Trade and Growth Revisited: Managing to Converge, Agreeing to Diverge

Marc-Andreas Muendler*

University of California, Berkeley and

Pontifícia Universidade Católica do Rio de Janeiro

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Abstract

This paper revisits the impact of trade liberalization on domestic growth under static and dynamic increasing returns to scale. The model embraces features of both classical and new growth and trade theories, allows for knowledge accumulation, and integrates several strains of thought in a general equilibrium with two regions. In contrast to previous work, the model shows that international convergence of growth rates can occur despite the fact that the less developed region specializes in low-growth sectors. This is due to a distortion of the Ricardian or Heckscher-Ohlin type specialization forces through monopolistic competition. By participating in intraindustry trade, less developed regions can thus manage to converge. On the normative side, the model clarifies that repeated static gains from free trade weigh so heavily that a welfare-maximizing developing country may choose to give up modern sectors and to grow more slowly. It may agree to diverge in order to exploit the gains from trade, but it can manage to converge through participating in intraindustry trade.

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If a pure trade theorist were to advise a country today about whether, when and to what extent it should open up to free trade, she would have to reconcile a large and partly contradictory array of results. An advisor who wanted to rely on the Ricardian motive for free trade would recommend liberalization unconditionally.

*E-mail: muendler@econ.berkeley.edu (URL: http://socrates.berkeley.edu/~muendler/). I am greatful to Pranab K. Bardhan, David Romer, Chris Shannon, and participants at the Development Workshop 2000, Berkeley for helpful comments and suggestions.

Open up to trade, she would conclude, no matter what your production technologies look like, world markets will start to work so that your comparatively more efficient sectors will become export industries—and your national economy will be better off in the aggregate. An advisor who has a static Heckscher-Ohlin model in mind would argue on very similar grounds. Liberalize no matter what your factor endowments look like, world markets will start to work so that your industries which make relatively more use of your relatively more abundant factors will become export industries—and again, your national economy will be better off in the aggregate. An advisor who got to admire new trade theories would be inclined to argue: irrespective of what the rest of your economy does, if your consumers or firms care about varieties of goods, open up to trade and they will be better off because they benefit from the added choice of international varieties. Here, things already become difficult because the location of industries producing the varieties is theoretically indeterminate in some new trade models, but may matter. Finally, an advisor who adheres to new growth theory will warn: be careful. If you liberalize, but the trade pattern develops in the wrong direction, your industries specialize mainly in low-innovation sectors and you may be worse off after liberalization. If you cannot rapidly implement knowledge that is created elsewhere, you may become locked into low-tech production and that forever. After all, the advisor won't know.

This paper sets out to develop a simple but comprehensive theoretical framework that is intended to serve as a baseline model. The model will allow for the four sources and consequences of specialization that an economist such as the one above has in mind: international productivity gaps, differences in factor endowments, benefits from variety, and dynamic externalities from knowledge creation. In this model, learning-by-doing externalities will be the source of productivity growth. I will keep the model simple by assuming explicit functional forms. It may not seem insightful at first to model so much. As wisdom tells us, understanding is sharpened when we isolate effects instead of mixing them. However, once we want to understand the strength of some causes as compared to others, a more comprehensive approach is key.

The current model adds an explicit welfare analysis to growth theory. While it is convenient, and mostly correct for closed economies, to assert that higher growth means faster welfare increases, the relationship is different for open economies and worth to keep in mind. The long-known but sometimes overlooked reason is that open economies benefit from an improvement in their terms of trade when growing more slowly than their trading partners. In addition, repeated static gains from free trade can sum up to vast dynamic gains and easily outweigh dynamic losses from slower growth.

In addition, integrating various ingredients of trade and growth theory will show that their interplay can produce previously unexpected results. So far, researchers have mostly argued that diverging growth rates would result when dynamic externalities in factor accumulation or productivity change are present. This need not be the case. Eicher (1999) has shown in a setting of human capital accumulation that convergence in growth rates (β-convergence) may in fact come about. This paper takes a further step and argues, using simple closed-form solutions, that convergence can arise in many standard models of trade and growth under imperfect competition, including Romer's (1990) seminal paper.

