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Industrialisation and the Big Push in a Global Economy*

February 29, 2016

Abstract

Is it possible to escape from a poverty trap through international trade? To answer this question, we extend [Murphy et al.'s \(1989b\)](#) famous “Big Push” model towards a global economy. In general oligopolistic equilibrium, firms choice between a traditional CRS and a modern IRS technology results in three different equilibria, featuring *no*, *incomplete*, or *complete* industrialisation across a continuum of sectors. With labour being sufficiently scarce, multiple equilibria exist, and the economy may end up trapped in an incompletely industrialised low-welfare equilibrium as firms fail to coordinate their technology choices. Since the adoption of the modern technology is impeded by tougher competition through international trade, the vicious circle of poverty is aggravated by the forces of globalisation.

JEL-Classification: F12, O14, F43

Keywords: Poverty traps, Multiple equilibria, Int. Trade, Technology upgrading, GOLE

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1 Introduction

“Let us assume that 20,000 unemployed workers [...] are taken from the land and put into a large shoe factory. They receive wages substantially higher than their previous meagre income in natura. [...] If these workers spent all their wages on shoes, a market for the products of their enterprise would arise representing an expansion which does not disturb the pre-existing market [...]. The trouble is that the workers will not spend all their wages on shoes.”

“If, instead, one million unemployed workers were taken from the land and put, not into one industry, but into a whole series of industries which produce the bulk of the goods on which the workers would spend their wages, what was not true in the case of one shoe factory would become true in the case of a whole system of industries: it would create its own additional market, thus realising an expansion of world output with the minimum disturbance of the world markets.”

(Rosenstein-Rodan, 1943, pp. 205-206)

The above example of a shoe factory, that by paying high wages generates positive demand spill-overs for other industries, and therefore can not break even unless it benefits itself from the demand spillover exerted by other sectors, often is seen as a synonym for a poverty trap (cf. Matsuyama, 2008). Reviewing 50 years of development theory, Krugman (1993) celebrates Murphy et al. (1989b) for the formalisation of Rosenstein-Rodan’s (1943) “Big Push” hypothesis, which in his view marked an important first step towards a “counter-counterrevolution in development theory”, that would lead to a resurgence of what Krugman (1993) summarises as a “high development theory” (cf. Rosenstein-Rodan, 1943; Nurkse, 1952; Fleming, 1955), which became forgotten (mainly) due to the lack of theoretical codification.

Although several authors have followed Krugman’s (1993) call, in particular those who were interested in an open-economy analysis quickly abandoned Murphy et al.’s (1989b) formalisation of a “Big Push” based on increasing returns to scale at the firm-level in favour of models with external increasing returns to scale (cf. Ethier, 1982; Matsuyama, 1991). In this paper we argue that the turn away from Murphy et al.’s (1989b) “Big Push” model can be largely explained by the authors’ deliberate choice to formalise Rosenstein-Rodan’s (1943) original idea in a closed-economy setting.¹² Several authors (cf. Matsuyama, 1991; Stiglitz, 1993) have responded to Murphy et al.’s (1989b) modelling choice with an open-economy critique, according to which limited (initial) market size as a reason for a poverty trap should be much less an issue if firms can sell their goods abroad. More importantly, however, it turned out that Murphy et al.’s (1989b) closed-economy model is particular unsuited to explore the link between poverty traps and international trade (cf. Rodrik, 1996; Trindade, 2005), resource booms (cf. Sachs and

¹To justify the assumption of a closed economy, Murphy et al. (1989b) emphasise (at length) the importance of domestic markets for economic development (cf. Murphy et al., 1989b, pp. 1006-7). A similar line of argumentation can be found in Murphy et al. (1989a).

²As evident from the quote at the beginning of the introduction, Rosenstein-Rodan’s (1943) argumentation, although lacking a theoretical foundation, does by no means restrict the analysis to a closed economy.

Warner, 1999) or foreign direct investment (cf. Rodriguez-Clare, 1996).

To overcome the limitations associated with the closed-economy-assumption, we use the general oligopolistic equilibrium (GOLE) framework of Neary (2003, 2016) to extend the “Big Push” model by Murphy et al. (1989b) towards an global economy in which firms compete under Cournot competition. As in Murphy et al. (1989b), firms in a continuum of sectors can chose between a traditional constant-returns-to-scale (CRS) and a modern increasing-returns-to-scale (IRS) technology. Due to the richer market structure our model not only captures the two familiar polar cases of no versus complete industrialisation, but also a third *new* equilibrium type with incomplete industrialisation, in which the modern technology is adopted by firms in some, but not all, sectors. For a sufficiently labour-scarce (world) economy with relatively high wages and low mark-ups our model predicts a multiplicity of equilibria, characterised by incomplete versus complete industrialisation. Unlike Murphy et al. (1989b), whose firm-level mark-ups are fixed, we do not rely on the assumption of an exogenously given wage premium to generate a multiplicity of equilibria. In our model the adoption of the modern IRS technology is associated with rising wages, such that late technology adopters are confronted with higher costs and, therefore charge lower mark-ups. As mark-ups decline, we ultimately end up in a situation, in which the adoption of the modern IRS technology, although unprofitable for the individual firm, is socially desirable for the economy as a whole, given that all other firms would benefit from the positive demand externality that arises from a (further) increase in labour income. We characterise a condition under which the multiplicity of equilibria is associated with a poverty trap, in which an economy with decentralised technology upgrading decisions is caught in a low-welfare equilibrium with incomplete industrialisation, although a sustainable high-welfare equilibrium with complete industrialisation could be reached either by coordinating firms’ technology choice or by allowing for a big push, that renders the adoption of the modern technology profitable for all and not just for some firms.³

Allowing for an increasing number of trading partners suggest that international trade can not substitute for the aforementioned big push. Unlike in models with external increasing returns to scale (cf. Sachs and Warner, 1999; Trindade, 2005), there are no overall efficiency gains from a deeper division of labour (cf. Rodriguez-Clare, 1996) as the result of (more) international trade.⁴ The primal effect of (more) international trade is a redistribution of incomes away from

³Since we place our analysis in an perfectly integrated world economy, it is worth to note that the existence of multiple equilibria does not depend on the assumption that world trade is sufficiently costly, as suggested by Fn. 24 in Matsuyama (1991) or by Fn. 3 in Stiglitz (1993). As in an closed economy with initially too small market size, a multiplicity of equilibria can also arise in an open economy if the world market initially is too small. In either case, if the adoption of the modern technology is associated with a sufficient expansion of the market, industrialisation becomes a self-fulfilling prophecy.

⁴As shown in Neary (2016), the absence of gains from trade between featureless economies (without inter-sectoral heterogeneity), is explained by the fact that there is no scope for an optimal factor reallocation (cf.

firms, whose mark-ups shrink due to a more intense competition, towards workers, who benefit from trade's pro-competitive effect through higher wages. In an economy, which initially is trapped in an incompletely industrialised low-welfare equilibrium, firms' ability to appropriate the full returns to their technology investment is severely limited by falling mark-ups, such that it becomes more difficult, or sometimes even impossible, to reach the completely industrialised high-welfare equilibrium.

Our work is related to different stands of the literature. As already pointed out above, several authors have turned to models with external increasing returns to scale (cf. [Ethier, 1982](#)) to analyse multiple equilibria in an open economy setting, focussing for example on the spatial distribution of economic activity (cf. [Krugman and Elizondo, 1996](#)) or on the effects of resource booms (cf. [Sachs and Warner, 1999](#)).⁵ [Rodrik \(1996\)](#) and [Rodriguez-Clare \(1996\)](#) both develop small-open-economy models, in which intermediate inputs are assembled under external increasing returns to scale, and in which coordination failure gives rise to a poverty trap. However, neither of them explores the link between poverty traps and international trade. [Trindade \(2005\)](#) develops an asymmetric North-South model with international trade in intermediate inputs, which are assembled under external increasing returns to scale. Coordination failure among complementary industries gives rise to a poverty trap from which countries can escape through a trade-induced big push.

Finally, our paper also builds up on the modelling of general oligopolistic equilibrium (GOLE) in [Neary \(2016\)](#).⁶ For the modelling of cost-reducing R&D investments in general oligopolistic equilibrium see [Neary \(2003\)](#). In [Neary and Tharakan \(2012\)](#) the mode of competition is endogenized by allowing firms to invest into higher capacity constraints. Unlike in our model, technology upgrading always requires a second factor of production. More importantly, however, neither of the papers is related to the analysis of poverty traps in general oligopolistic equilibrium.

The paper is structured as follows: In Section 2 we provide a short recap of the Big Push model by [Murphy et al. \(1989b\)](#) following the exposition in [Krugman \(1993\)](#). In Section 3 we then lay out our model and derive a general characterisation of firms' technology upgrading decision. Section 4 consists of three Subsections: Subsection 4.1 establishes the existence of multiple equilibria in a global economy. In Subsection 4.2 we then demonstrate under which

[Lerner, 1934](#)).

⁵Studies, which directly build up on the framework of [Murphy et al. \(1989b\)](#), typically focus on aspects which can be well addressed within an closed economy setting. See [Ciccone \(2002\)](#) for the role of input chains, [Mehlum et al. \(2003\)](#) for the role of organised crime, and [Magruder \(2013\)](#) for the effect of introducing a minimum wage. Further examples include [Matsuyama \(1992\)](#), [Gans \(1997\)](#), [Yamada \(1999\)](#) as well as [Bjorvatn and Coniglio \(2012\)](#). For a broader account of the literature see [Azariadis and Stachurski \(2005\)](#).

⁶See [Colacicco \(2015\)](#) for a recent literature review.

