares and these other elements in a series of cointegrating regressions; these constitute the auxiliary model. We would hope to find around a dozen key coefficients from this to use as elements of the Wald statistic matching the data behaviour to the simulated behaviour from the structural model.

These can be used to summarise the relationships found in the data for a country whose trade behaviour we wish to explain.

In what follows, in section 1 we give a brief outline of the features of the two CGE models; the full model as applicable to the UK is set out in detail by MX- the full updated model applicable to all countries is listed here in a Model Appendix. In section 2, we explain the operation of indirect inference on the part of model basis. In section 3 we describe our testing results for each country. We end by drawing some conclusions.

2. The rival classical and gravity models of trade - a brief overview

At the current time the gravity model of trade is widely used-see [Breinlich et al. \(2016\)](#) and [Costinot and Rodriguez-Clare \(2014\)](#). Though there is no one general equilibrium model proposed as generating the gravity predictions, in this class of models trade is determined largely by the forces of demand, from neighbours wanting imports and from others modified by the factor of distance- due to transport costs and border costs; products are differentiated and imperfectly substitutable and a natural accompanying feature is imperfect competition, with prices set by

producers as a mark-up on costs, so they move rather little; alternatively perfect competition can be assumed at the level of the industry, implying that price equals marginal cost, an assumption that in practice differs little from the mark-up one. Once demand has determined trade and the production to meet it, foreign direct investment (FDI) and associated innovation follow it, boosting productivity. In short, while supply is important in this gravity approach, supply is largely determined by the forces of demand.

The general equilibrium models proposed to date to embody the gravity approach can be summarised by gravity modellers, [Dhingra et al. \(2016\)](#), in their own words: “these models have four primitive assumptions in common: (a) Dixit-Stiglitz preferences; (b) one factor of production; (c) linear cost functions; (d) perfect or monopolistic competition. They also share three common macro-level restrictions: (A) trade is balanced; (B) aggregate profits are a constant share of aggregate revenues; (C) the import demand system exhibits constant elasticity of substitution (CES). As this set of assumptions is extremely restrictive, one would be forgiven for thinking they have limited practical relevance. What makes, instead, those restrictive assumptions relevant is that some of the most popular trade models do satisfy them, from the workhorse CGE model by ([Armington, 1969](#)) to the hallmark ‘new trade theory’ model by ([Krugman, 1980](#)), to the Ricardian model by ([Eaton and Kortum, 2002](#)) and several variations of the heterogeneous model of [Melitz \(2003\)](#).” In this model output is given as fixed supplies of each product. In demand different products are poorly substitutable.

This account of how a gravity general equilibrium model is put together is revealing. Essentially the gravity equations are taken to be identified by a consumer demand system, which is the main transmission channel. Supply-side forces are restricted to one factor of production with linear cost functions, which determine how much GDP is produced and via interaction with demand/costs in which sectors. Yet there is no structural model of consumers at the retail level, as distinct from the intermediate level at which retailers buy. Nor are factor markets fully included, with demand functions from producers and supply functions from households and endowments. The gravity equations too cannot be thought of as structural consumer demands; they are asso-

ciations between reduced form behaviour of key endogenous variables, trade, GDP and traded prices. A full general equilibrium model needs to be solved to see whether it can mimic this behaviour.

The rival model of trade is the classical one developed by the trade theorists of the past two centuries- starting with [Ricardo](#) (1817)- and pursued in much empirical work based on it; in contrast to the gravity model, a complete set of factor markets is at its centre. The classical model assumes high competition and little if any product differentiation across world markets in intermediate products, with world prices being the same across the world subject to transport costs and trade barriers; there is free entry into all industries so that prices equal average costs. Capital flows freely across borders in the modern world version, but each country has largely fixed supplies of other factors, namely unskilled labour, skilled labour and land. In this model supply forces such as the supply factors and their productivity determine the size of a country's different sectors. The resulting income is then spent according to home demands and the surplus of supply over demand is then exported, the deficit imported in each sector. The model is silent on the allocation of demand to imports and home goods and on the allocation of exports to different foreign markets. However, it would be normal to add on some such allocative model on top of the basic structure, as we will do here by adding a retail sector. Thus it can be seen that the causal structure of the classical model is quite different from that of the gravity model. In the classical model supply determines the essential structure of trade; demand adjusts to be consistent with this. In the gravity model demand determines the structure of trade and in turn forces supply to adjust to this.

Our aim here is to create a gravity version of a full CGE model, with the complete set of goods and factor markets. What then are the essential gravity components to be included? We suggest two main key features:

(1) that on the demand side there is highly imperfect substitutability between products: it is this feature that makes geography so dominant, since once demanded a product is difficult to dislodge; similarly, selling into distant markets is hard because it has to be broken into by

large price cuts. It is natural in this set-up to assume imperfect competition, with firms setting intermediate prices as a mark-up on costs; however it makes no practical difference to assume perfect competition where the mark-up simply goes to zero and so we make perfect competition our default assumption in the retail sector in both our models.

(2) that trade itself stimulates productivity in the growing traded sector. A popular channel for this is FDI but the idea is more general: the bigger trade, the bigger the market size and hence the profits to investment and knowledge transfer. (Feyrer, 2009, 2011; Pain and Young, 2004; Dhingra et al., 2016; Cai et al., 2019). These ideas on the transmission of productivity via trade have given rise to much econometric estimation, often in large panel data sets, of micro relationships at low SIC levels between productivity, FDI, patents, trade and other variables. Gravity theorists have interpreted these as showing that trade, as an exogenous factor determined by demand and distance, determines FDI, patents etc and so productivity. However, in a classical model the exogenous variables are countries' factor supplies and policies determining productivity; the identification is entirely different, usefully distinguishing the gravity CGE version from the classical version.

2.1. The modelling of product differentiation in the two models

Faced with product differentiation, in which products differ by product type and also origin-type we can specify a demand system, as done for example by Armington (1969) with a CES system, as having two levels: one in which utility depends on product type, the other on origin. The elasticity of substitution can then differ between these two levels. This set-up is widely used in trade models so that demand can be determined for intermediate goods by type; then demand for their differing origins can be derived and market-clearing for origin achieved by their origin relative price, the real exchange rate of the origin country: market-clearing implies that $Output (GDP) = Aggregate Demand for Output (AD) + Real Exchange Rate (RXR) * Export(X) - Import(M)$. Hence if $GDP = AD$, as imposed in the CGE model, then this becomes $RXR * X = M$, so the current account equilibrium condition solves for RXR , the real exchange rate, the ratio

of export (home) prices to import (foreign) prices. Market-clearing for product types occurs via the product-type price varying across the world economy.

In the classical model, the elasticity of substitution across origins is infinite, perfect substitutability. Thus country products go in trade to satisfy demand wherever it is. In this sense demand ‘matters’ for trade. The classical model therefore has an effect of ‘gravity’ on trade; for this reason classical modellers never thought of the Tinbergen equations as causing an empirical problem for their models. In effect the models embody a form of perfect trade-diversion, exemplified by the customs union model, where preferential tariffs diverted trade away from external partners to union partners.

In the gravity model, the elasticity of substitution across origins is finite. Hence demand affects the real exchange rate via current account equilibrium.

Here we do not use a two-layered system of demand for intermediate goods; depending on how many commodity types (i) and geographic origins (j) there are, this creates a very large number of demand equations, $i * j$, possibly thousands, each with its own residual error term; such a large amount of variability in the CGE model this could cause problems for the power of our test. Indeed possibly for this reason, no group managing a model of this type has hitherto attempted to test it, though it would be of great interest to do so. Instead, to get the equivalent contrast, we introduce retail demand as an extra ‘layer’ between final and intermediate goods; this corresponds naturally to a concrete distinction in reality; it also helpfully allows us to keep the intermediate product CGE model the same across both the gravity and the classical versions, under the default assumption of perfect competition. In the retail layer we place geographical origin; all intermediate goods, we assume, get branded at the retail level. In major markets we assume this branding is by geographical origin. However in the classical model we assume that one major market, the ROW, brands in an origin-free way; therefore intermediate goods unsold in major markets may be sold there at the going price for the product type in perfect substitution with other origins. This creates de facto perfect origin substitutability in the classical model. For the gravity model, we make the ROW retail demand branded by origin as elsewhere, so that there

is now imperfect substitutability by origin *across all markets*. Each country's real exchange rate must now move to ensure demand for its products equals supply, as above which we achieve by making export demand equal import demands for the country: current account equilibrium. Hence in our specification the perfect substitutability of origin in the classical model is achieved by there being a residual 'world market' where surplus country product can be freely sold at 'world prices'; in the gravity model there is no such 'world market'.

There are thus two sets of firms in our model selling into associated markets. The first set are intermediate-product firms, who sell to the second set, final-product firms. The latter sell branded, differentiated, products to consumers.

3. The classical model of trade

We begin with the 'classical' model of world trade, whose intellectual origins lie in the work of Ricardo (1817), [Heckscher](#) (1919), [Ohlin](#) (1933), [Stolper and Samuelson](#) (1944) and [Rybczynski](#) (1955). In this model output is determined by factor supplies and sectoral productivity. Outputs here are defined as intermediate products, which will be used as inputs into final goods for consumption; they are divided into primary (agriculture and raw materials), manufactures, traded services and nontraded output. For the UK world prices are exogenous as is also the commercial policy regime setting tariffs and non-tariff barriers. Capital is freely available from the rest of the world at the world's exogenous cost of capital. To this set-up we add a model of Retail Consumption, which follows below the model of intermediate trade.

3.1. The model of intermediate trade

The model of intermediate trade is as in [Minford et al.](#) (2015), a CGE model of trade, output, factor supply and demand; with four products, four factors and here five 'countries', of which the UK is one, and the others are the EU, the US, China, and the Rest of the World. Capital is mobile. The products are manufactures, other goods (agriculture and raw materials), traded

services and non-traded; all supplies of each product are assumed to be perfectly substitutable, as if defined commodities in a supply chain.

We will describe the models from the viewpoint of a home country, which we will take to be the UK, for illustration.

These products are considered as intermediates which are supplied at the border or the factory gate in country markets to country retail distribution industries that operate under imperfect competition as set out above.

This intermediate model follows the one [Minford et al. \(1997\)](#) developed for assessing the effects of globalisation on the world economy. This model performed well empirically in accounting for the trade trends of the 1970-1990 period; it identified a group of major causal 'shocks' during this period which between them gave a good fit to the salient features of the period- including terms of trade, production shares, sectoral trade balances, relative wage movements and employment/unemployment trends.

The model adopts the key assumptions of the Heckscher-Ohlin-Samuelson set-up. Production functions are assumed to be Cobb-Douglas and identical across countries, up to a differing productivity multiplier factor; thus factor shares are constant, enabling us to calibrate the model parsimoniously from detailed UK data that we were able to gather. There are four sectors: non-traded and three traded ones, viz. primary, basic (unskilled-labour-intensive) manufacturing, and services and other (skilled-labour-intensive) manufacturing. Three immobile factors of production are identified: unskilled and skilled labour and land. Capital is mobile. All sectors are competitive and prices of traded goods of each sector are equalised across borders.