Before turning to the specifics of the model in section 2, I will devote section 1 to a brief summary of the vast body of related literature. Section 3 spells out the unique autarky and the unique free-trade equilibrium. Section 4 analyzes the dynamics of the 'global economy' and the technology gap between rich and poor regions. Section 5 investigates under what conditions free trade is desirable for a less developed country that has to specialize in low-growth sectors. Section 6 concludes.

1 Related Literature

Krueger (1997) states in a review of the past decades of (neo-classical) trade theory and its policy implementation in LDCs:

> It is generally believed that import substitution at a minimum outlived its usefulness and that liberalization of trade and payments is crucial for both industrialization and economic development. While other policy changes also are necessary, changing trade policy is among the essential ingredients if there is to be hope for improved economic performance.

Empirical cross-country studies investigated this and related conjectures (Wolf 1993, Ben-David 1993, Sachs and Warner 1995, Helliwell 1996). Sachs and Warner (1995), for example, regress growth rates on several explanatory variables in a cross-country study and conclude to have "found strong evidence that protectionist trade policies reduce over-all growth when controlling for the other variables." Sachs and Warner, like many others in this literature, measure the degree of openness of an economy with a crude index number that not only involves indicators of trade barriers but also of several other factors relating to the financial aspects of openness, and possibly domestic variables. It remains unclear what these indices measure, and it is even less clear whether any policy recommendation could be based on them. This and other shortcomings have spawned strong criticism (see, e.g. Rodríguez and Rodrik 2000). Rodrik (1999) expresses a different view:

> Now that outward-orientation is the norm, there is excessive faith in what openness can accomplish. Early on, planning models emphasized capital accumulation at the expense of price incentives and the role of markets. Today the importance of investment is consistently downplayed. ... Governments and policy advisors alike have to stop thinking of international economic integration as an end itself. Developing nations have to engage the world economy on their own terms, not on terms set by global markets or multilateral institutions.

From a theoretical point of view, the question what impact trade has on growth has been reopened from mainly two perspectives during the last decade and a half—from the perspectives of endogenous trade theory and regional economics. Endogenous growth theory seems to make certain patterns of globalization little desirable under certain conditions. Young (1991), Stokey (1991) and Peletier (1998) show that trade liberalization may inhibit learning by doing and knowledge creation in less developed countries (LDCs). The reason is that liberalization could induce LDCs to specialize in product lines where the learning potential has been largely exhausted. Similarly, Xie (1999) shows for a Leontief production technology with intermediate inputs that there can be several, partly offsetting effects of trade on growth. Depending on the relative strength of the forward and backward linkages, trade may harm or spur growth.

Another line of argument relates to the fact that industries with economies of scale tend to cluster in few locations in order to exploit the increasing returns. Krugman and Venables (1995) argue that, when transportation costs and tariffs fall, manufacturers will relocate to a core region where initial demand happens to be high. A periphery will evolve and suffer income losses. This effect can be aggravated when innovation is endogenous (Martin and Ottaviano 1999), but can be partly offset by immobile labor because wages will differ between regions (Puga 1999). Similarly, Matsuyama (1996) shows how a world divided in rich and poor evolves when there are agglomeration effects and countries trade.

The present paper shows that under certain conditions—such as strong monopoly power in the innovative sector and little use of the key factor to growth in technologically 'old' sectors—monopolistic competition can make some of the negative effects of trade fade. The reason is that monopolistic competition distorts the old-style specialization forces. To my knowledge, the first author to observe this phenomenon is Eicher (1999). The present paper suggests conditions under which this type of convergence occurs. A variety of models including Romer's (1990) model share such convergence features but economies with perfect competition cannot exhibit it. The model also clarifies, beyond a mere positive analysis, that we understate the welfare gains from trade considerable when focusing on output growth instead of welfare change.