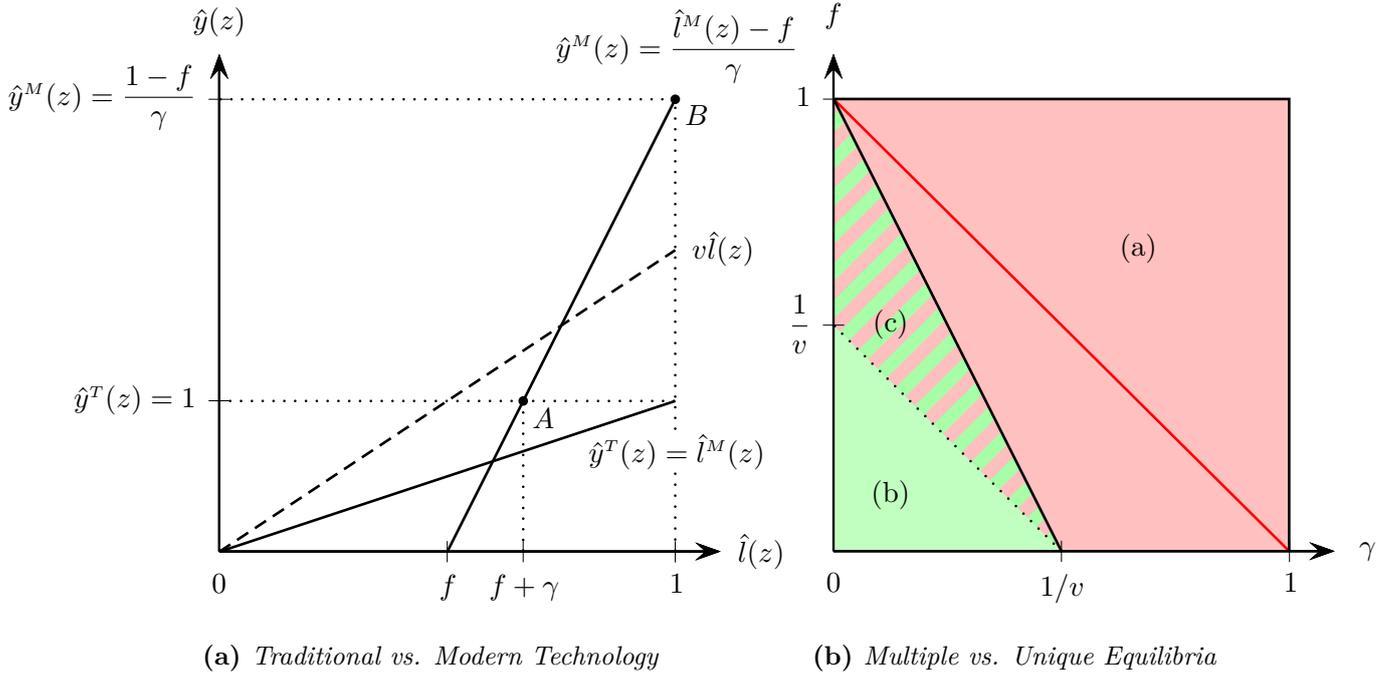
conditions a multiplicity of equilibria results in a poverty trap. Finally, we show in Subsection 4.3 that international trade does not substitute for a big push if an economy wants to escape from a poverty trap. Section 5 concludes.

2 Industrialisation, the Big Push, and No International Trade

We begin our analysis with a short recap of the Big Push model by [Murphy et al. \(1989b\)](#). Consider a closed economy with a continuum of sectors $z \in [0, 1]$ and Cobb Douglas preferences $U[x(z)] = \exp[\int_0^1 \ln x(z) dz]$. The economy is endowed with a fixed supply of labour $L > 0$, which also serves as *numéraire*, such that wages $w \stackrel{!}{=} 1$ can be normalised to equal one without loss of generality. Following [Neary \(2003\)](#), firms are assumed to be large in the small and small in the large. Put differently, while we allow for imperfect competition at sectoral goods markets, it is assumed that the national labour market clears under perfect competition. In each sector a competitive fringe of firms has access to a traditional technology (denoted by superscript T), with a unitary labour input coefficient $y^T(z) = l^T(z)$. Out of the competitive fringe, a single firm has access to a unique modern technology with increasing returns to scale (denoted by superscript M), which is characterised by production function $y^M(z) = \max\{0, [l^M(z) - F]/\gamma\}$, with $\gamma \in (0, 1)$ as marginal and $F \in (0, L)$ as fixed labour requirement. To adopt the modern technology and to become a monopolist, firms in each sector have to pay an exogenously given (multiplicative) wage premium $v \geq 1$. Given these assumptions, what are the conditions for a successful industrialisation (i.e. the modernisation of all sectors $z \in [0, 1]$)?

To answer this question we follow the exposition in [Krugman \(1993\)](#) and relate *per capita* labour input $\hat{l}(z) \equiv l(z)/L$ to *per capita* sectoral output $\hat{y}(z) \equiv y(z)/L$ in Subfigure 1a, with $f \in (0, 1)$ being defined as $f \equiv F/L$. Solid lines represent the traditional technology as a ray from the origin and the modern technology as a line with slope $1/\gamma$. If all sectors use either the traditional or the modern technology, labour market clearing implies $L = \int_0^1 l(z) dz = \int_0^1 l dz = l$ (or equivalently $\hat{l}(z) = 1$), and per capita output under the traditional/modern technology equals $\hat{y}^T(z) = 1$ and $\hat{y}^M(z) = (1 - f)/\gamma$, respectively. In Subfigure 1a, we illustrate the interesting case of $\hat{y}^M(z) = (1 - f)/\gamma > \hat{y}^T(z) = 1$, which requires that the (percentage) reduction in the marginal labour requirement $(1 - \gamma) < 1$ more than offsets the additional fixed labour requirement $f > 0$ associated with the modern technology. However, the mere fact that the modern technology constitutes a Pareto improvement does not mean that it necessarily will be implemented. Implementation has to be profitable, given the exogenous wage premium v . Suppose a single firm in a particular sector starts to modernise given that firms in all other sectors stick to the traditional technology. The modern firm charges the same (limit) price as

Figure 1: *The Big Push*



the traditional firms and sells the same quantity, which in the absence of income effects (each sector only marginally contributes to the economy as a whole), equals $\hat{y}^T(z) = \hat{y}^M(z) = 1$. To produce this quantity in point A of Subfigure 1a the modern firm uses less labour $f + \gamma < 1$ but pays a higher wage $v > 1$, which renders modernisation at this point unprofitable given that the costs per worker (dashed line in Subfigure 1a) exceed output and, hence, revenue per worker $(f + \gamma)v > 1$.

Now suppose firms in all sectors modernise simultaneously. Production and employment then correspond to point B in Subfigure 1a, which renders modernisation profitable given that per-worker output exceeds the cost per worker $(1 - f)/\gamma > v$.

Subfigure 1b depicts firms' individual indifference condition $(f + \gamma)v = 1$ as black, dotted line below which each firm finds it optimal to adopt the modern technology irrespective of what other firms do. Condition $(1 - f)/\gamma = v$ is depicted as a black, solid line below which modernisation is profitable, given that firms coordinate their actions across all sectors. For combinations of γ and f below the red diagonal industrialisation (i.e. the modernisation of all sectors) constitutes a Pareto improvement. In the red parameter space (a) no sector modernises, while industrialisation always succeeds in the green parameter space (b). In the red-green striped parameter space (c) multiple equilibria exist: With a sufficient willingness to coordinate across sectors firms can reach the superior equilibrium with industrialisation. Without coordination the economy is trapped in a non-industrialised low-income equilibrium.

Although celebrated for the revival of what [Krugman \(1993\)](#) summarises as “high development

theory” (cf. [Rosenstein-Rodan, 1943](#); [Nurkse, 1952](#); [Fleming, 1955](#)), the Big Push model by [Murphy et al. \(1989b\)](#) from the beginning faced the critique that insufficient initial (domestic) demand as cause for multiple equilibria becomes less an issue if the economy has the possibility to access the world market via international trade (cf. [Matsuyama, 1991](#); [Stiglitz, 1993](#)). Ironically, the clever combination of Bertrand competition and hyperbolic demand, which greatly simplifies the analysis of the closed-economy model above, immensely complicates the incorporation of international trade into the setting of [Murphy et al. \(1989b\)](#): On the one hand, quasi-rents from technology adoption and therefore the incentives to modernise are eliminated if two or more modern firms from different countries compete over the prices of two homogeneous goods.⁷ On the other hand, Cournot competition as a natural alternative is greatly complicated by the fact that demand is iso-elastic.⁸ Confronted with these difficulties, subsequent studies analysing the effects of international trade on multiple equilibria (cf. [Krugman and Elizondo, 1996](#); [Rodriguez-Clare, 1996](#); [Sachs and Warner, 1999](#)) abandoned the original Big Push model by [Murphy et al. \(1989b\)](#) in favour of models with external increasing returns to scale (cf. [Ethier, 1982](#)). In the following, we will incorporate firms’ technology upgrading decision as originally formalised in [Murphy et al. \(1989b\)](#) into a General Oligopolistic Equilibrium (GOLE) model (cf. [Neary, 2003, 2016](#)), which not only allows us to study more flexible market structures but also the effects of opening up for international trade if the respective country under autarky would be caught in poverty trap.

3 Technology Upgrading in General Oligopolistic Equilibrium

Section 3 is structured as follows: In Subsection 3.1 we establish continuum-quadratic preferences (cf. [Neary, 2003, 2016](#)) as an alternative to the Cobb-Douglas preferences in [Murphy et al. \(1989b\)](#). Subsection 3.2 then characterises firms’ technology upgrading decision without imposing specific assumptions on the market structure.

⁷Intuitively, the “Bertrand paradox” only arises under free trade. In the presence of non-prohibitive (variable) trade costs monopolists in each country resort to a limit pricing strategy, slightly undercutting the foreign competitors’ unit costs. With blocked foreign market entry investments into increasing-returns-to-scale technologies are constrained by the (initial) size of the domestic market and multiple open-economy equilibria may exist. However, with international trade as a mere threat, we would arrive at the bewildering conclusion that industrialisation is associated with zero trade.

⁸As pointed out by [Neary \(2016\)](#), quantities are strategic complements for many parameter values. Moreover, reaction functions may be non-monotonic. [Bandyopadhyay \(1997\)](#) demonstrates the complexities that arise with iso-elastic demands even in the simplest Cournot duopoly.

3.1 Preferences

Following Neary (2003, 2016), we adopt continuum-quadratic preferences⁹

$$U[x(z)] = \int_0^1 u[x(z)]dz \quad \text{with} \quad u[x(z)] = \alpha x(z) - \frac{1}{2}\beta x(z)^2, \quad (1)$$

which results in a (perceived) linear demand system

$$p(z) = \frac{\alpha - \beta x(z)}{\lambda}, \quad \text{and} \quad x(z) = \frac{\alpha - \lambda p(z)}{\beta} \quad \text{with} \quad \lambda = \frac{\alpha \int_0^1 p(z)dz - \beta Y}{\int_0^1 p(z)^2 dz}, \quad (2)$$

implying well-behaved best-response functions under Cournot competition.¹⁰ Thereby, we denote sectoral demand by $x(z)$, prices by $p(z)$, and aggregate income by Y . Without loss of generality we can normalise the exogenous preference parameters $\alpha, \beta \stackrel{!}{=} 1$, such that the saturation point equals $\alpha/\beta = 1$. Marginal utility of income λ is a non-linear function of *aggregate* variables only, and therefore may be interpreted as a “sufficient statistic” for how firms perceive the rest of the economy as a whole. Given that we are free to choose any *numéraire*, we simplify the analysis and follow Neary (2003, 2016) by adopting the normalisation $\lambda \stackrel{!}{=} 1$.

3.2 Technology Upgrading

Without imposing strong assumptions on the structure of goods markets, we can generalise firms’ technology upgrading decision from Section 2 to a world with $m \geq 1$ symmetric countries, each having a continuum of symmetric sectors $z \in [0, 1]$ with $n \geq 1$ symmetric firms in each sector.¹¹ Following Neary (2003), we assume that firms within a sector *simultaneously* choose between the traditional technology (denoted by superscript T) and the modern technology (denoted by superscript M). Denoting firms’ revenues by r^M and r^T , we can use the accounting equality $Y(\tilde{z}) = \tilde{z}nr^M + (1 - \tilde{z})nr^T$, with $\tilde{z} \in [0, 1]$ as the share of sectors using the modern technology, to solve for the revenues

$$r^i(\tilde{z}) = \eta^i(\tilde{z}) \frac{Y(\tilde{z})}{n} \quad \forall i \in \{M, T\}, \quad (3)$$

⁹Continuum-quadratic preferences are a sub-class of the Gorman polar form (cf. Gorman, 1961). Thereby, Quasi-homotheticity (i.e. linear income-consumption paths) ensures a consistent aggregation of equally sloped individual demand functions within and across countries.