This set-up gives rise to a well-known set of equations:

(1) given world prices of traded goods, price=average costs determine the prices of immobile factors of productions.

(2) these factor prices induce domestic supplies of these factors.

(3) outputs of each sector are determined by these immobile factor supplies; non-traded sector output is fixed by demand, the traded sector outputs by the supplies of immobile factors

not used in the non-traded sector.

(4) demands for traded goods are set by the resulting level of total GDP.

(5) world prices are set by world demand=world supply

The world is divided into five blocs: UK, EU (the EU, excluding the UK), US, China, ROW (rest of world).

We treat primary sector output (agriculture mainly) as politically controlled and essentially fixed exogenously because of interventionist planning systems. The supply of land is adjusted (via planning and other controls) to enforce this output requirement but otherwise to satisfy land demands from other sectors.

4. Model of retail consumption and the gravity model

Consumers can choose consumption by product origin for each sector. The idea is that distribution is imperfectly competitive, while intermediate output is all sold in perfectly competitive world markets. Retail products are bundles of intermediate supply-chain products. These bundles are 'branded' to create distinct products that consumers will not easily switch from owing to shortage of time, habit etc. However bundlers will buy inputs that are commoditised to yield best value.

We make the assumption that in the major consumer markets of the EU, US and China, these retail brands are differentiated by geographical origin because country suppliers own retailer groups as their marketing agents and also face country-specific trade frictions such as differential tariffs and transport costs. However in the rest of the world countries retailers are independent of country suppliers, and buy intermediate inputs from any supply source without preference, with the typical country imposing mfn tariffs and facing the same transport costs from all origins. These assumptions imply that any excess supply of an intermediate product by any country's industry in the EU and NAFTA can be sold in the rest of the world's markets at the going world price. This can be seen informally as follows. Imagine a country, the EU, puts a tariff on the

manufactures from the UK and we assume for simplicity that it lowers the tariffs on other sources so that consumer income is unchanged and only relative prices altered. We assume total EU demand for the product is unchanged therefore; this is the case in the model where total demand equals GDP, and the share of the product depends on its relative price, determined in world markets. Now demand for the UK product in the EU falls, demand for non-UK product rises. With world prices of intermediates unchanged total supplies of intermediates from all countries remain the same. Hence in ROW markets supplies from non-UK sources will be smaller by exactly the amount that UK supplies will be larger. Hence we can think of ROW retail bundlers using more UK supply and less non-UK supply in retail brands where the two origins are equal in frictional costs. Effectively the UK output displaced from the EU is diverted to ROW markets while non-UK output is diverted from ROW to the EU market; in the ROW markets bundlers are indifferent between the two supplies and switch seamlessly between them, so avoiding any movement in world prices. We get pure trade diversion from the imposition of the EU tariff.

Under the gravity model however the ROW retail industry brands by geographic origin just as the other country retailers do. In this case the real exchange rate, RXR , must move to ensure that $RXR * X = M$ by origin. The elasticity of demand for both imports and exports (ψ) is assumed to be low, as close to the lower stability boundary of 0.5 as possible, consistently with the model solving stably; the Marshall-Lerner stability condition is that the sum of elasticities of exports and imports must exceed 1. Typically we set $\psi = 0.6$; but it may be set higher to ensure a stable solution- the value assumed is noted for each country.

In the gravity model additionally there is transmission of the trade share, T , into productivity, $\pi_{i,t}$, via the parameter v_i , for the i th sector, according to the equation: $\Delta \ln(\pi_{i,t}) = c_{1i} + v_i \Delta T + \varepsilon_{i,t}$ $i = M, S, A, D$. We set all $v_i = 2$.

5. Indirect Inference and testing part of a model

Indirect Inference has been a relatively unfamiliar method of estimation and testing until recently, when it has been used increasingly widely because of its empirical power in small samples (Le et al, 2016); previously it was mainly used in the form of the Simulated Method of Moments. We use it here because we need a method that will powerfully reject a mis-specified model in the small samples that we have (for these trade models we have limited samples of annual data). The two main alternatives today are Bayesian estimation with strong priors or Maximum Likelihood (equivalent to Bayesian estimation with flat priors).

The former is an appropriate method when much is already known about the issue at hand, so that priors can be set out that command general assent; often the case in the physical sciences and indeed in some parts of the social sciences. However, this condition does not apply here: the macroeconomics of trade in the world economy remains controversial.

Maximum Likelihood (ML) estimation is based on minimising the model's now-casting prediction errors and its associated test is based on the likelihood implied by these errors. The two main difficulties of this method are first that it exhibits high estimation bias in small samples and second that the power of the test in small samples is also rather limited and in particular its power to reject a mis-specified model is close to zero, because such a model including its error processes can be fitted closely to the data, so creating small errors. Le et al. (2016) carried out a Monte Carlo comparison of this method with Indirect Inference, treating the widely used [Smets and Wouters \(2007\)](#) model of the US as the true model, and concluded that, while indeed ML methods suffered from these problems, by contrast Indirect Inference offered very low bias and potentially large power. The method involves first describing the data behaviour in the sample by an 'auxiliary model', for which we use an appropriate description of the data behaviour; and then simulating the Dynamic Stochastic General Equilibrium (or here CGE) model by bootstrapping its innovations to create many parallel samples (or histories) from each of which implied auxiliary model coefficients are estimated, generating a distribution of these coefficients accord-

ing to the model. We then ask whether the auxiliary model coefficients found in the actual data sample (the actual history) came from this distribution with a high enough probability to pass the Wald test (where we put the test threshold at 5%).

5.1. The Indirect Inference part-of-model test

Here we test each country model individually, to check whether it is better modelled by the classical or gravity model; of course each country may obey a different model because of its trade composition. Specifically, in our model here a country's trade at the retail level may obey a particular geographically-based branding strategy, that has more or less substitutability. To give a concrete example, the UK may mostly export business services that are highly substitutable, whereas the EU may mostly export machine tools that are not. In our model, this would show up as a differing substitution elasticity across geographic origin in the country model.

For testing the country part of the full World Model set out here, we use a part-of-model test set out by Minford et al (2019). This is designed to test the country model on its own while allowing for the effects of shocks in the other parts of the model. For the UK, the focus of MX, these other parts could be treated as exogenous, subject to their own shocks but unaffected by UK shocks, the UK being such a small part of the world economy (around 4% of world GDP). However, this does not apply to the countries to which this paper extends our tests: the US, China and the EU, all of which are large with substantial effects on the rest of the world. To deal with their largeness, the part-of-model, country, version of the test simulates the country model by bootstrapping its own shocks together with bootstrapped values of all other variables generated by a reduced form model of the data, assumed to come from the unknown true structural model; for the reduced form here we use a VAR. In effect the test bootstraps the shocks from the world VAR to produce simulated world variables and inputs these into the country model together with its simulated country shocks; the resulting simulated country variables are used to generate the auxiliary model behaviour jointly implied by the country model together with the unknown true world model. If the data-based auxiliary model has too low a likelihood according to this

distribution, the country model is rejected as the source of the inaccuracy, as plainly the rest of world variables are obeying the true unknown world model. This test is also unbiased like the full-model test- Minford et al (2019)- and has considerable power, as shown below in a Monte Carlo experiment.

In testing the UK model we used a Monte Carlo experiment to assess the power of our various potential tests, ranging from using some of the four regressions in the auxiliary model to using all; the more that are used the higher the test power but we need to be careful the power does not get so large that no tractable model within moderate distance of the truth could pass the test. In fact we find that using an auxiliary model with all four regressions in full, the power is substantial but not excessive². Our Monte Carlo experiment for this, for the UK case with exogenous world variables is shown in Table 1, taken from MX, where we see how frequently the true trade model of the UK is rejected as it becomes more false: we falsify all parameters by $x\%$ alternately odd and even; we create 1000 samples from the classical model, treated as true, and test the model, true and falsified on these samples to check the frequency of rejection. The test rejects models whose parameters are only 3% falsified, virtually all the time. Thus if not rejected by this test, a model must be very close to the truth. Any model with 3% or more inaccuracy is rejected virtually 100% of the time. This is the test we apply to the two models for the UK.

We repeated the experiment for the part-of-model test, this time using the US model data set, in Table 1. Again, we find the power, though reduced from our full model test of the UK, is considerable and appropriate when the four equations are used; it rises steeply as inaccuracy exceeds 5%.

²The detail of auxiliary models for the UK and the US can be found in Apendix B, B.1.1-B.1.4 and B.2.1-B.2.4, respectively.

Table 1: Power of Indirect Inference Wald test

Percent Misspecified	Rejection Rates at 95% Confidence Level	
	UK	US
True	5.00%	5.00%
1%	40.5%	6.4%
3%	99.9%	15.8%
5%	100.0%	27.6%
7%	100.0%	43.5%
10%	100.0%	74.5%
15%	100.0%	90.7%
20%	100.0%	91.4%

6. The test results

In this section we set out our findings from this extensive set of tests. Full details of each country's data and test results are set out in Appendices B1-4. For all countries except the UK we use the part-of-model test procedure in which rest of world variables are simulated by a VAR, assumed to be the reduced form of the unknown true model. For the UK, we simply treat rest of world variables as exogenous, since the UK is very small relative to the world. As we have seen, this gives the UK test somewhat more power than the others. The [Table 2](#) shows the findings in summary.

What we can see from these results is a pattern in which the classical model is comfortably accepted with good p-values and has a probability as high as or higher than the gravity model. The Gravity Model is however only rejected in the case of the UK and China-in both cases rather strongly. The figures showing the behaviour of the auxiliary model variables' data and average simulations reveal that the reason for the gravity model's poor performance: this lies in its creating unrealistic movements in trade shares as the gravity mechanism forces current account balance on all trade origins via *RXR* movements; the classical model, for which trade origin is irrelevant, does not have this problem. Nevertheless the Gravity model's ability to pass the test for the US and the EU is revealing. It seems that both the EU and the US have strong links with neighbouring economies which are modelled in the Gravity version and do not

Table 2: Summary of test results

Country	P-values	
	Classical Model	Gravity Model
UK	0.090	0.000*
US	0.070	0.070
EU	0.115	0.075
CH	0.110	0.034*

Note: p-value with * indicates a rejection of the model at 5% significance level. For the UK, we treat rest of the world as exogenous.

damage the model's ability to match their trade facts. The US neighbourhood includes Canada and Mexico, members of NAFTA; while the EU's includes the UK and other countries in the ROW such as Switzerland.