2 The Model

There are two regions, call them 'North' and 'South' for simplicity. Both regions employ two homogeneous factors of production, capital and skilled labor. In order to focus on effects of commodity trade, labor is assumed to be perfectly mobile within one region but immobile across borders.The second factor, capital or land, is assumed to be internationally immobile, too, for the time being. There are two sectors in each region, one 'traditional' and one 'modern' sector. For convenience, I will refer to the traditional sector as agriculture. This sector makes relatively intensive use of capital (or land). The second sector is manufacturing, making relatively intensive use of skilled labor. It heavily relies on engineering services and software creation, say. All productivity growth stems from the latter sector. The idea is that workers in manufacturing are learning by doing. Their knowledge then benefits the entire economy, as workers can freely change their employment within a region. In agriculture, however, these learning-by-doing effects are largely exhausted.

The economies of each region are endowed with fixed amounts of labor L^i and capital K^i.[1] Consumers are the same everywhere. Their preferences are homothetic. Demand for the agricultural good is standard, but consumers care about varieties in their demand for the 'modern' goods. At every income level, they prefer adding another variety to consuming more of the same varieties.

2.1 Production

Let the regions North and South be denoted by $i = N, S$. Then the agricultural sector in region i produces X^i with a Cobb-Douglas technology at time t:

$$X^i(t) = \left[A^i(t)L^i_X(t)\right]^\gamma \left[K^i(t)\right]^{1-\gamma}, \qquad \gamma \in (0, 1). \tag{1}$$

[1] Earlier drafts of this paper have allowed for capital to be accumulated over time, without much change for the main results.

The variable A^i denotes the economy-wide labor productivity. L^i_X is the number of region i's workers employed in sector X^i. The product of labor with its efficiency A^iL^i can also be thought of as a stock of skills or human capital, justifying the assumption that labor here means skilled labor. K^i denotes capital employed in the agricultural sector. It does not carry a subscript because the modern sector will not employ capital.

The modern sector, on the other hand, looks like Krugman's (1980) one-sector economy. It consists of a measure N^i of firms. This measure, the number of firms in the modern sector, will be endogenously determined in equilibrium. Each single firm n manufactures a quantity z^i_n of goods under an identical increasing-returns-to-scale production technology that uses skilled labor as its only input:

$$z^i_n(t) = A^i(t)\left[L^i_n(t) - L_0\right]. \tag{2}$$

L^i_n denotes the number of workers employed in region i's firm n, and L_0 is a fixed amount of labor that has to be employed each period to keep the firm running. For simplicity, L_0 is the same in both regions and it is not sunk. So, the increasing returns to scale are never exhausted in the modern sector. While natural monopolies can loose their economies of scale over time, there will always be new entrants and innovators that again exhibit scale economies for some period of time. Since it is beyond the scope of this model to endogenize the entry of innovators, I allow the modern sector to retain its increasing returns.

The above production technologies embody two classical and one modern source of trade specialization. Firstly, since labor productivity A^i may differ between North and South and $\gamma < 1$, Ricardian trade theory predicts that *ceteris paribus* the region with the higher labor productivity A^i specializes in modern goods production. Secondly, Heckscher-Ohlin theory predicts that the region with the higher capital-labor ratio will *ceteris paribus* specialize in agriculture. This ratio will be endogenous when capital can be accumulated. Heckscher-Ohlin theory also predicts that the specialization after trade will be incomplete when the two regions are sufficiently similar. Thirdly, new trade theory predicts that both regions will engage in intraindustry trade of manufactured goods. That is, both regions will produce varieties of the modern good and consume all foreign varieties along with the domestic varieties. Due to increasing returns to scale, monopolistic competition will arise in the modern sector and prices will remain above marginal cost. However, freely entering firms will compete away all rents. The only benefit from hosting the modern sector within the own borders stems from a dynamic externality in technological change.

2.2 Technological Change

Workers employed in the manufacturing sector learn from every product they manufacture. However, modern firms do not internalize this knowledge creation as byproduct of their manufacturing activity. This phenomenon could be called a 'dynamic externality.' Similar externalities have been elaborated in Arrow (1962) and, more recently, Romer (1986). As Romer (1990) argues, many forms of endogenous growth stem from sources that cannot be internalized completely by markets since knowledge is a public good so that knowledge creation is generally underpriced. Under the assumption that there will be a continuum of modern firms, each producing exactly one variety, I give knowledge creation in this model the form of a pure externality for simplicity:

$$\dot{A}^i(t) \equiv B \int_0^{N^i} z_n^i(t)\,\mathrm{d}n, \qquad (3)$$

where B is some positive constant and identical in both regions.