¹⁰See Neary (2016) for a detailed discussion of the demand system in Eq (2).

¹¹Exploiting the symmetry assumption, we can save on notation and, hence, drop all country-, sector-, and firm-specific indices.

as functions of the economy's aggregate income $Y(\tilde{z})$. Thereby the sectoral expenditure multipliers

$$\eta^M(\tilde{z}) \equiv \frac{\theta(\tilde{z})}{\tilde{z}} \quad \text{and} \quad \eta^T(\tilde{z}) \equiv \frac{1 - \theta(\tilde{z})}{1 - \tilde{z}}, \quad (4)$$

with

$$\theta(\tilde{z}) \equiv \frac{\tilde{z}r^M(\tilde{z})}{\tilde{z}r^M(\tilde{z}) + (1 - \tilde{z})r^T(\tilde{z})} \in [0, 1], \quad (5)$$

as the share of total expenditure that is allocated to modernised sectors, take values of $\eta^M(\tilde{z}) \geq 1 \geq \eta^T(\tilde{z})$ for $r^M(\tilde{z}) \geq r^T(\tilde{z})$, whereas in particular $\eta^M(0) = r^M(0)/r^T(0) \geq \eta^M(1) = 1$ and $\eta^T(0) = 1 \geq \eta^T(1) = r^T(1)/r^M(1)$.¹²

Introducing $\mu^i(\tilde{z}) \in [0, 1] \quad \forall i \in \{M, T\}$ as percentage mark-up, we can link revenues to profits, which may be expressed as:

$$\pi^M(\tilde{z}) = \mu^M(\tilde{z})\eta^M(\tilde{z})\frac{Y(\tilde{z})}{n} - w(\tilde{z})F \quad \text{and} \quad \pi^T(\tilde{z}) = \mu^T(\tilde{z})\eta^T(\tilde{z})\frac{Y(\tilde{z})}{n}, \quad (6)$$

with $w(\tilde{z})$ denoting the ongoing equilibrium wage if the share \tilde{z} of all sectors has already adopted the modern technology. Using $\pi^T(\tilde{z})$ and $\pi^M(\tilde{z})$ from Eq. (6) in accounting equality $Y(\tilde{z}) = \tilde{z}n\pi^M(\tilde{z}) + (1 - \tilde{z})n\pi^T(\tilde{z}) + w(\tilde{z})L$ allows us to solve for aggregate income

$$Y(\tilde{z}) = A(\tilde{z})w(\tilde{z})(1 - \tilde{z}nf)L, \quad (7)$$

in which $f \equiv F/L \in (0, n)$. Thereby, the multiplier

$$A(\tilde{z}) \equiv \frac{1}{1 - \theta(\tilde{z})\mu^M(\tilde{z}) - [1 - \theta(\tilde{z})]\mu^T(\tilde{z})} \geq 1, \quad (8)$$

captures the extent to what workers' labour income $w(\tilde{z})$ is scaled up through the distribution of profit income. Intuitively, we have $A(\tilde{z})$ for $\mu^i(\tilde{z}) = 0$. Finally, substituting $Y(\tilde{z})$ from Eq. (7) into $\pi^M(\tilde{z})$ and $\pi^T(\tilde{z})$ from Eq. (6), allows us to derive the following proposition:

Lemma 1 *Given that the share $\tilde{z} \in [0, 1]$ of sectors has already modernised, firms in the marginal sector will adopt the modern technology if and only if*

$$\pi^M(\tilde{z}) - \pi^T(\tilde{z}) = A(\tilde{z})w(\tilde{z})[\mu^M(\tilde{z})\eta^M(\tilde{z}) - \mu^T(\tilde{z})\eta^T(\tilde{z})(1 - nf) - nf]L/n \geq 0. \quad (9)$$

Proof Formal analysis and discussion in the text.

¹²For $r^M(\tilde{z}) \geq r^T(\tilde{z})$ the multipliers $\eta^M(\tilde{z})$ and $\eta^T(\tilde{z})$ may alternatively be interpreted as the slopes of the first and second segment of the Lorenz curve for the inter-sectoral expenditure distribution.

Intuitively, the profit gain from modernisation is more likely to be positive if firms using the modern (traditional) technology have high (low) mark-ups $\mu^i(\tilde{z})$ as well as high (low) sectoral expenditure multipliers $\eta^i(\tilde{z})$. Under the reasonable presumption $r^M(\tilde{z}) \geq r^T(\tilde{z})$, it moreover follows from $\eta^T(\tilde{z}) \leq 1$ that $\pi^M(\tilde{z}) - \pi^T(\tilde{z})$ is more likely to be positive if the sectoral share of the fixed labour requirements nf is sufficiently low.

4 Multiple Equilibria, Poverty Traps, and International Trade

Section 4 is structured as follows: In Subsection 4.1 we demonstrate under which conditions multiple open-economy equilibria may exist, even if there is no exogenous wage premium for modern firms. Subsection 4.2 then establishes a sufficient condition under which a multiplicity of equilibria results in a poverty trap. Finally, in Subsection 4.3 it is shown that opening up for international trade does not allow countries to escape the vicious circle of poverty if they are caught in a poverty trap under autarky.

4.1 Multiple Equilibria in a Global Economy

Let us consider an integrated world economy of $m \geq 1$ symmetric countries, each with a continuum of monopolised sectors $z \in [0, 1]$, in which firms compete under Cournot competition.¹³ Without loss of generality we fix the number of firms in each country and sector at $n = 1$, such that the variable m not only refers to the number of trading partners but also to the number of firms in the global market. Table 1 summarises the firm-level outcomes for the marginal firm, using either the traditional (T) or the modern (M) technology, given that the share $\tilde{z} \in [0, 1]$ of sectors already has adopted the modern technology. Firm-level outcomes in

Table 1: *Firm-level Outcomes under Cournot competition*

i	$p^i(\tilde{z})$	$x^i(\tilde{z})$	$r^i(\tilde{z})$	$\mu^i(\tilde{z})$
T	$\frac{1+m\gamma w(\tilde{z})}{1+m}$	$\frac{1-w(\tilde{z})}{(1+m)}$	$\frac{[1+m\gamma w(\tilde{z})][1-w(\tilde{z})]}{(1+m)^2}$	$\frac{1-w(\tilde{z})}{1+m\gamma w(\tilde{z})}$
M	$\frac{1+m\gamma w(\tilde{z})}{1+m}$	$\frac{1-\gamma w(\tilde{z})}{(1+m)}$	$\frac{[1+m\gamma w(\tilde{z})][1-\gamma w(\tilde{z})]}{(1+m)^2}$	$\frac{1-\gamma w(\tilde{z})}{1+m\gamma w(\tilde{z})}$

Table 1 solely depend on the wage rate $w(\tilde{z})$, which follows from the full employment condition $L = \tilde{z}[\gamma m x^M(\tilde{z}) + F] + (1 - \tilde{z})m x^T(\tilde{z})$ as

$$w(\tilde{z}) = \frac{1}{\tilde{z}\gamma^2 + 1 - \tilde{z}} \left[(\tilde{z}\gamma + 1 - \tilde{z}) - \frac{1+m}{m}(1 - \tilde{z}f)L \right] \geq 0. \quad (10)$$

¹³In a technical supplement, which is available from the authors upon request, we also study Bertrand competition, replicating Murphy et al.'s (1989b) finding, that without assuming an exogenous wage premium $v > 1$ no multiplicity of equilibria exists.

Using the expressions from Table 1 to replace $\mu^i(\tilde{z})$ and $\eta^i(\tilde{z})$ in Eq. (9), finally allows us to derive Proposition 1.

Proposition 1 *Under the condition:*

$$L < \frac{m}{1+m} \min \left\{ 1, \frac{\gamma(1-\gamma)}{1-f-\gamma^2} \right\} \quad (11)$$

a non-saturated equilibrium with Cournot competition exists. For $L \geq \bar{L}(m)$ with

$$\bar{L}(m) \equiv \frac{m}{2[m + \sqrt{2m(1+m)}]},$$

three type of equilibria, characterised by:

$$(a) \pi^M(0) < \pi^T(0) \wedge \pi^M(1) < \pi^T(1) \wedge \pi^M(1) < \pi^T(0) \Rightarrow \text{no industrialisation,}$$

$$(b) \pi^M(0) > \pi^T(0) \wedge \pi^M(1) > \pi^T(1) \wedge \pi^M(1) < \pi^T(0) \Rightarrow \text{complete industrialisation,}$$

$$(c) \pi^M(0) > \pi^T(0) \wedge \pi^M(1) < \pi^T(1) \wedge \pi^M(1) < \pi^T(0) \Rightarrow \text{incomplete industrialisation,}$$

can be distinguished. For $L < \bar{L}(m)$ multiple equilibria, characterised by:

$$(d) \pi^M(0) > \pi^T(0) \wedge \pi^M(1) < \pi^T(1) \wedge \pi^M(1) > \pi^T(0) \Rightarrow \text{complete vs. incomplete ind.,}$$

exist in addition to the three equilibria types from above.

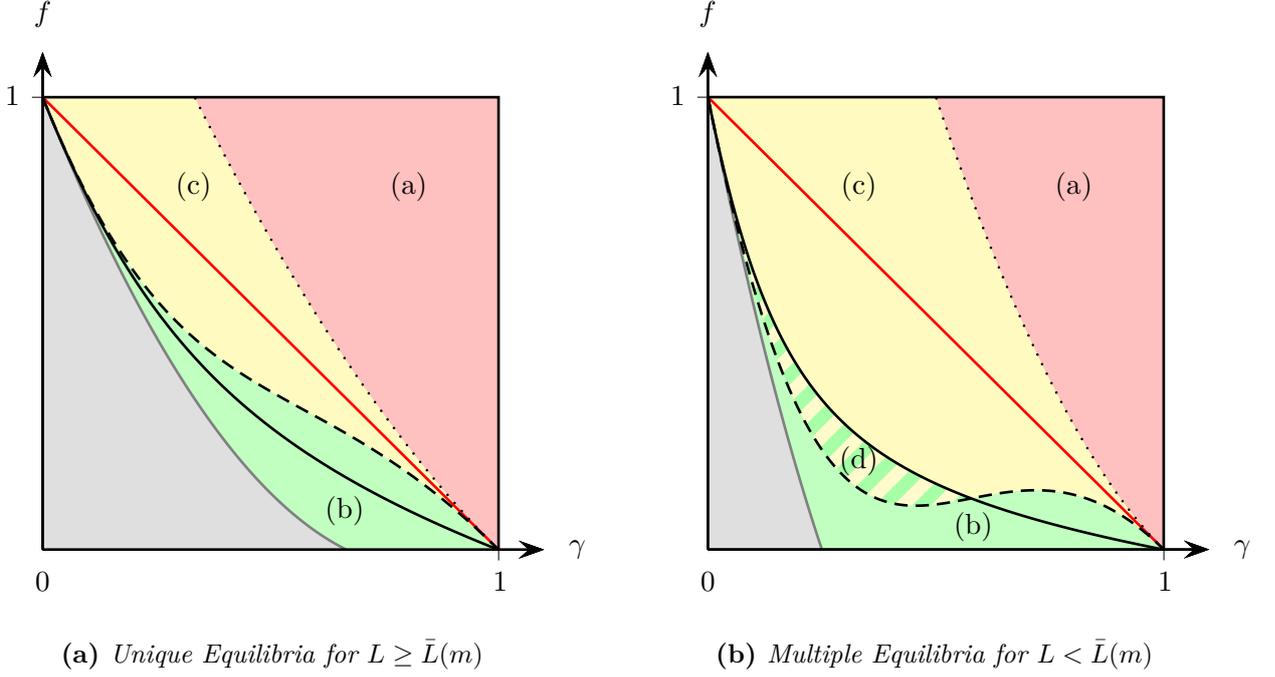
Proof See Appendix A.1.