7. Policy implications of the two models

In the [Table 3](#) we show how tariff policy is assessed by these models to lower welfare. Both models imply there are substantial welfare costs in levying tariffs on agriculture and manufacturing. They differ mainly because in the gravity model the tariff affects *RXR* by targeting the geographic origin of trade; this forces the terms of trade to move to create current account equilibrium- a 'beggar my neighbour' policy, often dubbed the 'optimal tariff' policy. A country reduces its imports from another, forcing it to lower prices. The tariff policies assessed here could be refined according to commodity and trade partner to create a bigger import response and so optimal tariff bonus; crudely set even as assumed here they can be seen to give a large offsetting welfare gain to protection. Thus the gains due to improved terms of trade across the four countries, shown in the third column of the Table come to a total of 15.4%. These gains reveal the bias of the Gravity model towards protection, due to the optimal tariff motivation.

Table 3: Summary of welfare costs of tariff policies (10% tariff on agriculture and manufacturing)

Country	Welfare costs		
	Classical Model	Gravity Model	<i>RXR</i> effects in Gravity Model
UK	7.2	1.0	-5.7
US	9.4	10.9	-1.6
EU	6.4	3.3	-3.7
CH	8.1	4.4	-4.4
Total	31.1	19.6	-15.4

Note: the figures are % changes of welfare costs.

7.1. Which model should be used to analyse trade policies?

What we see from these results is that the Classical Model is in general closer to the trade facts than the gravity model. Furthermore, the Classical Model is compatible with all country's trade facts, whereas the Gravity Model is definitely incompatible with the facts for two of our countries. From a policy viewpoint the Gravity model encourages the idea that tariffs can create terms of trade gains; this however will be false if the gravity Model is false and in any case will encourage tariff policies that damage international welfare.

Hence from the viewpoint of both accuracy and normative considerations, the model to use appears to be the Classical Model. It both fits the facts, and encourages welfare-enhancing trade policy.

8. Conclusions

In this paper we have set up two rival CGE models of world trade, one based on classical theories of comparative advantage, the other based on recent gravity theories. We have tested them by indirect inference on the time-series of trade facts for five major countries or country blocs: the UK, the US, China and the EU. The UK is a small enough economy for the rest of the world's behaviour to be treated as exogenous, so we test the UK model with this held constant; the other countries/blocs are large so we test their model by a 'part of model' test in which the other world

variables are simulated by a reduced form VAR of the unknown true world model. We show by Monte Carlo experiments that these tests have high power. Our findings are that the Gravity version of the world model is rejected strongly for two of these country cases, but passes the test for the other two. By contrast the Classical model is comfortably accepted in all cases; our power experiment implies that this world model is very likely to be close to the truth and should therefore be used for policy analysis. The policy message of the classical model is that protection is damaging to welfare; this includes protection by customs union, where even though some members may gain, general welfare is reduced.

Appendix A: Listing of Model

A.1 Model listing - Classical Model (use the UK as an example)

Eq.1-4 Prices

$$p_M = w^{0.52234} * h^{0.14366} * l^{0.035} * (p_M * r)^{0.299} * \pi_M^{-1} \quad (\text{A.1.1})$$

$$p_S = w^{0.21168} * h^{0.51832} * l^{0.033} * (p_M * r)^{0.237} * \pi_S^{-1} \quad (\text{A.1.2})$$

$$p_A = w^{0.147} * h^{0.132} * l^{0.079} * (p_M * r)^{0.642} * \pi_A^{-1} \quad (\text{A.1.3})$$

$$p_D = w^{0.38024} * h^{0.168} * l^{0.113} * (p_M * r)^{0.331} * \pi_D^{-1} \quad (\text{A.1.4})$$

p_M , p_S , and p_A have been used to solve for w , h , and l respectively.

$$\ln(w) = \left(\frac{1}{0.52234}\right) * [\ln(p_M * \pi_M) - 0.14366 * \ln(h) - 0.035 * \ln(l) - 0.299 * \ln(p_M * r)]$$

$$\ln(h) = \left(\frac{1}{0.51832}\right) * [\ln(p_S * \pi_S) - 0.21168 * \ln(w) - 0.033 * \ln(l) - 0.237 * \ln(p_M * r)]$$

$$\ln(l) = \left(\frac{1}{0.079}\right) * [\ln(p_A * \pi_A) - 0.147 * \ln(w) - 0.132 * \ln(h) - 0.642 * \ln(p_M * r)]$$

$\pi_M, \pi_S, \pi_A, \pi_D$ are exogenous productivity error processes.

Eq.5-8 Factor demands

$$N = w^{-1} * (0.38024 * p_D * y_D + 0.52234 * y_M * p_M + 0.21168 * p_S * y_S + 0.147 * p_A * y_A) * e_M \quad (\text{A.1.5})$$

$$H = h^{-1} * (0.168 * p_D * y_D + 0.14366 * y_M * p_M + 0.51832 * p_S * y_S + 0.132 * p_A * y_A) * e_S \quad (\text{A.1.6})$$

$$L = l^{-1} * (0.113 * p_D * y_D + 0.035 * y_M * p_M + 0.033 * p_S * y_S + 0.079 * p_A * y_A) * e_A \quad (\text{A.1.7})$$

$$K = \frac{1}{p_M * r} * (0.331 * p_D * y_D + 0.299 * p_M * y_M + 0.237 * p_S * y_S + 0.642 * p_A * y_A) * e_K \quad (\text{A.1.8})$$

$$y_M = \left(\frac{1}{0.52234 * p_M}\right) * [N * w * e_M - 0.38024 * p_D * y_D - 0.21168 * p_S * y_S - 0.147 * p_A * y_A]$$

$$y_S = \left(\frac{1}{0.51832 * p_S}\right) * [H * h * e_S - 0.168 * p_D * y_D - 0.14366 * p_M * y_M - 0.132 * p_A * y_A]$$

e_M, e_S, e_A, e_K are factor demand error processes; y_A follows exogenous process.

Eq.9-11 Factor supplies

$$N = e_N * \left(\frac{w}{b}\right)^{0.1} * POP^{0.5} * G^{0.5} \quad (\text{A.1.9})$$

$$H = e_H * \left(\frac{h}{w}\right)^{0.1} * G^{0.5} \quad (\text{A.1.10})$$

$$L = l^{-1} * (0.113 * p_D * y_D + 0.035 * y_M * p_M + 0.033 * p_S * y_S + 0.079 * p_A * y_A) * e_A \quad (\text{A.1.11})$$

L is supplied equal to demand through the government/planning system (which fixes agricultural output exogenously). e_M and e_H are error processes.

Eq.12 Domestic Output

$$y_D = 0.5 * E \quad (\text{A.1.12})$$

Eq.13 Output

$$y = y_D + y_M + y_S + y_A \quad (\text{A.1.13})$$

Eq.14 Equilibrium condition

$$E = y \quad (\text{A.1.14})$$

Eq.15 Demand of tradable goods

$$E_T = E - y_D \quad (\text{A.1.15})$$

Eq.16 Demand for goods in manufacturing sector

$$E_M = E_T - E_S - E_A \quad (\text{A.1.16})$$

Eq.17 Demand for goods in service sector

$$E_S = 0.9 * E_T - 238.90 - 12.0 * (p_S - p_T) \quad (\text{A.1.17})$$

Eq.18 Demand for goods in agriculture sector

$$E_A = 0.05 * E_T + 47.95 - 5.0 * (p_A - p_T) \quad (\text{A.1.18})$$

Eq.19 Consumer price index

$$p = p_M * \left(\frac{E_M^{base}}{E^{base}}\right) + p_S * \left(\frac{E_S^{base}}{E^{base}}\right) + p_A * \left(\frac{E_A^{base}}{E^{base}}\right) + p_D * \left(\frac{E_T^{base}}{E^{base}}\right) \quad (\text{A.1.19})$$

Eq.20-22

$$p_M = p_M^{World} * (1 + T_M) \quad (\text{A.1.20})$$

$$p_S = p_S^{World} * (1 + T_S) \quad (\text{A.1.21})$$

$$p_A = p_A^{World} * (1 + T_A) \quad (A.1.22)$$

T_M, T_S, T_A are simply the tariff+non-tariff+transport cost real barriers to trade between the target country (UK, US, EU, China) and world markets. As we do not have time-series data on these, they are all set to unity; what this implies is that all these effects are absorbed into the model's error terms. The exchange rate simply changes all prices in proportion in sterling, leaving them unchanged in dollars. So effectively all the prices in this model are in dollars relative to world manufacturing prices in dollars- the numeraire. World prices, p_M^{World} , p_S^{World} , p_A^{World} are exogenous processes.

Eq.23

$$p_T = p_M * \left(\frac{E_M}{E_T}\right) + p_S * \left(\frac{E_S}{E_T}\right) + p_A * \left(\frac{E_A}{E_T}\right) \quad (A.1.23)$$

Eq.24-25 Error process

We assume the log (errors) in the model follow a AR(1) process with intercept and trend, i.e.,

$$\ln(\pi_{i,t}) = c_{1i} + \rho_{1i}\ln(\pi_{i,t-1}) + \phi_{1i}t + \varepsilon_{i,t} \quad (A.1.24)$$

$i = M, S, A, d$

$$\ln(e_{i,t}) = c_{2i} + \rho_{1i}\ln(e_{i,t-1}) + \eta_{i,t} \quad (A.1.25)$$

$i = M, S, A, N, H, K$

Eq.26-28 Trade share bloc:

1) UK import demand for trade bloc i , where $i=EU, NAFTA, ROW$; 2) Trade bloc i demand for UK exports, where $i=EU, NAFTA$; 3) Exports to ROW: residual supply of UK traded output.

Tariffs and other trade barriers affect these demands, but as already noted we have not got time-series data for these so their effects are included in the errors.

$$\ln(M_i) = a_i + b_i * \ln(E_T) + em_i \quad (A.1.26)$$

$i = NAFTA, EU, ROW$

$$\ln(X_i) = c_i + d_i * \ln(E_i) + ex_i \quad (A.1.27)$$

$i = NAFTA, EU$

$$X_{ROW} = Y_T - E_T - (X_{NAFTA} + X_{EU} - M_{NAFTA} - M_{EU} - M_{ROW}) \quad (A.1.28)$$

em_i and ex_i are trade share error process. We estimate a_i, b_i, c_i, d_i by OLS.

A.2 Model listing - Gravity Model Variant (use the UK as an example)

Because we must now have current account balance in the presence of geographically branded

goods, we drop the above equation for X_{ROW} , in which exports to ROW act as an automatic equilibrant of the current account. Instead, where $i=EU, NAFTA, China, ROW, UK$ import demand for trade bloc i becomes

$$\ln\left(\frac{M_i}{E_T}\right) = cm_i + \psi * RXR + e_{M,i} \quad (A.2.1)$$

and trade bloc i demand for UK exports becomes

$$\ln\left(\frac{X_i}{E_i}\right) = cx_i + \psi * RXR + e_{X,i} \quad (A.2.2)$$

Now, for current account balance, across all traded sectors there is a real devaluation adjusting mark-ups in all sectors, via RXR , forcing export demand to be equal to import demand: thus RXR moves to solve for current account equilibrium in the equation replacing that for X_{ROW} , namely

$$X_{ROW} + X_{NAFTA} + X_{EU} = M_{NAFTA} + M_{EU} + M_{ROW} \quad (A.2.3)$$

Across all traded sectors there is a real devaluation adjusting mark-ups in all sectors, via RXR , forcing export demand to be equal to import demand.