In a more realistic model, learning by doing in agriculture would also contribute to this knowledge creation. However, employees in the modern sector accumulate skills much more quickly, whereas the learning by doing potential is largely exhausted in agriculture. Relaxing the assumption and explicitly including knowledge creation in agriculture would not change the essential results of the model as long as learning by doing is faster in industry.

2.3 Demand

Consumers are identical in both regions. Their preferences take the form that Dixit and Norman (1980) introduced for simultaneous interindustry and intraindustry trade. Consider the following consumption index of modern goods and the related price index

$$D^i \equiv \left(\int_0^N (d_n^i)^\alpha \, dn \right)^{\frac{1}{\alpha}} \quad \text{and} \tag{4}$$

$$P \equiv \left(\int_0^N (p_n)^{-\frac{\alpha}{1-\alpha}} \, \mathrm{d}n \right)^{-\frac{1-\alpha}{\alpha}}, \tag{5}$$

respectively, which are harmonic means of the N consumed varieties and their prices. A representative consumer in region i has an instantaneous utility u

$$u(C^i, D^i) = (C^i)^{1-\theta}(D^i)^\theta = (C^i)^{1-\theta} \left(\int_0^N (d_n^i)^\alpha \, \mathrm{d}n \right)^{\frac{\theta}{\alpha}} \tag{6}$$

of consuming a quantity C^i of the agricultural good, and quantities d_n^i of each variety n of the modern good. The representative consumer purchases a measure N of these modern goods. The parameters α and θ are both restricted to values between zero and one: $\alpha, \theta \in (0, 1)$.[2] In every period, each household maximizes (6) with respect to C^i, d_n^i, and N, such that the budget constraint $C^i + \int_0^N p_n(d_n^i) \, \mathrm{d}n \leq Y^i$ is satisfied. Here and from now on, I choose the agricultural good as *numéraire*, $P_X \equiv 1$, while p_n is the unit price of variety n of the modern good. For the consumer problem to be well-defined, the constraint $N \leq \bar{N}$ must be satisfied in addition to the budget constraint. $\bar{N}$ is the total number of varieties available to the consumer.

[2] θ has to lie between zero and one as in any Cobb-Douglas utility function. The requirement that α not exceed unity can be justified from the implied elasticities of substitution. Like in any other Cobb-Douglas utility function, the elasticity of substitution between C and a modern good d_j is one. However, the elasticity of substitution between one modern good and another modern good is $\frac{1}{1-\alpha}$. In order to obtain stronger substitutability among modern goods than between these and the agricultural product, we want $\frac{1}{1-\alpha} \in (1, \infty)$, i.e. $\alpha \in (0, 1)$.

Then the resulting demand for the agricultural good and each variety of the modern good become

$$C^i = (1 - \theta)\, Y^i \tag{7}$$

and

$$d_n^i = \theta Y^i \cdot \left(\frac{P^\alpha}{p_n}\right)^{\frac{1}{1-\alpha}}, \tag{8}$$

respectively. The price elasticity of demand for a modern good n is

$$\varepsilon_{d_n,p_n} = \frac{1}{1-\alpha}\left[1 - \alpha\left(\frac{P}{p_n}\right)^{\frac{\alpha}{1-\alpha}}\right]. \tag{9}$$

For the above utility function, consumers prefer adding another variety over consuming more quantity of each variety. That is, when modern goods sell at sufficiently close prices, the optimal N equals $\bar{N}$ (or is zero). As long as $N < \bar{N}$, consumers lower the quantity d_n^i (for all the $n \in [0, N]$ they are consuming) and add another variety (to increase N), while they still satisfy the budget constraint.

Given these demand functions, indirect utility at each instant τ in time becomes

$$u(\tau) = T \cdot Y^i(\tau) \frac{1}{P(\tau)^\theta}, \tag{10}$$

where $T \equiv (1-\theta)^{1-\theta}\, \theta^\theta$.