As in Section 2, there are two (unique) equilibria with and without industrialisation. As a necessary condition for a (completely) industrialised equilibrium (illustrated by the green-coloured parameter space (b) in Figure 2) to exist, the modern technology has to be sufficiently good, i.e. $\gamma < 1 - f$. On the contrary, industrialisation fails (illustrated by the red-coloured parameter (a) space in Figure 2) if the marginal cost reduction implied by $\gamma < 1$ is not sufficiently strong for a given fixed labour requirement $f \in (0, 1)$. Finally, in contrast to the baseline model from Section 2, there is a third equilibrium type with incomplete industrialisation (illustrated by the yellow-coloured parameter space (c) in Figure 2), in which the modern technology is adopted by some but not by all sectors.¹⁴

To understand why – unlike in Murphy et al. (1989b) – it is possible to obtain an incompletely industrialised equilibrium, it is instructive to recall firms' (individual) technology upgrading

¹⁴An interactive version of Figure 2 is available from the authors upon request as a computable data file (CDF), which can be used in combination with Wolfram's CDF-player (available as free download under: www.wolfram.com/cdf-player/).

Figure 2: *Technology Upgrading under Cournot Competition*



$$\cdots f_F(\gamma) \geq f \Leftrightarrow \pi^M(0) \geq \pi^T(0) \quad - - f_L(\gamma) \geq f \Leftrightarrow \pi^M(1) \geq \pi^T(1) \quad - f_c(\gamma) \geq f \Leftrightarrow \pi^M(1) \geq \pi^T(0)$$

decision from Eq. (9), which links firms' technology choice to the share of industrialised sectors $\tilde{z} \in [0, 1]$. Depending on the underlying value of \tilde{z} , firms in the marginal sector \tilde{z} may arrive at quite different conclusions on whether they should or should not adopt the modern technology.¹⁵ Firms' technology upgrading decision thereby depends on the mark-ups $\mu^i(\tilde{z}) \forall i \in \{M, T\}$ and on the sectoral expenditure multipliers $\eta^i(\tilde{z}) \forall i \in \{M, T\}$, and since the former ones only depend on \tilde{z} via its impact on $w(\tilde{z})$, we begin our analysis by exploring the link between the wage $w(\tilde{z})$ and the share of modernised sectors \tilde{z} . In Appendix A.1 we demonstrate that in the relevant parameter space (i.e. in the non-grey area of Figure 2) the wage rate $w(\tilde{z})$ is increasing in the share \tilde{z} of modernised sectors. However, it is important to note that in principle there are two countervailing effects that technology upgrading has on firms' labour demand and, hence, on the equilibrium wage rate. On the one hand, the introduction of the labour-saving modern technology (for $\gamma < 1 - f$) is associated with a reduction in firms' (total) labour demand per unit of output. On the other hand, we find that, by reducing the marginal cost of production, the modern technology allows firms to expand their output. By imposing condition (11), we not only ensure non-satiation, but also a sufficiently elastic aggregate demand for the latter effect

¹⁵Under (asymmetric) Bertrand competition with a unitary price elasticity of demand as in Section 2, we have $\mu^M(\tilde{z}) = 1 - \gamma > \mu^T(\tilde{z}) = 0$ and $\eta^M(\tilde{z}) = \eta^T(\tilde{z}) = 1$. Firms' technology upgrading decision $\pi^M(\tilde{z}) \geq \pi^T(\tilde{z})$ in Eq. (9) then collapses to the simple inequality $\gamma \geq 1 - f$, which does not depend on \tilde{z} and, hence, is the same for all firms.

to prevail.¹⁶

Lemma 1 and Table 1 together suggest that early technology adopters benefit from low wages $w(0) < w(1)$, which translate into high mark-ups $\mu^M(0) > \mu^M(1)$, rendering an early adoption of the modern technology – ceteris paribus – more attractive than a late adoption. However, high mark-ups are not the only reason for an early adoption. By setting a lower prices $p^M(\tilde{z}) < p^T(\tilde{z})$ vis-à-vis all traditional firms, modern firms are able to divert expenditure away from their traditional competitors, which is reflected by $\eta^M(\tilde{z}) > \eta^T(\tilde{z})$. Intuitively, the diversion effect is most pronounced for the first modern firms, which offer lower prices $p^M(0)$ vis-à-vis the traditional firms in all other sectors, and therefore experience the largest boost in their sectoral demand $\eta^M(0) = r^M(0)/r^T(0) > 1$. In contrast, the last technology adopters, when upgrading to the modern technology, only match up to all other firms already offering low prices $p^M(1)$, thereby ensuring that expenditure is (again) allocated equally across all sectors, i.e. $\eta^M(1) = r^M(1)/r^M(1) = 1$. Taking stock, pioneering firms benefit from inter-sectoral demand diversion $\eta^M(0) > \eta^M(1)$ as well as from high mark-ups $\mu^M(0) > \mu^M(1)$. However, as the modern technology is sequentially adopted by more and more firms, the marginal firms’ incentives to modernise are eroded and eventually neutralised by decaying inter-sectoral spillovers and falling mark-ups.

Finally, it is important to note that not only $\mu^M(\tilde{z})$ and $\eta^M(\tilde{z})$ are affected by \tilde{z} . Going through the same steps as above, we find that $\eta^T(0) > \eta^T(1)$ and $\mu^T(0) > \mu^T(1)$, such that the opportunity costs of technology adoption in form of the “replacement effect” familiar from Arrow (1962) are smaller for late rather than for early adopters. Reassuringly, we demonstrate in Appendix A.1 that the worsening of firms outside option is of second order, such that we always have $\pi^M(0) - \pi^T(0) \geq \pi^M(1) - \pi^T(1)$, which inevitably results in an incompletely industrialised equilibrium with some but not all firms adopting the modern technology.

In addition, Proposition 1 also suggests that a multiplicity of equilibria arises if labour is sufficiently scarce in the (world) economy, i.e. $L < \bar{L}(m)$.¹⁷ Figure 2b identifies parameter combinations of γ and f (depicted as green/yellow area) that support a multiplicity of equilibria, with one of the two possible equilibria featuring incomplete industrialisation and the respective other equilibrium being characterised by complete industrialisation. Focussing on a scenario, in which *all* firms are able to coordinate their individual technology upgrading decisions, we can

¹⁶Suppose condition (11) is violated. Firms in labour-rich countries then enjoy (initially) low costs, facing at the same time a relatively inelastic sectoral demands. As a consequence, technology upgrading is associated with falling wages, and as equilibrium wages $w(\tilde{z})$ fall to zero, consumers reach their saturation point, rendering the economy’s full-employment condition non-binding. To ensure non-saturation we, hence, focus on parameter constellations of γ and f for which wages $w(\tilde{z})$ are increasing in \tilde{z} we.

¹⁷Although, labour is the only factor of production in our model, we use the term “scarcity” to describe a country’s relative endowment with workers and firms, whose total mass – for the sake of simplicity – has been normalised to unity.

visualise indifference condition $\pi^M(0) = \pi^T(1)$ through $f_C(\gamma)$, which is depicted as solid, black curve in Figure 2. For parameter combinations of γ and $f < f_C(\gamma)$ coordination is sustainable. On the contrary, for combinations of γ and $f \geq f_C(\gamma)$ an equilibrium without industrialisation is preferred over a coordinated technology upgrade by all firms. For multiple equilibria to exist $f_C(\gamma) > f_L(\gamma)$ has to hold at least for some values of $\gamma \in (0, 1)$, whereas $f_L(\gamma)$ is equivalent to the last (traditional) firms' indifference condition $\pi^M(1) = \pi^T(1)$, which we depict as dashed, black curve in Figure 2. Intuitively, for combinations of γ and $f < f_L(\gamma)$ the last traditional firms will adopt the modern technology, while for parameter constellations of γ and $f \geq f_L(\gamma)$ the opposite is the case. Figure 2a depicts a labour-rich economy with $L \geq \bar{L}(m)$, in which $f_C(\gamma) < f_L(\gamma) \forall \gamma \in (0, 1)$. In Figure 2b a labour-scarce economy with $L < \bar{L}(m)$ is depicted. As we demonstrate in Appendix A.1, there always exist some values of $\gamma \in (0, 1)$ for which the existence of multiple equilibria can be established by $f_C(\gamma) > f_L(\gamma)$, given that $L < \bar{L}(m)$ holds.

Although the existence of multiple equilibria is established in the absence of an exogenously given wage premium $v > 1$ (cf. Murphy et al., 1989b), the rationale behind the multiplicity of equilibria is the same as in Section 2: For $1 - \gamma > f$, the adoption of the modern technology, even if unprofitable for individual firms, inevitably shifts out the aggregate demand of *all* sectors $z \in [0, 1]$. Since this positive demand externality is rationally ignored by individual firms, there is a systematic underinvestment in the adoption of the modern technology, which results in an incompletely instead of a completely industrialised equilibrium. By coordinating their investment decisions, firms are able to internalise the mutual beneficial demand spillovers, which renders a joint modernisation profitable, given that aggregate demand spillovers are sufficiently important.