These equations now also give us total trade. The em_i and ex_i are exogenous error processes—these include the effects of trade barriers which we cannot observe in a time-series manner. We estimate cm_i and cx_i by OLS and bootstrap the trade share data ($\frac{M_i}{E_T}$ and $\frac{X_i}{GDP_i}$) from above equations; we set the elasticities of demand to the real exchange rate at (import) $\psi = 2$, (export) $\psi = -2$.

To embody the gravity model idea that trade affects productivity via intensifying links with foreign firms, including FDI, we now also rewrite the productivity terms as a function of total trade, T . $\pi_M, \pi_S, \pi_A, \pi_D$ are now no longer purely exogenous productivity error processes but now each contain a term in T , defined as follows:

$$TotalTrade = M_{EU} + M_{NAFTA} + M_{ROW} + X_{EU} + X_{NAFTA} + X_{ROW} \quad (A.2.4)$$

$$T = \frac{TotalTrade}{E_{UK}} \quad (A.2.5)$$

The productivity terms are then written as

$$\Delta \ln(\pi_{i,t}) = c_{1i} + v_i \Delta T + \varepsilon_{i,t} \quad (A.2.6)$$

$i = M, S, A, d$

Table 4: Summary of Variables

Notation	Definition
P	Price
y	Output(GDP)
N	(Unskilled)labour
H	Skilled labour or human capital
L	Land
K	Capital (physical)
w	Wages (of unskilled labour)
h	Skilled wages or rent on human capital
r	Real rate of return on physical capital
E	Expenditure
l	Rent on land
FPC	Aggregate factor productivity
b	Rate of unemployment benefit
POP	Working population
G	Government expenditure/GDP
Suffixes	Definition
A	Agriculture
M	Manufacturing
S	Services
ROW	Rest of World

Appendix B: Country Results: Testing the models with the (part-of-model) country test- empirical results

B.1 Updated empirical results of the country test for the UK

We now illustrate our testing procedure by setting out our updated test of the UK model. Because the UK is too small an economy to affect world market prices, we can carry out the country test under the assumption that other countries are exogenous to it; we therefore do not need to simulate their GDP or world prices, but simply hold them fixed at their values in the data. We can then simulate UK shocks to explore simulated UK behaviour, holding rest of world behaviour as it actually was- treating them as exogenous time series. To maintain consistency with MX we use NAFTA in place of the US as a country group, with ROW adjusted accordingly.

UK Data

The sources of the UK data are as follows: 1) Output by sector: Agriculture, Industry, Service, Nontraded - source ONS national accounts. For: 2) Trade data (export and import data) by sector: Agriculture, Industry, Service; 3) Population and employment. Sources are: World Bank, World Development Indicators. 4) Skilled workers (Adult Tertiary education as Sources: Statistical abstract for the United Kingdom 1935, Board of Trade; Annual abstract of statistics, ONS/CSO; Higher Education Statistics Agency. 5) Earnings of skilled workers: Ratio of skilled earning to unskilled earnings (Decile9/Decile5); Source: OECD Database. 6) Goods price index: Agriculture, Industry, Service. Source: Free market commodity price indices, United Nations Conference on Trade and Development. It has two price index: agriculture and raw materials price index, unit value of index of manufactured goods exports by developed economies. We use them as world agriculture and manufacture price index respectively. The world service price data is not available. We use UK service producer prices, which are obtained from Office of National Statistics(ONS),to proxy world service index. 7) Rent on land (£ per hectare), Real interest rate; Source: ONS.

All data are annual data from 1965 to 2019. Figure 1 below plots the data series.

The auxiliary model for the UK

The variables in the auxiliary model are $TS_{EU} = \frac{(M_{EU}+X_{EU})}{(GDP_{UK})}$, $TS_{NAFTA} = \frac{(M_{NAFTA}+X_{NAFTA})}{(GDP_{UK})}$, $TS_{ROW} = \frac{(M_{ROW}+X_{ROW})}{(GDP_{UK})}$, $OS_{UK} = \frac{y_M}{y_S}$, which we put on the left hand side for convenience; and on the right hand side we have the relative productivity residual of manufacturing/services, $\frac{\pi_M}{\pi_S}$; the relative factor share, skilled/unskilled labour, $\frac{H}{N}$; the wage of unskilled relative to skilled workers, $\frac{w}{h}$; and EU GDP and NAFTA GDP.

The auxiliary model equations are potentially:

$$TS_{EU} = \gamma_1 + a_{11} \frac{\pi_M}{\pi_S} + a_{12} \frac{N}{H} + a_{13} \log(GDP_{EU}) + a_{14} \log(GDP_{NAFTA}) + a_{15} \frac{w}{h} + \varepsilon_1 \quad (\text{B.1.1})$$

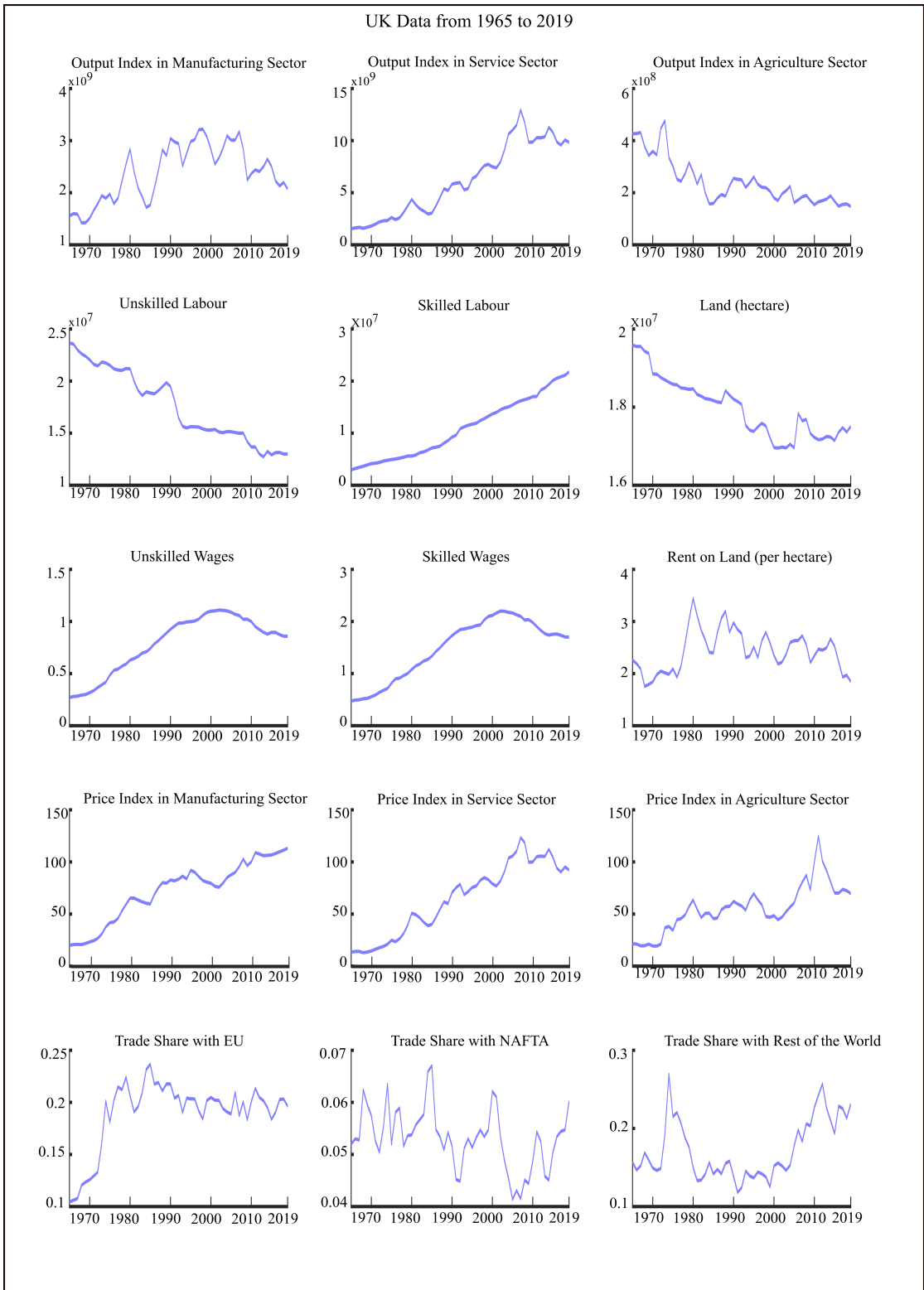


Figure 1: UK Data from 1965 to 2019

$$TS_{NAFTA} = \gamma_2 + a_{21} \frac{\pi_M}{\pi_S} + a_{22} \frac{N}{H} + a_{23} \log(GDP_{EU}) + a_{24} \log(GDP_{NAFTA}) + a_{25} \frac{w}{h} + \varepsilon_2 \quad (\text{B.1.2})$$

$$OS_{UK} = \gamma_3 + a_{31} \frac{\pi_M}{\pi_S} + a_{32} \frac{N}{H} + a_{33} \log(GDP_{EU}) + a_{34} \log(GDP_{NAFTA}) + a_{35} \frac{w}{h} + \varepsilon_3 \quad (\text{B.1.3})$$

$$TS_{ROW} = \gamma_4 + a_{41} \frac{\pi_M}{\pi_S} + a_{42} \frac{N}{H} + a_{43} \log(GDP_{EU}) + a_{44} \log(GDP_{NAFTA}) + a_{45} \frac{w}{h} + \varepsilon_4 \quad (\text{B.1.4})$$

We will use these equations in full or in part in our test, after gauging the test power by Monte Carlo experiment. As noted above, the more features are included in the test - in this case the features are the coefficients α_{ij} - the higher generally the test's power; it is therefore possible for the power to be so great that only models very close to the real world can pass, in which none will. Our test is chosen to keep a limit on the test's power while still giving considerable power.

These variables, endogenous and exogenous, will not be stationary but rather will have either deterministic or stochastic trends. However the residuals in the reduced form are stationary since the regressions will be relationships derived from equilibrium structural relationships such as those found in our CGE model; these should be co-integrated therefore (Table 5).

We can see that the gravity model is totally rejected with a p-value of 0, whereas the classical model survives.

Note on revised gravity results for the UK

The results shown above for the gravity models differ in detail from the results shown in MX, for several reasons. First, we have used the latest data. Second, we have lowered the value of psi (the demand substitution elasticity between geographic origin) in the gravity model from 2.0 to 0.6, reflecting more closely the low substitutability assumed in it. A final change is that we imposed current account equilibrium in value terms as RXR . $EX = IM$, so that market clearing occurs in monetary value, an exact representation, whereas MX imposed it in volume terms, as $EX = IM$, a less accurate approximation.