3 Autarky and Free Trade Equilibrium

Since only labor is employed in both sectors of industry, the entire per period equilibrium allocation and all prices can be expressed in terms of the *share of the labor force employed in the modern sector*. Call this share λ^i:

$$\lambda^i(t) \equiv \frac{\int_0^{N^i} L_n^i(t)\,\mathrm{d}n}{L^i} = \frac{L_N^i(t)}{L^i} \in [0,1], \tag{11}$$

where $L_N^i(t) \equiv \int_0^{N^i} L_n^i(t)\,\mathrm{d}n$. Ultimately, the equilibrium growth rate will be entirely determined by this labor share as well.

In this section I first derive two convenient equilibrium conditions, the equilibrium scale of production of modern firms and the equilibrium number of modern firms. These take the same functional forms under autarky and free trade. Then I derive the autarky equilibrium, and finally the world trade equilibrium. For ease of notation, I will drop the time variable for parts of the exposition with the understanding that all endogenous variables remain time dependent and that the per period equilibrium values of the variables may change over time.

3.1 Monopolistic competition in the modern sector

In order to enter the market for a new variety, a modern firm must incur the fixed cost $w^i L_0$, where w^i is the wage rate in region i. Since there are no economies of scope or sunk cost, incumbent firms have no advantage over entrants. Hence, one can assume without loss of generality that each firm in the modern sector can manufacture only one variety. Because of the increasing returns to scale, no second firm can successfully compete in the market for any single variety. Each variety is thus manufactured by one and only one firm. However, free entry into 'neighboring' markets for modern goods will still drive profits down to zero. Given the production technology (2), each firm's cost function is $C(w^i, z_n^i) = w^i z_n^i / A^i + w^i L_0$, and every firm n finds it optimal to employ $L_n^i = \frac{z_n^i}{A^i} + L_0$ workers for the production of a positive quantity z_n^i of variety n (for $z_n^i = 0$, optimal labor demand is $L_n^i = 0$ because L_0 is not sunk). Note that every firm needs the fixed amount of labor for its operation in each period. So, the fixed factor is employed again and again, as long as the firm remains in business. Since every firm is a monopolist in the market for its own variety, it will take into account how demand responds to its supply decision. Hence, the optimal quantity z_n^i is determined by the profit maximizing condition that marginal revenue equal marginal cost $p_n^i \left(1 - \epsilon_{p_n, d_n}\right) = \frac{w^i}{A^i}$.

Neglecting equilibria in which varieties are sold at different prices, I will follow Dixit and Norman (1980) and Krugman (1980) and assume that the equilibrium is symmetric. This simplifies the following analysis considerably. Let prices for modern goods p_n^i satisfy $p_n^i = p^i \, \forall n$. Then, for a sufficiently high number of firms in the modern sector, each firm will set its quantity so that consumers have to pay the price

$$p^i \simeq \frac{1}{\alpha}\frac{w^i}{A^i}, \tag{12}$$

where the mark-up $\frac{1}{\alpha}$ approximately derives from demand elasticity (9) for a large measure of firms. The approximation only means that firms cannot squeeze out the entire consumer rent they would optimally choose to extract. Thus, the resulting number of entrants will be lower than it could be if firms were allowed to take the term into account. However, the allocation of labor between sectors (λ^i, the main variable I am aiming at) will not depend on this simplification.

In an unregulated market entry will occur until profits are driven down to zero: $\pi_n^i = (p_n^i - w^i/A^i) \cdot z_n^i - w^i L_0 = 0$. Using the quantity decision implied by (12), each firm will produce at the break-even scale

$$z^i = \alpha \cdot A^i \frac{L_0}{1-\alpha} \tag{13}$$

and employ $L^i = \frac{L_0}{1-\alpha}$ workers in a symmetric equilibrium. Were the firms unable to charge a premium over their marginal cost, they could not sustain production because their fixed cost would not be covered. The quantity choice that results from monopolistic competition is, as (13) shows, lower by a factor of α than it would be in a social optimum (where a social planner would need to compensate firms for their fixed cost through a lump sum transfer).