Despite all the resemblance to Murphy et al. (1989b), there are some important differences to the case of asymmetric Bertrand competition with limit pricing from Section 2: With isoelastic demand, limit pricing implies a mark-up $\mu^M(\tilde{z}) = 1 - \gamma$, that is constant and decoupled from changes in the underlying wage rate. Hence, for aggregate demand spillovers to arise an exogenously given wage premium of $v > 1$ is required. Without this wage premium all income effects are channelled through firms' profits and, hence, through the income multiplier $A(\tilde{z}) = 1/[1 - \tilde{z}(1 - \gamma)] \geq 1$ in Eq. (8). As a consequence firms' decentralised technology upgrading decisions are perfectly aligned with the social planner's choice (consider Subfigure 1b for the case of $v = 1$), ruling out the existence of multiple equilibria. By allowing aggregate income to increase through other channels than through firms' profits, the wage premium $v > 1$ creates a situation in which modernisation, although individually unprofitable, is socially desirable for

the economy as a whole. Under Cournot competition, no exogenously given wage premium $v > 1$ is needed to create this pecuniary demand externality. Mark-ups $\mu^i(\tilde{z})$ in Table 1 are not constant and depend negatively on wages $w(\tilde{z})$. Firms rationally ignore that their technology investments, by increasing the wage and lowering the mark-ups, will limit the marginal firms' ability to appropriate the full returns to their technology investment. And, as a consequence, all firms, except for the first technology adopters, are faced with an endogenously emerging wage premium $w(\tilde{z})/w(0) > 1$, that gives rise to a pecuniary demand externality as in [Murphy et al. \(1989b\)](#). As an immediate implication of the endogenously emerging wage premium multiple equilibria in our model – unlike in [Murphy et al. \(1989b\)](#) – always materialise in the form of “incomplete industrialisation” versus “complete industrialisation”. A multiplicity of equilibria that is characterised by “no industrialisation” versus “complete industrialisation” can be ruled out, given that for the first technology adopter no pecuniary demand externality exists.

Also note that multiple equilibria only arise if labour is sufficiently scarce, i.e. $L < \bar{L}(m)$. Labour-scarce economies not only have high wages $w(\tilde{z})$ but also low mark-ups $\mu^i(\tilde{z})$ (see Table 1), which limits firms' ability to appropriate the (full) returns of their technology investments, creating a situation in which technology upgrading, although individually unprofitable, is socially desirable. In particular, we find that rather than through higher profits, captured by change in the multiplier $A(\tilde{z})/A(0)$, the efficiency gains from technology upgrading materialise in form of a steeply increasing wage premium $w(\tilde{z})/w(0) \geq 1$, causing a multiplicity of equilibria along the lines outlined above. On the contrary, in labour-rich economies with $L \geq \bar{L}(m)$, mark-ups are always sufficiently high for firms to cover the fixed cost of technology upgrading, even if wages are increasing as the modern technology is adopted sequentially by more and more firms. As we will explore in more detail below (cf. Subsection 4.3), the distribution of income in terms of wages $w(\tilde{z})$ and mark-ups $\mu^i(\tilde{z})$ (or alternatively in terms of profits $\pi^i(\tilde{z})$) not only depends on the size of the labour force L , but also on the number of firms m in specific sector. With a larger number of firms competition is tougher and mark-ups are lower, which limits firms ability to appropriate the (full) returns of their technology investments, leading to $\bar{L}'(m) > 0$ with $\bar{L}(m)$ being defined in Proposition 1.

4.2 Multiple Equilibria and Poverty Traps

For multiple equilibria to result in a poverty trap, which is characterised as a situation, in which an economy is stuck in the worse of two (or more) possible equilibria, we have to compare welfare across the different equilibria types, that we have identified in Proposition 1.

Proposition 2 *For $f < 1 - \gamma$, welfare under complete industrialisation is always higher than*

without industrialisation, i.e. $U(1) > U(0)$. For interior solution of $\tilde{z} \in (0, 1)$, welfare $U(\tilde{z})$ has at most one extremum, which is a maximum. Focussing on the parameter space (d), for which multiple equilibria exist, welfare $U(\tilde{z})$ in all equilibria with incomplete industrialisation is monotonically increasing in \tilde{z} under the sufficient condition $L \in (\underline{L}(m), \bar{L}(m))$.

Proof See Appendix A.2.

Intuitively, an equilibrium with complete industrialisation, i.e. $\tilde{z} = 1$, is always preferred over an equilibrium without industrialisation, i.e. $\tilde{z} = 0$, provided that the modern technology constitutes an actual improvement (i.e. the fix labour requirement F does not exceed the amount of labour $(1 - \gamma)L$ that is saved by implementing the new production technology). From the inspection of indirect utility

$$U[p(z), Y] = \frac{1}{2} \left\{ 1 - \frac{[\int_0^{\tilde{z}} p^M(\tilde{z}) dz + \int_{\tilde{z}}^1 p^T(\tilde{z}) dz - Y(\tilde{z})]^2}{\int_0^{\tilde{z}} [p^M(\tilde{z})]^2 dz + \int_{\tilde{z}}^1 [p^T(\tilde{z})]^2 dz} \right\}, \quad (12)$$

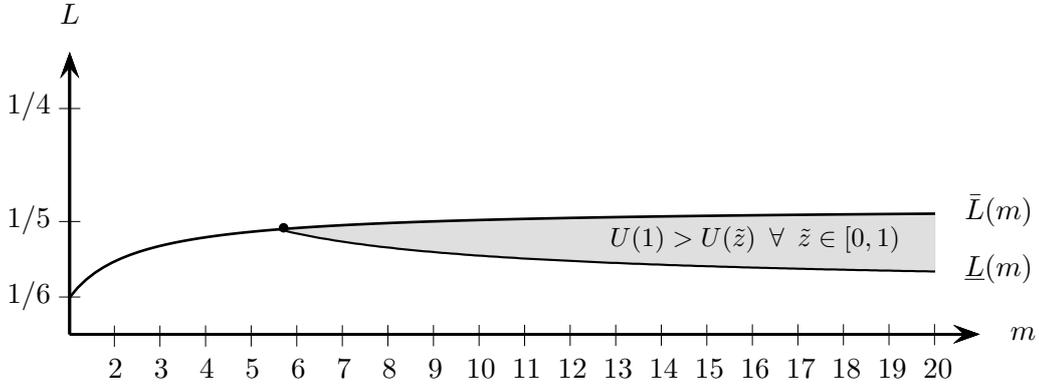
for which we can solve by substituting $x^M(\tilde{z}) \forall z \in [0, \tilde{z}]$ and $x^T(\tilde{z}) \forall z \in (\tilde{z}, 1]$ from Table 1 into the utility function Eq. (1), it follows that in a perfectly symmetric (featureless) economy welfare ($U(1)$ or $U(0)$, respectively) is proportional to real income ($Y(1)/p^M(1) = x^M(1)$ or $Y(0)/p^T(0) = x^T(0)$, respectively). Finally, to show that $U(1) > U(0)$ if $f < 1 - \gamma$, we use $w(\tilde{z})$ in Eq. (10) and evaluate $x^M(\tilde{z})$ and $x^T(\tilde{z})$ from Table 1 at $w(1)$ and $w(0)$, respectively.

Given that $U(1) > U(0)$, it might be tempting to conclude that welfare $U(\tilde{z})$ increases monotonically in \tilde{z} as more and more sectors adopt the modern technology. However, as we demonstrate in Appendix A.2, it is possible that $U(\tilde{z})$ has a maximum in $\tilde{z} \in (0, 1)$, which implies that welfare in an equilibrium with complete industrialisation $U(1)$ may be surpassed by welfare in an equilibrium with incomplete industrialisation $U(\tilde{z}) \forall \tilde{z} \in (0, 1)$. To understand the (potential) non-monotonicity in welfare $U(\tilde{z})$, we can again resort to direct utility in Eq. (12). For $\tilde{z} \in (0, 1)$ welfare not only depends on real income, reflecting the efficiency gains from technology upgrading, but also on the (uncentered) second moment of prices, which (conditional on real income) is associated with increasing utility, as individuals optimally adjust their consumption towards (relatively) cheaper goods (see also Neary, 2016). Unlike in an equilibrium with incomplete specialisation, there is no welfare-enhancing price heterogeneity in an equilibrium without or with complete industrialisation, such that welfare – conditional on real income – should be higher for interior solution of $\tilde{z} \in (0, 1)$.

For the multiple equilibria in parameter space (d) of Figure 2b to result in a poverty trap, we have to show that welfare in an incompletely industrialised equilibrium without coordinated technology upgrading is lower than welfare in a completely industrialised equilibrium with co-

ordinated technology upgrading. While the implicit determination of a sufficient condition for the existence of poverty traps is delegated to Appendix A.2, we depict in Figure 3 the parameter constraint $L > \underline{L}(m)$ for which *all* values of γ and f in parameter space (d) from Proposition 1 and Figure 2b are associated with $U(1) > U(\tilde{z}) \forall \tilde{z} \in [0, 1)$. Hence, for $L \in (\underline{L}(m), \bar{L}(m))$

Figure 3: *Technology Upgrading and Aggregate Welfare*



there always exist parameter combinations of γ and f for which an economy inevitably is trapped in a vicious circle of poverty, given that a (global) coordination of firms' technology upgrading decisions is likely to fail.

It is important to note that Proposition 2 formulates a *sufficient* condition for the existence of poverty traps, and that Figure 3 does not suggest that poverty traps do not exist for $L \leq \underline{L}(m)$ (including the case of autarky, i.e. $m = 1$). First, for $L \leq \min\{\underline{L}(m), \bar{L}(m)\}$ it is possible, that not the complete set but rather a subset of all parameter combinations of γ and f in parameter space (d) of Figure 2b are associated with $U(1) > U(\tilde{z}) \forall \tilde{z} \in [0, 1)$ and, hence, with a poverty trap.¹⁸ Second, even if $U(\tilde{z})$ is non-monotonic in \tilde{z} for all combinations of γ and f in parameter space (d) of Figure 2b, it is still possible that a poverty trap results. For $L \leq \min\{\underline{L}(m), \bar{L}(m)\}$ we then have $\lim_{\tilde{z} \rightarrow 1} U'(\tilde{z}) < 0$, such that combinations of γ and f which are close to $f_L(\gamma)$ in the parameter space (d) of Figure 2b most likely are associated with rather high values of \tilde{z} for which the multiplicity of equilibria does not result in a poverty trap as $U(\tilde{z}) > U(1)$. However, for combinations of γ and f which are closer to $f_C(\gamma)$ in the parameter space (d) of Figure 2b it is well possible that the corresponding value of \tilde{z} is sufficiently small to be associated with a poverty trap, that is characterised by $U(\tilde{z}) < U(1)$.

Summing up, we find that an economy that is caught in a poverty trap inevitably ends up

¹⁸In an interactive version of Figure 2, that is available from the authors upon request in form of a CDF (see also Fn. 14), we illustrate condition $f \gtrsim f_U(\gamma)$ from Appendix A.2, which is equivalent to $\lim_{\tilde{z} \rightarrow 1} U'(\tilde{z}) \gtrsim 0$, such that the economy inevitably ends up in a poverty trap for all combinations of γ and f in parameter space (d) of Figure 2b for which $f < f_U(\gamma)$ is fulfilled.

in a low-welfare equilibrium characterised by incomplete industrialisation, while a sustainable high-welfare equilibrium with complete industrialisation could be reached if firms would coordinate their technology choice (globally). Under the *sufficient* condition $L \in (\underline{L}(m), \bar{L}(m))$, we are always able to identify parameter combinations of $\gamma \in (0, 1)$ and $f \in (0, 1)$ that support the existence of a poverty trap, which – unlike in [Murphy et al. \(1989b\)](#) – neither requires the assumption of a closed economy nor the presence of an exogenously given wage premium.