Tariff policy effects

Finally we consider a typical policy simulation where we raise the MFN tariff rate on all foreign countries on food and manufactures by 10%. We can see that the results do not differ much across the two models, except on the real exchange rate which appreciates in the gravity model; this creates a welfare gain due to the improvement of the terms of trade. What this Table shows is that otherwise the two models generate much the same effects and the same welfare

Table 5: Stationary test for UK

ADF test	Stationary	Trend Stationary	Nonstationary
TS_{EU}			√
TS_{NAFTA}			√
TS_{ROW}			√
OS_{UK}		√	
$\frac{\pi_M}{\pi_S}$			√
$\frac{N}{H}$		√	
$\frac{w}{h}$			√
$\log(E_{EU})$			√
$\log(E_{NAFTA})$			√
Residuals			
ε_1	√		
ε_2	√		
ε_3	√		
ε_4	√		

Table 6: Indirect Inference test results for the UK

	Equations in auxiliary model in full	p-value
Classical trade model	$B.1.1, B.1.2, B.1.3, B.1.4$	0.0904
Gravity model ($\psi = 0.6$)	$B.1.1, B.1.2, B.1.3, B.1.4$	0.0000*

Note: p-value with * indicates a rejection of the model at 5% significance level.

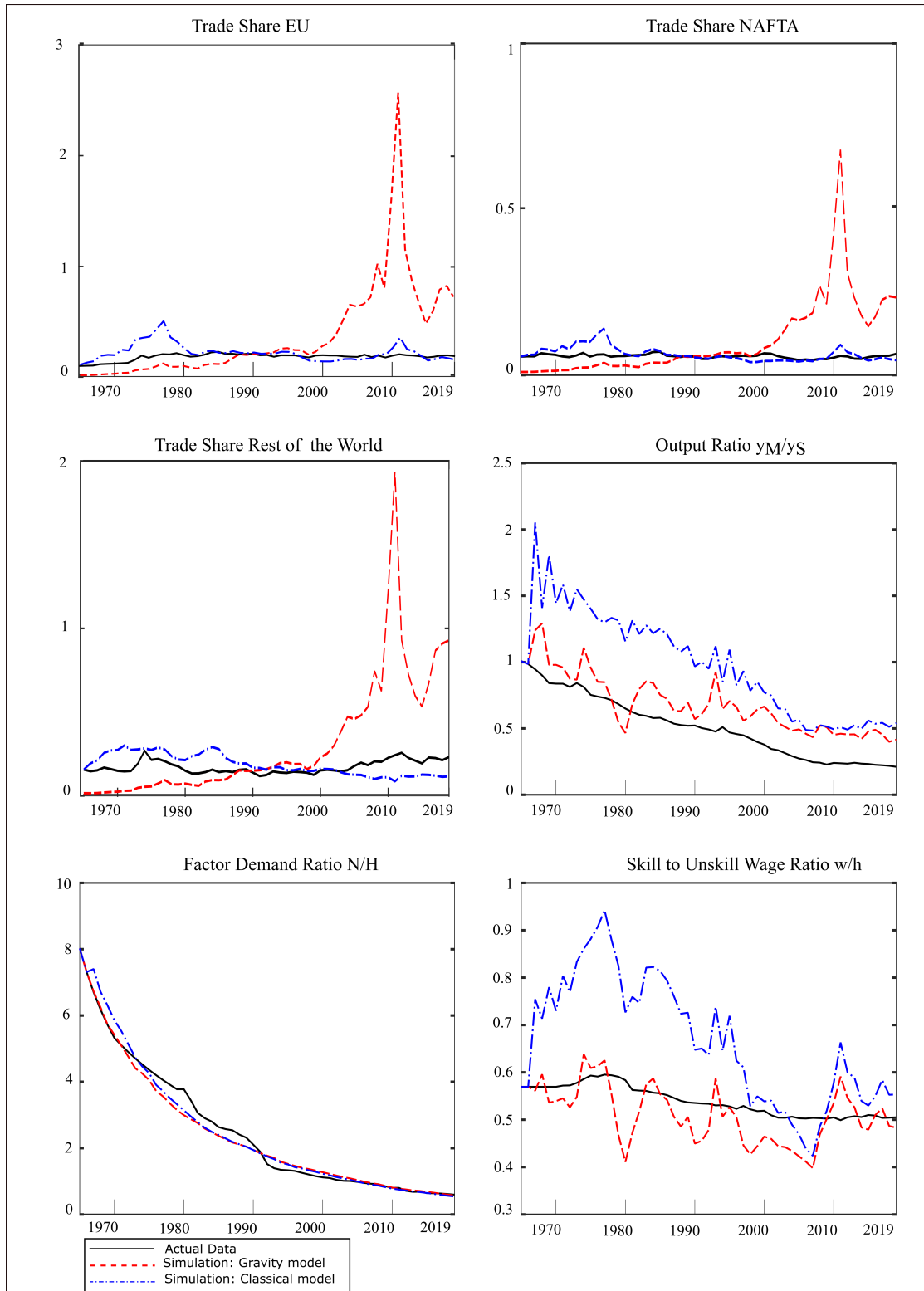


Figure 2: Actual and average of simulated data for the UK

Table 7: Effects of 10% tariff on food and manufacturing for the UK

Variables	Base Run	10% tariff on food and manufactures		% changes	
		Gravity	Classical	Gravity	Classical
y	$2.6943 * 10^{10}$	$2.5933 * 10^{10}$	$2.5784 * 10^{10}$	-3.75	-4.30
y_A	$1.6744 * 10^8$	$1.6744 * 10^8$	$1.6744 * 10^8$	0.00	0.00
y_M	$2.5058 * 10^9$	$5.5175 * 10^9$	$5.5410 * 10^9$	120.19	121.13
y_S	$1.0798 * 10^{10}$	$7.2816 * 10^9$	$7.1835 * 10^9$	-32.57	-33.48
y_D	$1.3472 * 10^{10}$	$1.2966 * 10^{10}$	$1.2892 * 10^{10}$	-3.75	-4.30
E_A	$1.0777 * 10^8$	$8.2521 * 10^7$	$7.8790 * 10^7$	-23.43	-26.89
E_M	$1.6166 * 10^9$	$1.5913 * 10^9$	$1.5876 * 10^9$	-1.56	-1.79
E_S	$1.1747 * 10^{10}$	$1.1293 * 10^{10}$	$1.1225 * 10^{10}$	-3.87	-4.44
w	0.8949	1.0307	1.0254	15.17	14.58
h	1.7550	1.5652	1.5508	-10.81	-11.64
l	2.5245	3.7003	3.7112	46.58	47.01
N	$1.2918 * 10^7$	$1.3101 * 10^7$	$1.3095 * 10^7$	1.42	1.37
H	$2.0119 * 10^7$	$1.9611 * 10^7$	$1.9603 * 10^7$	-2.52	-2.56
L	$1.7144 * 10^7$	$1.2441 * 10^7$	$1.2304 * 10^7$	-27.42	-28.23
K	$4.5615 * 10^9$	$3.0944 * 10^9$	$3.0727 * 10^9$	-32.05	-32.64
p	1.0407	1.1042	1.1022	6.19	5.92
p_A	0.6584	0.7243	0.7243	10.00	10.00
p_M	1.000	1.100	1.100	10.00	10.00
p_S	0.9812	0.9812	0.9812	0.00	0.00
p_D	1.1005	1.2275	1.2236	11.54	11.19
RXR	117.477	142.2073	117.477	21.05	0.00
Welfare				-1.0	-7.2

Note on welfare measure: Welfare loss from the tariff is computed as: [Welfare percent = % output loss/GDP + consumer surplus lost - Terms of Trade gain - TOT gain as % of GDP], where the consumer surplus loss = percent rise in CPI x 0.5 and the TOT gain = RXR percent rise x share of imports in GDP.

loss from this tariff increase. The damage caused by the tariff to consumers and productivity is somewhat offset under the gravity model by this terms of trade improvement, illustrating how the gravity model has a bias in favour of protection. An important part of the UK government's free trade policy is the negotiating away of the tariffs on food and manufacturing currently placed by the EU on UK imports from non-EU sources. In the Classical model this policy- abolishing the tariff shown- would raise welfare by 7.2%. With the EU tariffs the UK actually inherited being 20%, the actual gain would be estimated at double this- 14.4%.

B.2 Results for the US

In the case of the US, we need to simulate all other countries' GDPs and also world prices because plainly the US, as a large continental economy, has a major effect on them. Here therefore to test the US we simulate the US model as the part of the world model to be tested, and we

simulate the other country variables required to solve this part via a reduced form VAR model.

US Data The sources of the US data are as follows: 1) Output by sector: Agriculture, Industry, Service, Nontraded - sources are: FAOSTAT, OECD Statistics; World Bank; AMECO database. 2) Trade data (export and import data) by sector: Agriculture, Industry, Service - sources are: FAOSTAT; BEA - US department of commerce. 3) Population and employment - sources are: BLS; AMECO database. 4) Earnings of skilled workers: Ratio of skilled earning to unskilled earnings (Decile9/Decile5) - Source: OECD Statistics. 5) Goods price index: Agriculture, Industry, Service, Nontraded - Sources are: World Bank Commodity Price Data (The Pink Sheet); OECD Statistics; BEA - National Income and Product Accounts; BLS. 6) Rent on land (£ per hectare) - source: Board of Governors of the Federal Reserve System (US). 7) Real interest rate - source: AMECO database. 8) other world data: source as for UK.

All data are annual data from 1970 to 2018. Figure 3 below plots the data series.

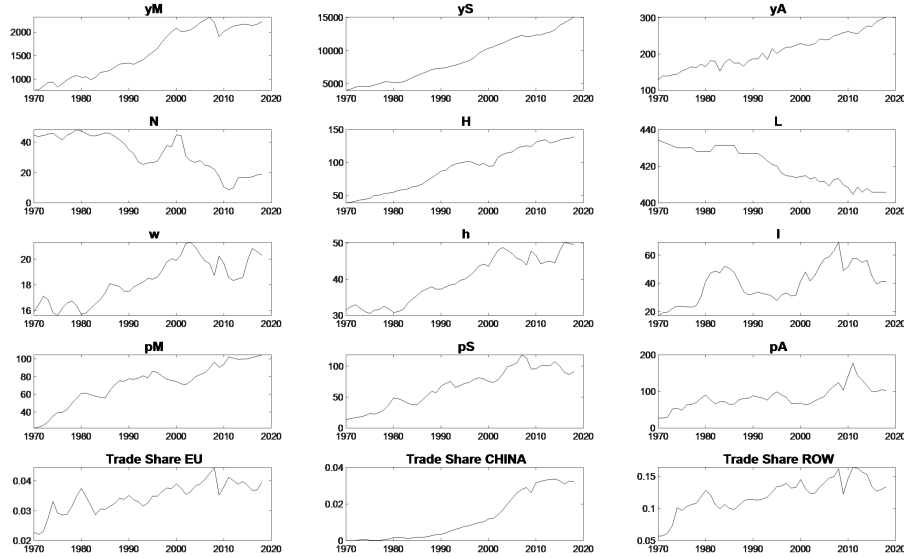


Figure 3: US Data from 1970 to 2018

The auxiliary model for the US

The variables in the auxiliary model are $TS_{EU} = \frac{(M_{EU} + X_{EU})}{(GDP_{US})}$, $TS_{China} = \frac{(M_{China} + X_{China})}{(GDP_{US})}$, $TS_{ROW} = \frac{(M_{ROW} + X_{ROW})}{(GDP_{US})}$, $OS_{US} = \frac{y_M}{y_S}$, which we put on the left hand side for convenience; and on the right hand side we have the relative productivity residual of manufacturing/services, $\frac{\pi_M}{\pi_S}$; the relative factor share, skilled/unskilled labour, $\frac{H}{N}$; the wage of unskilled relative to skilled workers, $\frac{w}{h}$; and EU GDP and China GDP.

Table 8: Stationary test for US

ADF test	Stationary	Trend Stationary	Nonstationary
TS_{EU}			√
TS_{UK}			√
TS_{ROW}			√
OS_{US}			√
$\frac{\pi_M}{\pi_S}$			√
$\frac{N}{H}$	√		
$\frac{w}{h}$			√
$\log(E_{EU})$			√
$\log(E_{China})$			√
Residuals			
ε_1	√		
ε_2	√		
ε_3	√		
ε_4	√		

The auxiliary model equations are potentially:

$$TS_{EU} = \gamma_1 + a_{11} \frac{\pi_M}{\pi_S} + a_{12} \frac{N}{H} + a_{13} \log(GDP_{EU}) + a_{14} \log(GDP_{China}) + a_{15} \frac{w}{h} + \varepsilon_1 \quad (\text{B.2.1})$$

$$TS_{China} = \gamma_2 + a_{21} \frac{\pi_M}{\pi_S} + a_{22} \frac{N}{H} + a_{23} \log(GDP_{EU}) + a_{24} \log(GDP_{China}) + a_{25} \frac{w}{h} + \varepsilon_2 \quad (\text{B.2.2})$$

$$OS_{US} = \gamma_3 + a_{31} \frac{\pi_M}{\pi_S} + a_{32} \frac{N}{H} + a_{33} \log(GDP_{EU}) + a_{34} \log(GDP_{China}) + a_{35} \frac{w}{h} + \varepsilon_3 \quad (\text{B.2.3})$$

$$TS_{ROW} = \gamma_4 + a_{41} \frac{\pi_M}{\pi_S} + a_{42} \frac{N}{H} + a_{43} \log(GDP_{EU}) + a_{44} \log(GDP_{China}) + a_{45} \frac{w}{h} + \varepsilon_4 \quad (\text{B.2.4})$$

We will use these equations in full in our analysis. These variables, endogenous and exogenous, will not be stationary but rather will have either deterministic or stochastic trends. However the residuals in the reduced form are stationary since the regressions will be relationships derived from equilibrium structural relationships such as those found in our CGE model; these should be co-integrated therefore (Table 8).

Table 9: Indirect Inference test results for the US

	Equations in auxiliary model in full	p-value
Classical trade model	B.2.1,B.2.2,B.2.3,B.2.4	0.0694
Gravity model ($\psi = 1$)	B.2.1,B.2.2,B.2.3,B.2.4	0.0698

In testing the US model we need to simulate all other countries' GDPs and also world prices because plainly the US, as a large continental economy, has a major effect on them. Here therefore to test the US we simulate the US model as the part of the world model to be tested, and we simulate the other country variables required to solve this part via a reduced form VAR model. As in the UK model, we assume in the US model that agricultural output is fixed by land zoning regulations. In the US gravity model, if we set the elasticities of demand to the real exchange rate at (import) ψ =(export) =1.0, implying relatively strong gravity;as can be seen, both the gravity modeland the classical model pass the test fairly comfortably with a p-value of 0.07.

The IRF of a tariff increase by the US What is of interest is to compare a policy change, here a tariff increase on food and manufactures, across the two models. It can be seen that under the gravity model a tariff, through the implied gain on the terms of trade, creates less of a welfare cost than implied by the classical model ($\psi=1$); thus gravity gives some bias towards protectionism.

B.3 Results for China

In the case of China, too, we need to simulate all other countries' GDPs and also world prices because plainly China, as another large continental economy, has a major effect on them. Here therefore to test China we simulate the China model as the part of the world model to be tested, and we simulate the other country variables required to solve this part via a reduced form VAR model. (Part of Model test)

China Data

The sources of the China data are as follows: 1) Output by sector: Agriculture, Industry, Service, Nontraded - source is: National Bureau of Statistics; 2) Export and import data (manufacturing and service)- source is: State Administration of Foreign Exchange; 3) Export and import data (agriculture)-source is: National Bureau of Statistics; 4) Goods price index: Agriculture, Industry, Service - source is: National Bureau of Statistics; 5) Working population - source is: National Bureau of Statistics; 6) Land supply and Return on land (Housing price) - source is: National Bureau of Statistics; 7) Gross capital formation (%GDP) and Real effective exchange rate index - source is: World bank; 8) China Average Yearly Wages - source is: Trading economics; 9) Skilled labour and unskilled labour - source is: National Bureau of Statistics; 10) Earnings of skilled workers: Ratio of skilled earning to unskilled earnings (Decile9/Decile5);

Table 10: Effects of 10% tariff on food and manufacturing for the US

Variables	Base Run	10% tariff on food and manufactures		% changes	
		Gravity	Classical	Gravity	Classical
<i>y</i>	19350	17032	17719	-11.98	-8.43
<i>y_A</i>	301	301	301	0.00	0.00
<i>y_M</i>	2222	4647	4769	109.14	114.63
<i>y_S</i>	13223	8912	9348	-32.60	-29.30
<i>y_D</i>	3604	3172	3300	-11.99	-8.44
<i>E_A</i>	1875	1780	1808	-5.07	-3.57
<i>E_M</i>	1714	1620	1648	-5.48	-3.85
<i>E_S</i>	12632	10934	11437	-13.44	-9.46
<i>w</i>	20.6117	22.9603	24.0125	11.39	16.50
<i>h</i>	57.747	46.7633	49.1422	-19.02	-14.90
<i>l</i>	42.3535	37.8776	58.8143	-10.57	38.87
<i>N</i>	18.8	19.0	19.10	1.06	1.60
<i>H</i>	139.1	134.7	134.8	-3.16	-3.09
<i>L</i>	405.9	384.8	260.4	-5.20	-35.85
<i>K</i>	4042.9	3477.7	3649.2	-13.98	-9.74
<i>p</i>	0.9369	0.9449	0.9543	0.85	1.86
<i>p_A</i>	0.9876	1.0863	1.0863	10.00	10.00
<i>p_M</i>	1.000	1.100	1.100	10.00	10.00
<i>p_S</i>	0.872	0.872	0.872	0.00	0.00
<i>p_D</i>	0.9848	1.0118	1.0674	2.74	8.39
<i>RXR</i>	99.1205	111.18	99.1205	12.17	0.00
Welfare				-10.9	-9.36

Note on welfare measure: Welfare loss from the tariff is computed as: [Welfare percent = % output loss/GDP + consumer surplus lost - Terms of Trade gain - TOT gain as % of GDP], where the consumer surplus loss = percent rise in CPI x 0.5 and the TOT gain = RXR percent rise x share of imports in GDP.

Source: World inequality. 11) Import and export by area - source is: International Monetary Fund; 12) other world data as for UK. All data are annual data from 1987 to 2018. Figure 5 below plots the data series.

The auxiliary model for China

The variables in the auxiliary model are $TS_{EU} = \frac{(M_{EU}+X_{EU})}{(GDP_{China})}$, $TS_{US} = \frac{(M_{US}+X_{US})}{(GDP_{China})}$, $TS_{ROW} = \frac{(M_{ROW}+X_{ROW})}{(GDP_{China})}$, $OS_{China} = \frac{y_M}{y_S}$, which we put on the left hand side for convenience; and on the right hand side we have the relative productivity residual of manufacturing/services, $\frac{\pi_M}{\pi_S}$; the relative factor share, skilled/unskilled labour, $\frac{H}{N}$; the wage of unskilled relative to skilled workers, $\frac{w}{h}$; and EU GDP and US GDP.

The auxiliary model equations are potentially:

$$TS_{EU} = \gamma_1 + a_{11} \frac{\pi_M}{\pi_S} + a_{12} \frac{N}{H} + a_{13} \log(GDP_{EU}) + a_{14} \log(GDP_{US}) + a_{15} \frac{w}{h} + \varepsilon_1 \quad (B.3.1)$$

$$TS_{US} = \gamma_2 + a_{21} \frac{\pi_M}{\pi_S} + a_{22} \frac{N}{H} + a_{23} \log(GDP_{EU}) + a_{24} \log(GDP_{US}) + a_{25} \frac{w}{h} + \varepsilon_2 \quad (B.3.2)$$

$$OS_{China} = \gamma_3 + a_{31} \frac{\pi_M}{\pi_S} + a_{32} \frac{N}{H} + a_{33} \log(GDP_{EU}) + a_{34} \log(GDP_{US}) + a_{35} \frac{w}{h} + \varepsilon_3 \quad (B.3.3)$$

$$TS_{ROW} = \gamma_4 + a_{41} \frac{\pi_M}{\pi_S} + a_{42} \frac{N}{H} + a_{43} \log(GDP_{EU}) + a_{44} \log(GDP_{US}) + a_{45} \frac{w}{h} + \varepsilon_4 \quad (B.3.4)$$

We will use these equations in full in our analysis, as discussed in earlier cases.

These variables, endogenous and exogenous, will not be stationary but rather will have either deterministic or stochastic trends. However the residuals in the reduced form are stationary since the regressions will be relationships derived from equilibrium structural relationships such as those found in our CGE model; these should be co-integrated therefore (Table 11).

We now show our test in which we use all four equations B.3.1-B.3.4).

The conclusion from this is that the classical model fits the China trade facts and passes, with a p-value of 0.105, while the strong gravity model (with a low demand elasticity of 0.6) is strongly rejected with a p-value of 0.034.