4.3 International Trade and the Big Push

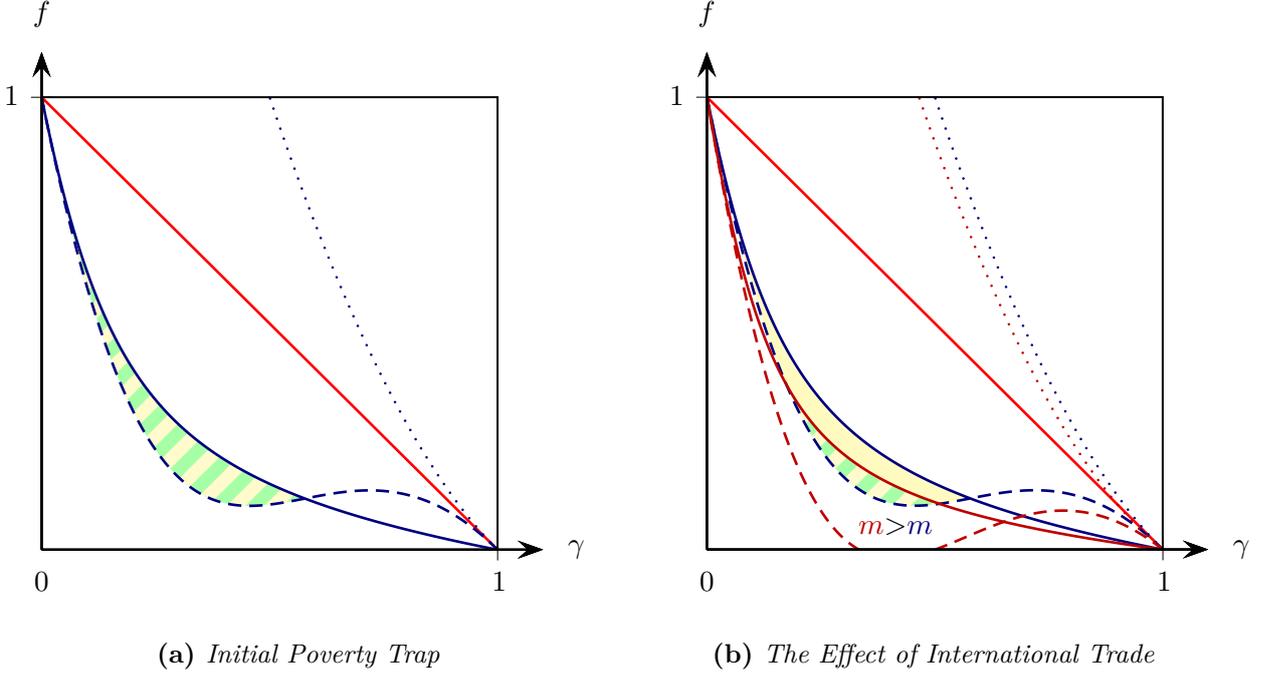
Having established the existence of poverty traps in the previous section, we now turn to a (global) economy, which initially is caught in a poverty trap with incomplete industrialisation. Is it possible to escape from the low-welfare equilibrium by allowing for more international trade, modelled through an increase in the number of trading partners m ?

Proposition 3 *An economy that initially is trapped in an poverty trap with incomplete industrialisation, does not reach the Pareto optimal high-welfare equilibrium with complete industrialisation by allowing for international trade with more partner countries m .*

Proof See Appendix [A.3](#).

To understand why international trade does not substitute for a “big push”, it is instructive to study [Figure 4](#), which illustrates the effect of international trade on an economy, that for parameter combinations of γ and f in the green/yellow coloured area of [Subfigure 4a](#) initially is caught in a poverty trap. Comparing in [Subfigure 4b](#) the equilibrium conditions *ex ante* (represented through dark blue curves) and *ex post* (represented through dark red curves) to a trade shock, suggests that parameter space (d), supporting multiple equilibria according to [Proposition 1](#), is shifted towards the origin. The impact of international trade on an economy, which, despite the existence of an alternative high-welfare equilibrium with complete industrialisation, initially is trapped in a low-welfare equilibrium with incomplete industrialisation then can be summarised as follows: After a trade shock the economy remains in an equilibrium with incomplete industrialisation. Thereby, the equilibrium is either unique (yellow area in [Figure 4b](#)) or the worse of two possible equilibria with the respective other equilibrium featuring complete industrialisation (green/yellow area in [Figure 4b](#)). It is important to note, that international trade not only fails in generating a big push that facilitates the transition to a high-welfare equilibrium with complete industrialisation. It also becomes more difficult and in some cases even impossible to reach the superior high-welfare equilibrium with complete industrialisation in other ways (e.g. through coordination). Finally, we also show in [Appendix A.3](#) that the

Figure 4: *International Trade and the Escape from Poverty*



$$\cdots f_F(\gamma) \geq f \Leftrightarrow \pi^M(0) \geq \pi^T(0) \quad - - f_L(\gamma) \geq f \Leftrightarrow \pi^M(1) \geq \pi^T(1) \quad - - f_C(\gamma) \geq f \Leftrightarrow \pi^M(1) \geq \pi^T(0)$$

curve $f = f_L(\gamma) \Leftrightarrow \pi^M(1) = \pi^T(1)$ shifts downward as m increases. Hence, for given values of γ and f , a rise in m will cause a decline in the share of industrialised sectors \tilde{z} . Provided that the parameter constraint $L \in (\underline{L}(m), \bar{L}(m))$ from Proposition 3 holds ex ante and ex post to the trade shock, falling values of \tilde{z} are then associated with less welfare as $U(1) > U(0)$ and $U'(\tilde{z}) > 0 \forall \tilde{z} \in [0, 1]$.

To explain why international trade, unlike in models with external increasing returns to scale (cf. Sachs and Warner, 1999; Trindade, 2005), appears to be more a boon than a blessing, it is important to understand, that the primal effect of an increase in the number of trading partners m is an intensified (global) competition, which lowers firms' mark-ups $\mu^i(\tilde{z})$ and ultimately is associated with an increase (decrease) in labour (profit) income.¹⁹ As mark-ups fall it becomes more difficult for firms to appropriate the full returns of their investment, while at the same time the pecuniary (inter-sectoral) demand externality is reinforced by increasing wages. Both partial effects reinforce a pre-existing circle of poverty and deprive the economy of its ability to reach the superior equilibrium with complete industrialisation. However, this is not the only difference to models of monopolistic competition with constant mark-ups and external increasing returns to scale (cf. Sachs and Warner, 1999; Trindade, 2005). As highlighted by Neary

¹⁹It is important to note that the effect of international trade goes beyond a pure competition effect, which intuitively becomes clear by comparing an increase in the number of trading partners $m \geq 1$ with an increase in the number of domestic firms $n \geq 1$. Unlike in the latter case, the increase of competitors in the former case always is accompanied by an proportional increase in market size L .

(2016), international trade between “featureless” economies (without inter-sectoral technology differences), does not change the Pareto efficient factor allocation in general oligopolistic equilibrium (cf. [Lerner, 1934](#)). As an immediate consequence, aggregate income in a completely industrialised high-welfare equilibrium does not depend on the number of trading partners m . Considering the same increase of m in models with external increasing returns to scale (cf. [Ethier, 1982](#)), we find that the effect of international trade is conceptually very similar to a direct increase in market size, which (almost by construction) translates into a higher aggregate income, thereby creating a big push.

In summary, more international trade is associated with a more competitive market environment, which has the consequence, that the quasi rents from technology upgrading are systematically undermined by shrinking mark-ups. As firms increasingly refuse to adopt the socially efficient modern technology, given that the private benefits are exceeded by the private costs, the vicious circle of poverty is reinforced and it becomes more difficult (and in some cases even impossible) to reach the Pareto efficient high-welfare equilibrium characterised by complete industrialisation.

5 Conclusion

By incorporating a binary technology choice into a general oligopolistic equilibrium with Cournot competition, we demonstrate the existence of multiple equilibria in a global economy. Thereby, our model not only refutes the popular misconception, that in an open economy insufficient (initial) demand becomes meaningless as an argument for economies to be trapped in low-income equilibria (cf. [Matsuyama, 1991](#); [Stiglitz, 1993](#)). We also demonstrate that if mark-ups are allowed to be non-constant, a multiplicity of equilibria can be generated without the notorious assumption of an exogenously given wage premium (cf. [Murphy et al., 1989b](#)). Within this richer framework three possible equilibrium types exist. As in the original “Big Push” model, our economy may end up in one of two polar cases, featuring either no or complete industrialisation. However, in addition, there also is an equilibrium with incomplete industrialisation, in which the modern technology is adopted by firms in some yet not in all sectors. If labour demand is sufficiently high to support high wages and low mark-ups, our model then features a multiplicity of equilibria, characterised by incomplete versus complete industrialisation. Thereby, the rationale for multiple equilibria is the same as in [Murphy et al. \(1989b\)](#): Due to an endogenously rising wage (premium) firms can not fully appropriate the returns from technology upgrading. Since firms rationally ignore the pecuniary demand externality that arises from paying higher wages, the decentralised equilibrium features a systematic underin-

vestment into in the modern technology. International trade, by strengthening the competition among firms, reduces the mark-ups and, hence, the firms' ability to appropriate the returns to their technology investments, which aggravates the underinvestment problem and reinforces the vicious circle of poverty.

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A Appendix

A.1 Proof of Proposition 1

Non-saturation and full employment is guaranteed by $w(\tilde{z}) > 0$. We hence assume $L < m/(1+m)$, which ensures $w(0) > 0$ as well as $L < [m/(1+m)](1-\gamma)/\{(1-f)/\gamma - \gamma\}$, which guarantees that $w'(\tilde{z}) > 0$. Together, we have $L < [m/(1+m)] \min\{1, (1-\gamma)/((1-f)/\gamma - \gamma)\}$. Moreover, $L < [m/(1+m)] \min\{1, (1-\gamma)/((1-f)/\gamma - \gamma)\}$ is equivalent to $g(\gamma) < f$, where²⁰

$$g(\gamma) = g(\gamma; m, L) \equiv \frac{(1-\gamma)[(1+m)(1+\gamma) - m\gamma/L]}{(1+m)}. \quad (\text{A.1})$$

Substituting $Y(\tilde{z})$ from Eq. (7) back into $\pi^T(\tilde{z})$ and $\pi^M(\tilde{z})$ from Eq. (6) yields

$$\pi^T(0) = \frac{[1-w(0)]}{(1+m)}L \quad \text{and} \quad \pi^T(1) = \frac{[1-w(1)]^2}{(1+m)[1-\gamma w(1)]} \frac{(L-F)}{\gamma}, \quad (\text{A.2})$$

as well as

$$\pi^M(0) = \frac{[1-\gamma w(0)]^2}{(1+m)[1-w(0)]}L - Fw(0) \quad \text{and} \quad \pi^M(1) = \frac{[1-\gamma w(1)]}{(1+m)} \frac{(L-F)}{\gamma} - Fw(1), \quad (\text{A.3})$$

²⁰To save on notation, parameters m and L are suppressed, if the dependence is clear from the context.

which are evaluated at $\tilde{z} = 0$ and $\tilde{z} = 1$, respectively. Substituting $w(0)$ from Eq. (10) into $\pi^M(0)$ and $\pi^T(0)$ from Eqs. (A.3) and (A.2) allows us to solve for

$$f_F(\gamma) = f_F(\gamma; m, L) \equiv \frac{(1+m)(1-\gamma^2) + (1-\gamma)^2 m/L}{(1+m)^2}, \quad (\text{A.4})$$

with $f_F(\gamma) \Leftrightarrow f$ being equivalent to $\pi^M(0) \Leftrightarrow \pi^T(0)$. Substituting $w(1)$ from Eq. (10) into $\pi^M(1)$ and $\pi^T(1)$ from Eqs. (A.3) and (A.2) allows us to solve for

$$f_L(\gamma) = f_L(\gamma; m, L) \equiv \frac{(1-\gamma)[(1+m)(1+\gamma) - m\gamma(1-\gamma)/L]}{(1+m)(1+m\gamma^2)}, \quad (\text{A.5})$$

with $f_L(\gamma) \Leftrightarrow f$ being equivalent to $\pi^M(1) \Leftrightarrow \pi^T(1)$. Finally, substituting $w(0)$ and $w(1)$ from Eq. (10) into $\pi^M(1)$ and $\pi^T(0)$ from Eqs. (A.3) and (A.2) allows us to solve for

$$f_C(\gamma) = f_C(\gamma; m, L) \equiv \frac{\sqrt{(1+m)^2 - 2m(m-1)\gamma/L - m(4-m/L^2)\gamma^2} + m(1-\gamma/L) - 1}{2m}, \quad (\text{A.6})$$

with $f_C(\gamma) \Leftrightarrow f$ being equivalent to $\pi^M(1) \Leftrightarrow \pi^T(0)$. At first, we show that for the relevant parameter space $f_F(\gamma) \geq \max\{f_L(\gamma), f_C(\gamma)\}$. For this purpose it is convenient to consider the cases $L \geq 1/(1+m)$ and $L < 1/(1+m)$ separately. For $L < 1/(1+m)$ the functions $f_F(\gamma)$ and $f_L(\gamma)$ have a single intersection point in $\gamma \in [0, 1]$ at $\gamma = 1$. The same holds true for the functions $f_F(\gamma)$ and $f_C(\gamma)$. Moreover, we have $f_C(0) = (1+m+m/L)/(1+m)^2 > 1 = f_L(0) = f_C(0)$, which implies that we have $f_F(\gamma) \geq \max\{f_L(\gamma), f_C(\gamma)\}$ for the relevant parameter space $\gamma \in [0, 1]$. Turning to the parameter range $L \geq 1/(1+m)$, we find that in addition to $f_F(1) = f_L(1) = f_C(1) = 0$ there is a second intersection point $f_F(\gamma_0(m, L)) = f_L(\gamma_0(m, L)) = f_C(\gamma_0(m, L)) = g(\gamma_0(m, L)) = (1-2L)/L[(1-L)m-L] \in [0, 1]$ for $\gamma_0(m, L) = [1 - (1+m)L]/[L - (1-L)m]$ with $\gamma_0(m, L) \Leftrightarrow 0$ for $L \Leftrightarrow 1/(m+1)$. Finally, taking into account $f'_F(1) = f'_L(1)$, $f''_F(1) > f''_L(1)$, and $f'_F(1) < f'_C(1)$, we have $f_F(\gamma) \geq \max\{f_L(\gamma), f_C(\gamma)\}$ for the relevant parameter space $\gamma \in [\gamma_0(m, L), 1]$.

In the next step we establish that $f_C(\gamma)$ and $f_L(\gamma)$ intersect twice in $\gamma \in (\max\{0, \gamma_0(m, L)\}, 1)$ if and only if $L < \bar{L}(m)$ with

$$\bar{L}(m) \equiv \frac{m}{2[m + \sqrt{2m(1+m)}}. \quad (\text{A.7})$$

Note that $f_C(\gamma)$ and $f_L(\gamma)$ intersect at most five times. In addition to the intersection points

at $\gamma = 0$ and $\gamma = 1$, we have $\gamma_0(m, L) = [1 - L(1 + m)]/[L - (1 - L)m]$ as well as

$$\gamma_1(m, L) = \frac{m(m-1) - (m+1)\sqrt{m[m - 4mL - 4(m+2)L^2]}}{2m[m + (m+1)L]}, \quad (\text{A.8})$$

$$\gamma_2(m, L) = \frac{m(m-1) + (m+1)\sqrt{m[m - 4mL - 4(m+2)L^2]}}{2m[m + (m+1)L]}, \quad (\text{A.9})$$

with $\gamma_1(m, L) \leq \gamma_2(m, L) \forall L \in (0, \bar{L}(m)]$. For $\gamma_1(m, L)$ and $\gamma_2(m, L)$ to exist, the discriminant in both expressions has to be non-negative, which is the case for $L \leq \bar{L}(m)$. Note that for $L = \bar{L}(m)$ we have $\gamma_1(m, L) = \gamma_2(m, L)$, which correspond to a tangency point between $f_C(\gamma)$ and $f_L(\gamma)$. Finally, using the solution for $\gamma_1(m, L)$ and $\gamma_2(m, L)$, it can be shown that $\gamma_1(m, L), \gamma_2(m, L) \in (\max\{0, \gamma_0(m, L)\}, 1)$.

In the last step we establish that $g(\gamma) \leq \min\{f_L(\gamma), f_C(\gamma)\}$. Again it is helpful to consider the cases $L \geq 1/(1+m)$ and $L < 1/(1+m)$ separately. For $L < 1/(1+m)$ the functions $g(\gamma)$ and $f_L(\gamma)$ as well as the functions $g(\gamma)$ and $f_C(\gamma)$ intersect twice in $\gamma \in [0, 1]$ at $\gamma = 0$ and $\gamma = 1$. Thereby, $g'(1) > f'_L(1)$ and $g'(1) > f'_C(1)$ guarantee that $g(\gamma) \leq \min\{f_L(\gamma), f_C(\gamma)\} \forall \gamma \in [0, 1]$ if $L < 1/(1+m)$. For $L \geq 1/(1+m)$ we focus on the relevant parameter space $\gamma \in [\gamma_0(m, L), 1]$ and find that the functions $g(\gamma)$ and $f_L(\gamma)$ as well as the functions $g(\gamma)$ and $f_C(\gamma)$ intersect twice in $\gamma \in [\gamma_0(m, L), 1]$ at $\gamma = \gamma_0(m, L)$ and $\gamma = 1$. Again, $g'(1) > f'_L(1)$ and $g'(1) > f'_C(1)$ guarantee that $g(\gamma) \leq \min\{f_L(\gamma), f_C(\gamma)\} \forall \gamma \in [\gamma_0(m, L), 1]$ if $L \geq 1/(1+m)$. ■

A.2 Proof of Proposition 2

Before analysing internal solutions of $U(\tilde{z})$ for $\tilde{z} \in (0, 1)$, we focus at the corner solutions at $\tilde{z} = 0$ and $\tilde{z} = 1$. In an equilibrium in which the modern technology is adopted either by no firm (i.e. $\tilde{z} = 0$) or by all firms (i.e. $\tilde{z} = 1$), we have $p(z) = p(0)$ and, $p(z) = p(1)$, respectively. It follows from Eq. (12) that indirect utility only depends on real income, such that $\tilde{U}(1) > \tilde{U}(0)$ may equivalently expressed as $[Y(1)/p^M(1)]/[Y(0)/p^T(0)] = x^M(1)/x^T(0) = (1-f)/\gamma > 1$. Thus, for the relevant parameter space $f < 1 - \gamma$ we have $U(1) > U(0)$.

We now consider $U(\tilde{z})$ for $\tilde{z} \in (0, 1)$. Using $p^M(\tilde{z}) \forall z \in [0, \tilde{z})$ and $p^T(\tilde{z}) \forall z \in [\tilde{z}, 1]$ from Table 1 together with $w(\tilde{z})$ from Eq. (10) in Eq. (12) allows us to derive

$$U(\tilde{z}) = \frac{L(1 - \tilde{z}f)\{L + 2[1 - (1 - \gamma)\tilde{z}]\}}{2[1 - (1 - \gamma^2)\tilde{z}]} + \frac{m(m+2)(1 - \gamma)^2(1 - \tilde{z})\tilde{z}}{2(m+1)^2[1 - (1 - \gamma^2)\tilde{z}]}. \quad (\text{A.10})$$

In the following we demonstrate that $U(\tilde{z})$ has at most one extremum in $\tilde{z} \in (0, 1)$, which is a maximum. Note that $U'(\tilde{z}) = 0$ has two solutions at $\tilde{z}_1 = (1 - \gamma\Gamma)/(1 - \gamma^2)$ and $\tilde{z}_2 =$

$(1 + \gamma\Gamma)/(1 - \gamma^2)$, with $\Gamma = \sqrt{\Gamma_1\Gamma_2} \in (0, 1)$ and

$$\Gamma_1 \equiv \frac{m(1 - \gamma) - (m + 1)\{[(1 - f)/\gamma] - \gamma\}L}{m(1 - \gamma) - (m + 1)fL} \in (0, 1), \quad (\text{A.11})$$

$$\Gamma_2 \equiv \frac{(m + 2)(1 - \gamma) - (m + 1)\{[(1 - f)/\gamma] - \gamma\}L}{(m + 2)(1 - \gamma) - (m + 1)fL} \in (0, 1). \quad (\text{A.12})$$

Since $\tilde{z}_2 > 1$, there exists at most one extremum in $\tilde{z} \in (0, 1)$.

We now demonstrate, that if the extremum \tilde{z}_1 falls into the relevant parameter space $\tilde{z} \in (0, 1)$, it has to be a maximum. Note that $\lim_{\tilde{z} \rightarrow 0} U'(\tilde{z}) > 0$ may be equivalently stated as $f < f_U^0(\gamma)$ with

$$f_U^0(\gamma) \equiv \frac{(1 - \gamma)[2(m + 1)^2L\gamma + m(m + 2)(1 - \gamma) - (m + 1)^2L^2(1 + \gamma)]}{2(m + 1)^2L(1 - L)}. \quad (\text{A.13})$$

It is easily verified that $f_U^0(\gamma) \geq f_C(\gamma) \forall \gamma \in (0, 1)$ if $L < \bar{L}(m)$. Since $f \leq f_C(\gamma)$ is a necessary condition for multiple equilibria to exist, we know that for the relevant parameter set $\lim_{\tilde{z} \rightarrow 0} U'(\tilde{z}) > 0$ has to hold. Moreover, we know from above that $U(1) > U(0)$ for $f < 1 - \gamma$, such that we can safely conclude that if \tilde{z}_1 falls into the relevant parameter space $\tilde{z} \in (0, 1)$, it has to be a maximum.