The IRF of a tariff increase by China

What is of interest is to compare a policy change, here a tariff increase on food and manufactures, across the two models. It can be seen that the gravity effect on welfare is more positive

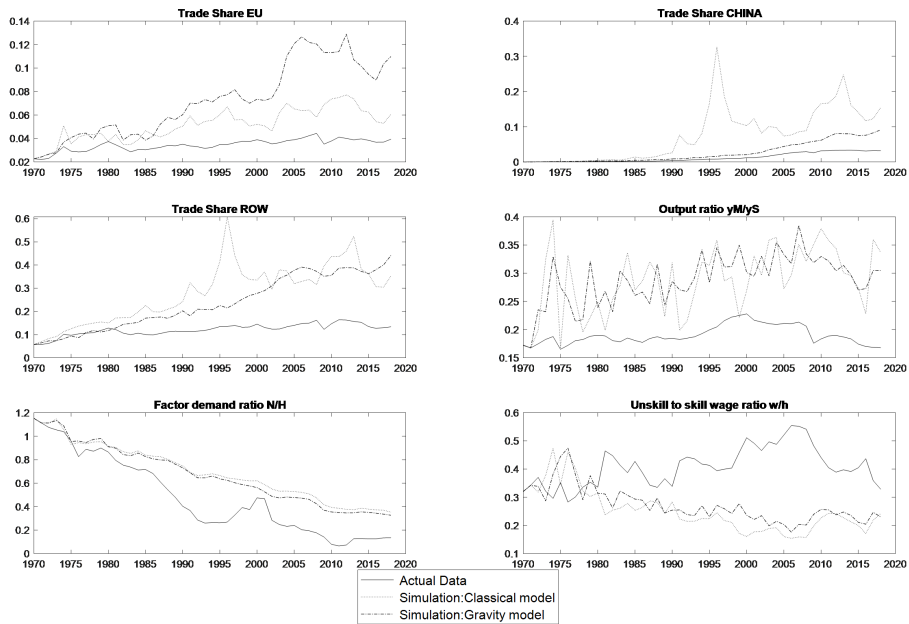


Figure 4: Actual and average of simulated data for the US

Table 11: Stationary test for China

ADF test	Stationary	Trend Stationary	Nonstationary
TS_{EU}			√
TS_{UK}			√
TS_{ROW}			√
OS_{China}			√
$\frac{\pi_M}{\pi_S}$			√
$\frac{N}{H}$			√
$\frac{w}{h}$			√
$\log(E_{EU})$			√
$\log(E_{US})$			√
Residuals			
ε_1	√		
ε_2	√		
ε_3		√	
ε_4	√		

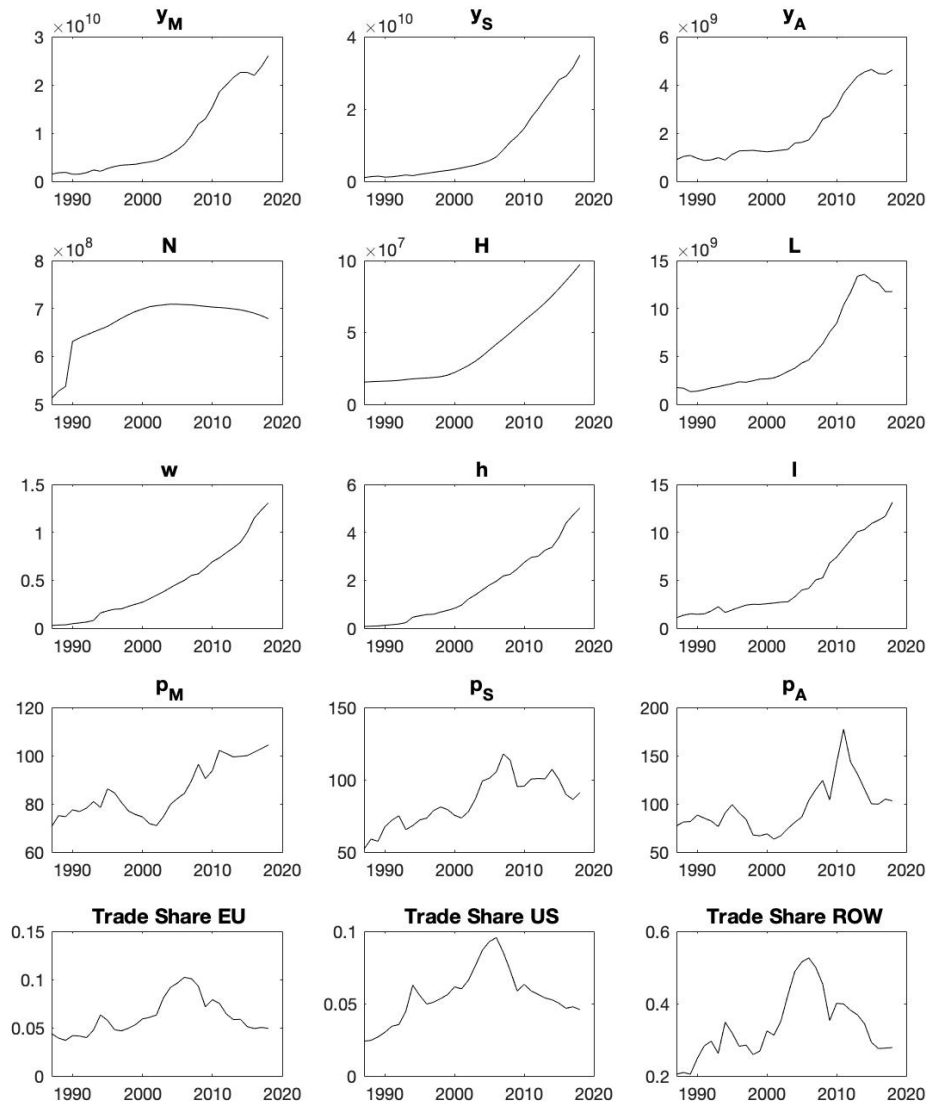


Figure 5: China Data from 1987 to 2018

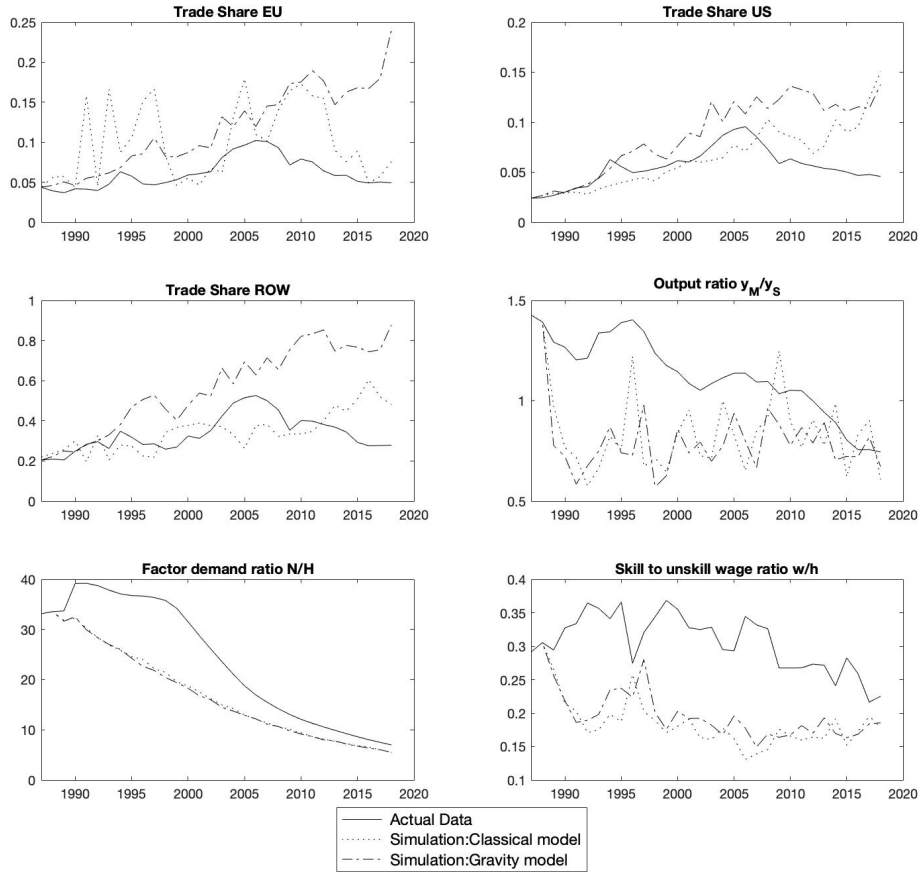


Figure 6: Actual and average of simulated data for China

Table 12: Indirect Inference test results for the China

	Equations in auxiliary model in full	p-value
Classical trade model	<i>B.3.1, B.3.2, B.3.3, B.3.4</i>	0.1052
Gravity model ($\psi = 0.6$)	<i>B.3.1, B.3.2, B.3.3, B.3.4</i>	0.0344*

Note: p-value with * indicates a rejection of the model at 5% significance level.

Table 13: Effects of 10% tariff on food and manufacturing for China

Variables	Base Run	10% tariff on food and manufactures		% changes	
		Gravity	Classical	Gravity	Classical
y	131120	125460	124490	-4.3167	-5.0564
y_A	4620	4620	40200	0.00	0.00
y_M	26020	40850	17420	56.9946	54.4965
y_S	34920	17260	62240	-50.5727	-50.1145
y_D	64460	62730	950	-4.3167	-5.0641
E_A	1110	970	14910	-12.6126	-14.4144
E_M	15080	14940	46380	-0.9284	-1.1273
E_S	49370	46820	149.7413	-5.1651	-6.0563
w	130.6859	154.9312	443.2067	18.5523	14.5811
h	501.5669	456.6338	166.9573	-8.9585	-11.6356
l	113.5687	225.0442	687.9808	98.1569	47.0100
N	678.68	690.3289	94.6877	1.7164	1.3704
H	97.18	94.6477	84.7111	-2.6058	-2.5646
L	117.5247	65.9792	55.2562	-43.8594	-27.9207
K	56.1775	57.3851	1.0836	2.1496	-1.6400
p	1.02	1.1172	1.1	9.5294	6.2353
p_A	0.9876	1.0863	0.872	10.00	10.00
p_M	1	1.1	1.1	10.00	10.00
p_S	0.872	0.872	0.872	0.00	0.00
p_D	1.1367	1.331	1.2639	17.0933	11.1903
RXR	93.6283	116.7607	93.6283	24.7066	0.00
RXR Welfare welfare		0.0978		-4.4	-8.1

Note on welfare measure: Welfare loss from the tariff is computed as: [Welfare percent = % output loss/GDP + consumer surplus lost - Terms of Trade gain - TOT gain as % of GDP], where the consumer surplus loss = percent rise in CPI x 0.5 and the TOT gain = RXR percent rise x share of imports in GDP.

than the large welfare loss under the Classical model because the currency appreciates, improving the terms of trade- we see once more the bias of the gravity model towards protectionism.

B.4 Results for the EU (excluded UK)

In the case of the EU, we also need to simulate all other countries' GDPs and also world prices because plainly the EU, as another large continental economy, has a major effect on them. Here therefore to test the EU we simulate the EU model as the part of the world model to be tested, and we simulate the other country variables required to solve this part via a reduced form VAR model.

Data is collected from World Bank, UNCTAD, International Monetary Fund, Eurostat. As member of European Union increases from EU15 to EU28, we use EU15 – original member of

European Union to maintain consistency. For missing data which is unavailable from any above source, EABCN provides an up-to-date Euro Area macroeconomic time series data from the Area Wide Model (AWM) dataset created by Gabriel Fagan, Jerome Henry and Ricardo Mestre.

For other countries and world data, it remains consistent with UK dataset.