Finally, to complete the proof, we formulate a sufficient condition for $\tilde{z}_1 \geq 1$, such that $U(1) \geq U(\tilde{z}) \forall \tilde{z} \in [0, 1]$. Note that $\tilde{z}_1 \geq 1$ if $\gamma \leq \Gamma$, which may equivalently expressed as $f \leq f_U(\gamma)$ with

$$f_U(\gamma) \equiv \frac{L - \gamma(1 - \gamma + \gamma^2)}{L(1 + \gamma^2)} + \frac{\gamma\sqrt{1 + \gamma\{3 - 2(m + 1)^2L + (m + 1)^2L^2 + m(m + 2) - (2 - \gamma)\gamma\} - 2}}{(m + 1)L(1 + \gamma^2)} \quad (\text{A.14})$$

It follows from the inspection of $f'_U(\gamma)$ that $f_U(\gamma)$ has at most three extrema. Accounting for $f_U(0) = 1 > f_U(1) = 0$ as well as for $f'_U(0) < 0$ and $f'_U(1) < 0$, it becomes clear that at most two of these three extrema can fall into the parameter range $\gamma \in (0, 1)$. From above we know that $f_C(0) = 1 > f_C(1) = 0$, and that $f'_C(\gamma) < 0 < f'_C(\gamma) \forall \gamma \in [0, 1]$. Furthermore, we have $f'_U(1) < f''_C(1)$ as well as $f'_U(0) = f'_C(0)$ and $f''_U(0) > f''_C(0) \forall L \in (1/(m + 1), m/(m + 1))$. Hence, if there is a solution $\underline{L}(m)$ to the system of equations $f_U(\gamma^*(L, m)) = f_C(\gamma^*(L, m))$ and $f'_U(\gamma^*(L, m)) = f'_C(\gamma^*(L, m))$, there exists a unique tangency point $\gamma^*(L, m)$ between $f_U(\gamma)$ and $f_C(\gamma)$, implying $f_U(\gamma) \geq f_C(\gamma) \forall \gamma \in [0, 1]$. We plot $\underline{L}(m)$ in Figure 3, and it is easily verified that $\bar{L}(m), \underline{L}(m) \in (1/(m + 1), m/(m + 1))$. ■

A.3 Proof of Proposition 3

Focussing only on parameter values for which multiple equilibria exist (e.g. $L < \bar{L}(m)$), we have to show that an increase in the number of trading partners m does not result in a transition from an equilibrium with incomplete industrialisation to an equilibrium with complete industrialisation. Inspecting Figure 2b and recalling the definition of $f_L(\gamma; m, L)$ and $f_C(\gamma; m, L)$ from Eqs. (A.5) and (A.6), it is clear that starting out from a multiplicity of equilibria an increase in m does not cause a transition from an equilibrium with incomplete industrialisation to an equilibrium with complete industrialisation if $f_L(\gamma; m, L)$ and $f_C(\gamma; m, L)$ are both weakly decreasing in m .

At first we establish $\partial f_C(\gamma; m, L)/\partial m \leq 0 \quad \forall \gamma \in (0, 1)$. It can be shown that $\partial f_C(\gamma; m, L)/\partial m > 0 \quad \forall \gamma \in (0, 1)$ is incompatible with $L \in (0, \bar{L}(m))$. Due to proof by contradiction, it hence follows that $f_C(\gamma; m, L)$ is weakly decreasing in m for all $\gamma \in (0, 1)$.

We now turn to $f_L(\gamma; m, L)$. Let us define $L_0(m) \equiv (3 - 2\sqrt{2})m/(m + 1) \in (0, \bar{L}(m))$. Then for $L \in (0, L_0(m))$, the function $f_L(\gamma; m, L)$ has two intersection points with the abscissa at

$$\gamma_1^0(m, L) \equiv \frac{m - (m + 1)L - \sqrt{[m - (m + 1)L]^2 - 4m(m + 1)L}}{2m} \in (0, 1), \quad (\text{A.15})$$

$$\gamma_2^0(m, L) \equiv \frac{m - (m + 1)L + \sqrt{[m - (m + 1)L]^2 - 4m(m + 1)L}}{2m} \in (0, 1), \quad (\text{A.16})$$

with $\gamma_1^0(m, L) \leq \gamma_2^0(m, L) \quad \forall L \in (0, L_0(m))$. At $L = L_0(m)$ the function $f_L(\gamma; m, L)$ has a unique tangency point at $\gamma_1^0(m, L_0(m)) = \gamma_2^0(m, L_0(m)) = [m - (m + 1)L]/2m$. Finally, for $L \in (L_0(m), \bar{L}(m))$ we have $f_L(\gamma; m, L) > 0 \quad \forall \gamma \in [0, 1)$ and $f_L(\gamma; m, L)|_{\gamma=1} = 0$. It is easily verified that $\partial f_C(\gamma; m, L)/\partial m > 0 \quad \forall \gamma \in (0, 1)$ is incompatible with $L \in [L_0(m), \bar{L}(m))$. Due to proof by contradiction, it hence follows that $f_C(\gamma; m, L)$ is weakly decreasing in m for all $\gamma \in (0, 1)$ as long as $L \in [L_0(m), \bar{L}(m))$. Taking into account that $\partial f_C(\gamma; m, L)/\partial m < 0$, it is clear that for the parameter range $L \in [L_0(m), \bar{L}(m))$ an increase in m is associated with a downward shift in $f_C(\gamma; m, L)$ and $f_L(\gamma; m, L)$. As a consequence, we find that parameter combinations of γ and f , which *ex ante* to the increase in m were associated with a multiplicity of equilibria, i.e. $\pi^M(0) > \pi^T(0) \wedge \pi^M(1) < \pi^T(1) \wedge \pi^M(1) > \pi^T(0)$, are *ex post* to the increase in m associated with one of three possible equilibria types: a unique equilibrium characterised by no industrialisation, i.e. $\pi^M(0) < \pi^T(0) \wedge \pi^M(1) < \pi^T(1) \wedge \pi^M(1) < \pi^T(0)$, a unique equilibrium characterised by incomplete industrialisation, i.e. $\pi^M(0) > \pi^T(0) \wedge \pi^M(1) < \pi^T(1) \wedge \pi^M(1) < \pi^T(0)$, or (as before) by a multiplicity of equilibria with $\pi^M(0) > \pi^T(0) \wedge \pi^M(1) < \pi^T(1) \wedge \pi^M(1) > \pi^T(0)$.

We now turn to the parameter range $L \in (0, L_0(m))$. Let us define $\hat{L}(m) \equiv m/[2 + m(m + 3)] \in$

$(0, L_0(m))$, such that $L \Leftrightarrow \hat{L}(m)$ is equivalent to $\gamma_1(m, L) \leq 0$. It is easily verified that $\partial f_C(\gamma; m, L)/\partial m > 0 \forall \gamma \in (0, \gamma_1(m, L)]$ is incompatible with $L \in (\hat{L}(m), L_0(m))$. Due to proof by contradiction, it hence follows that $f_L(\gamma; m, L)$ is weakly decreasing in m for all $\gamma \in (0, \gamma_1(m, L)]$ as long as $L \in (\hat{L}(m), L_0(m))$. Taking into account that $\partial f_C(\gamma; m, L)/\partial m < 0$ implies that $f_L(\gamma; m, L)|_{\gamma=\gamma_1(m, L)} = f_C(\gamma; m, L)|_{\gamma=\gamma_1(m, L)}$ declines in m . Note that $\partial \gamma_2(m, L)/\partial m \leq 0$ is incompatible with $L \in (0, L_0(m))$. Proof by contradiction then implies $\partial \gamma_2(m, L)/\partial m > 0 \forall L \in (\hat{L}(m), L_0(m))$. Taking into account $\partial f_C(\gamma; m, L)/\partial m < 0$ and $\partial f_C(\gamma; m, L)/\partial \gamma < 0$, it follows that $f_L(\gamma; m, L)|_{\gamma=\gamma_2(m, L)} = f_C(\gamma; m, L)|_{\gamma=\gamma_2(m, L)}$ declines in m . Finally, given that $\partial f_C(\gamma; m, L)/\partial m < 0$, we find that parameter combinations of γ and f , which *ex ante* to the increase in m were associated with a multiplicity of equilibria, i.e. $\pi^M(0) > \pi^T(0) \wedge \pi^M(1) < \pi^T(1) \wedge \pi^M(1) > \pi^T(0)$, are *ex post* to the increase in m associated with one of three possible equilibria types: a unique equilibrium characterised by no industrialisation, i.e. $\pi^M(0) < \pi^T(0) \wedge \pi^M(1) < \pi^T(1) \wedge \pi^M(1) < \pi^T(0)$, a unique equilibrium characterised by incomplete industrialisation, i.e. $\pi^M(0) > \pi^T(0) \wedge \pi^M(1) < \pi^T(1) \wedge \pi^M(1) < \pi^T(0)$, or (as before) by a multiplicity of equilibria with $\pi^M(0) > \pi^T(0) \wedge \pi^M(1) < \pi^T(1) \wedge \pi^M(1) > \pi^T(0)$.

Finally, we turn to parameter range $L \in (0, \hat{L}(m)]$ for which $\gamma_1(m, L) \leq 0$. From above we know that $\partial \gamma_2(m, L)/\partial m > 0 \forall L \in (0, \hat{L}(m)]$, which together with $\partial f_C(\gamma; m, L)/\partial m < 0$ and $\partial f_C(\gamma; m, L)/\partial \gamma < 0$ implies that $f_L(\gamma; m, L)|_{\gamma=\gamma_2(m, L)} = f_C(\gamma; m, L)|_{\gamma=\gamma_2(m, L)}$ declines in m . Since $f_C(\gamma; m, L) > f_L(\gamma; m, L) \forall \gamma \in (0, \gamma_2(m, L))$, we find that parameter combinations of γ and f , which *ex ante* to the increase in m were associated with a multiplicity of equilibria, i.e. $\pi^M(0) > \pi^T(0) \wedge \pi^M(1) < \pi^T(1) \wedge \pi^M(1) > \pi^T(0)$, are *ex post* to the increase in m associated with one of three possible equilibria types: a unique equilibrium characterised by no industrialisation, i.e. $\pi^M(0) < \pi^T(0) \wedge \pi^M(1) < \pi^T(1) \wedge \pi^M(1) < \pi^T(0)$, a unique equilibrium characterised by incomplete industrialisation, i.e. $\pi^M(0) > \pi^T(0) \wedge \pi^M(1) < \pi^T(1) \wedge \pi^M(1) < \pi^T(0)$, or (as before) by a multiplicity of equilibria with $\pi^M(0) > \pi^T(0) \wedge \pi^M(1) < \pi^T(1) \wedge \pi^M(1) > \pi^T(0)$. ■