EU Data

The sources of the EU data are as follows: 1) Output by sector: Agriculture, Industry, Service, Nontraded Source: World Bank, real, constant 2015, billion dollars. 2) Trade data (export and import data) by sector: Agriculture, Industry, Service Source: World Bank, real, constant 2015, billion dollars. 3) Government spending Source: World Bank, AWM database, real, constant 2015, billion dollars 4) Population, skilled workers and unskilled workers Sources: AWM database, million. 5) Earnings of skilled workers: Ratio of skilled earning to unskilled earnings (Decile9/Decile5); Source: OECD Database. 6) Goods price index: Agriculture, Industry, Service. Source: Free market commodity price indices, UNCTAD. We use them as world agriculture and manufacture price index respectively. The world service price data is not available. We use UK service producer prices, which are obtained from Office of National Statistics(ONS),to proxy world service index. 7) Rent on land (£ per hectare) Source: use UK rent of land price index as proxy. 8) Real interest rate, wage index, rent on capital Source: AWM database, real interest rate = nominal interest rate minus inflation. 8) Trade data (export and import data) by country Source: International Monetary Fund, real, constant 2015, billion dollars. 9) Capital formation, agricultural land Source: World Bank. 10) Other world data, including sector prices (agriculture, manufacture and service) as for UK.

All data are annual data from 1970 to 2018. Figure 7 below plots the whole data series.

The auxiliary model for the EU

The variables in the auxiliary model are $TS_{UK} = \frac{(M_{UK}+X_{UK})}{(GDP_{EU})}$, $TS_{US} = \frac{(M_{US}+X_{US})}{(GDP_{EU})}$, $TS_{ROW} = \frac{(M_{ROW}+X_{ROW})}{(GDP_{EU})}$, $OS_{EU} = \frac{y_M}{y_S}$, which we put on the left hand side for convenience; and on the right hand side we have the relative productivity residual of manufacturing/services, $\frac{\pi_M}{\pi_S}$; the relative factor share, skilled/unskilled labour, $\frac{H}{N}$; the wage of unskilled relative to skilled workers, $\frac{w}{h}$; and EU GDP and US GDP.

The auxiliary model equations are potentially:

$$TS_{UK} = \gamma_1 + a_{11} \frac{\pi_M}{\pi_S} + a_{12} \frac{N}{H} + a_{13} \log(GDP_{UK}) + a_{14} \log(GDP_{US}) + a_{15} \frac{w}{h} + \varepsilon_1 \quad (B.4.1)$$

$$TS_{US} = \gamma_2 + a_{21} \frac{\pi_M}{\pi_S} + a_{22} \frac{N}{H} + a_{23} \log(GDP_{UK}) + a_{24} \log(GDP_{US}) + a_{25} \frac{w}{h} + \varepsilon_2 \quad (B.4.2)$$

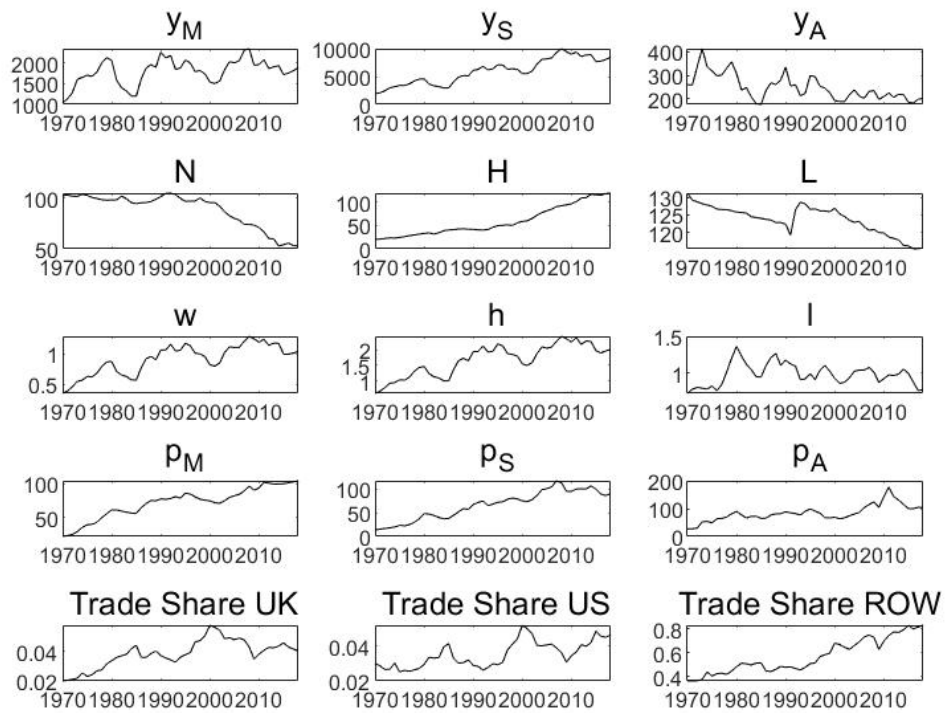


Figure 7: The EU Data from 1970 to 2018

Table 14: Stationary test for the EU

ADF test	Stationary	Trend Stationary	Nonstationary
TS_{UK}			√
TS_{US}			√
TS_{ROW}			√
OS_{EU}		√	
$\frac{\pi_M}{\pi_S}$			√
$\frac{N}{H}$		√	
$\frac{w}{h}$			√
$\log(E_{UK})$			√
$\log(E_{US})$			√
Residuals			
ε_1	√		
ε_2	√		
ε_3	√		
ε_4	√		

$$OS_{EU} = \gamma_3 + a_{31} \frac{\pi_M}{\pi_S} + a_{32} \frac{N}{H} + a_{33} \log(GDP_{UK}) + a_{34} \log(GDP_{US}) + a_{35} \frac{w}{h} + \varepsilon_3 \quad (\text{B.4.3})$$

$$TS_{ROW} = \gamma_4 + a_{41} \frac{\pi_M}{\pi_S} + a_{42} \frac{N}{H} + a_{43} \log(GDP_{UK}) + a_{44} \log(GDP_{US}) + a_{45} \frac{w}{h} + \varepsilon_4 \quad (\text{B.4.4})$$

We will use these equations in full. These variables, endogenous and exogenous, will not be stationary but rather will have either deterministic or stochastic trends. However the residuals in the reduced form are stationary since the regressions will be relationships derived from equilibrium structural relationships such as those found in our CGE model; these should be co-integrated therefore (Table 14).

The auxiliary data and average simulation from classical and gravity model is shown in diagram below Figure 8.

In EU part-of-model test, the demand substitution elasticity between geographic origin in the gravity model is set to 0.6 ($\psi=0.6$), reflecting more closely the assumption of low substitutability. Furthermore, the ν parameter for all sectors (agriculture, manufacture and service) is set to 2, just as other countries.

We see that the classical model passes the test with a p-value of 0.115, while the full gravity

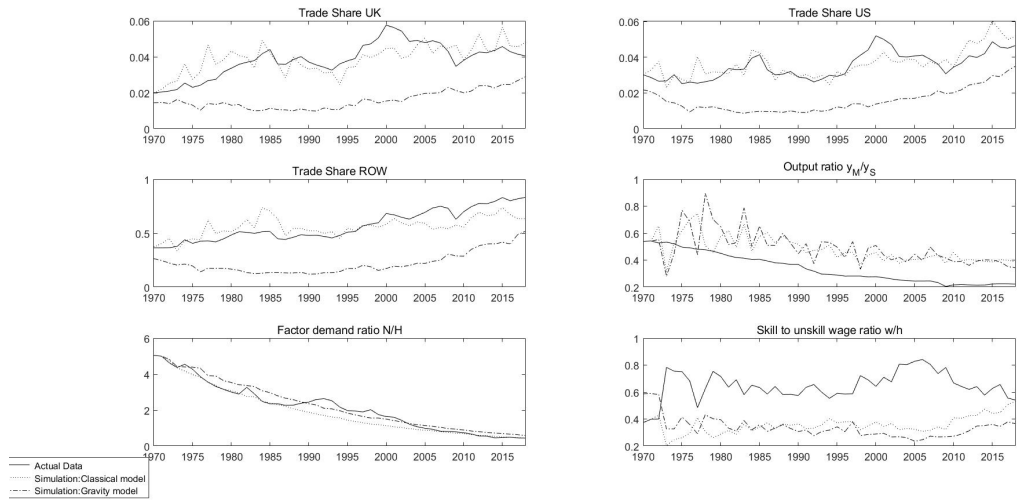


Figure 8: Actual and average of simulated data for the EU

Table 15: Indirect Inference test results for the EU

	Equations in auxiliary model in full	p-value
Classical trade model	<i>B.4.1, B.4.2, B.4.3, B.4.4</i>	0.1146
Gravity model ($\psi = 0.6$)	<i>B.4.1, B.4.2, B.4.3, B.4.4</i>	0.0746

Table 16: Effects of 10% tariff on food and manufacturing for the EU

Variables	Base Run	10% tariff on food and manufactures		% changes	
		Gravity	Classical	Gravity	Classical
y	12369	11942	11834	-3.45	-4.33
y_A	202	202	202	0.00	0.00
y_M	1890	4708	4738	149.10	150.69
y_S	8535	5372	5256	-37.06	-38.42
y_D	1742	1660	1638	-4.71	-5.97
E_A	186	175	173	-5.91	-6.99
E_M	2442	2365	2345	-3.15	-3.97
E_S	8001	7742	7678	-3.24	-4.04
w	1.03	1.15	1.14	11.65	10.68
h	1.76	1.29	1.30	-26.70	-26.13
l	0.63	0.80	0.87	-26.98	38.09
N	52.81	56	55.67	6.04	5.42
H	118.77	103.02	102.74	-13.26	-13.50
L	115.54	102.79	100.86	-11.04	-12.71
K	2780	2396	2382	-13.81	-14.32
p	0.95	1.0021	0.99	5.48	4.21
p_A	1.21	1.331	1.331	10.00	10.00
p_M	1	1.1	1.1	10.00	10.00
p_S	1.12	1.12	1.12	0.00	0.00
p_D	0.88	0.99	0.94	12.78	7.09
RXR	108.88	118.71	108.88	9.23	0.00
<i>Welfare</i>				-3.27	-6.43

Note on welfare measure: Welfare loss from the tariff is computed as: [Welfare percent = % output loss/GDP + consumer surplus lost - Terms of Trade gain - TOT gain as % of GDP], where the consumer surplus loss = percent rise in CPI x 0.5 and the TOT gain = RXR percent rise x share of imports in GDP.

model passes the test marginally at the 5% significance level, with a p-value of 0.07.

The IRF of a tariff increase by the EU

Considering there is 10% a tariff increase on price of food and manufactures, across the two models. Both model have moderately similar tariff effect, imposing 10% tariff will result welfare loss of 6.4% classical model and 3.3% for gravity model. It can be seen that under the gravity model a tariff, through the implied gain on the terms of trade, creates less of a welfare cost than implied by the classical model.

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