3.2 Equilibrium number of varieties

In general equilibrium, the number of modern firms will be determined by the relative size of the manufacturing sector. Solving for the equilibrium levels of variables turns out to be much easier when we also look at the economy from the income side. The modern sector exclusively employs labor. It follows immediately from (13) that each manufacturer generates revenues of $p^i z^i = p^i \cdot [\alpha/(1-\alpha)] A^i L_0$. Since monopolistic competition drives profits down to zero, all these revenues must go to workers. Thus,

$$w^i \cdot \lambda^i L^i = N^i \cdot p^i \frac{\alpha}{1-\alpha} A^i L_0 \tag{14}$$

in the modern sector.

Together with the monopolistic pricing rule (12), this income identity yields a simple relationship between the number of firms N^i and the equilibrium labor share λ^i:

$$N^i = (1-\alpha)\frac{L^i}{L_0} \cdot \lambda^i. \tag{15}$$

The smaller is the fixed amount of labor L_0 needed for running a modern company, the more modern firms enter in equilibrium. The higher the monopoly power of each firm, that is the closer α gets to zero, the more firms enter. Firms compete all rents away.

3.3 Autarky equilibrium

Four markets will have to clear in region i in autarky. The labor market, the capital market, and the two commodity markets. Take the two commodity markets first. Since prices for all varieties are equal in symmetric equilibrium ($p_n = p$), demand for each variety (8) simplifies to $d_n^i = d^i = \theta Y^i / N^i p^i$. So, the market clearing condition for each variety becomes:

$$d^i = \frac{\theta Y^i}{N^i p^i} = \alpha \cdot A^i \frac{L_0}{1-\alpha} = z^i. \tag{16}$$

Similarly, the agricultural goods market clears if

$$C^i = (1-\theta) Y^i = X^i. \tag{17}$$

By expressing (16) and (17) in terms of λ^i, I have implicitly imposed that the labor market clears: $L_N^i + L_X^i = L^i$. Then, the last among the four markets—the capital market—must clear by Walras' Law, too.

The equilibrium wage w^i and the interest rate r^i are such that the agricultural sector finds it optimal to employ the capital supply and the market-clearing number of workers. The market for modern goods clears at a price p^i given by (12), while the agricultural good sells at a price of $P_X = 1$ for convenience. So,

$$w^i = \frac{\gamma \cdot X^i}{(1-\lambda^i)L^i}, \tag{18}$$

$$r^i = \frac{(1-\gamma)X^i}{K^i}, \tag{19}$$

$$p^i = \frac{1}{\alpha}\frac{w^i}{A^i}. \tag{20}$$

Agricultural production X^i is a function of the labor share λ^i, the capital stock and parameters, $X_i = [A^i(1-\lambda^i)L^i]^\gamma [K^i]^{1-\gamma}$.

Hence, all equilibrium prices and quantities in each period can be expressed as functions of the labor share λ^i. What, then, is the equilibrium labor share λ^i? Total income must equal total consumption expenditure in equilibrium

$$w^i L^i + r^i K^i = (1-\theta)Y^i + \theta Y^i = Y^i. \tag{21}$$

Using this income and expenditure relationship (21) along with the market clearing and price equations (16) through (20) yields the equilibrium. There are six equations in six unknowns λ^i, N^i, p^i, w^i, r^i, Y^i. The following statement summarizes what the equilibrium looks like.

Proposition 1 *In autarky, the equilibrium share of workers employed in agriculture is*

$$1 - \lambda^i_{aut} = \frac{\gamma(1-\theta)}{\theta + \gamma(1-\theta)}. \tag{22}$$

The size of the modern sector is given by the equilibrium number of modern firms

$$N^i_{aut} = \frac{(1-\alpha)\,\theta}{\theta + \gamma(1-\theta)}\frac{L^i}{L_0}, \tag{23}$$

so that productivity grows at a rate

$$g^i_{A,aut} \equiv \alpha B L^i \, \frac{\theta}{\theta + \gamma(1-\theta)} \tag{24}$$

in equilibrium.

Proof. In appendix A, p. 36. ■

None of these equilibrium variables changes over time. Thus, the autarky equilibrium is also a steady-state. The allocation of labor to the modern sector increases whenever modern goods are in high demand (large θ), and falls when labor is intensively used in agriculture (large γ). The equilibrium labor allocation is independent of the level of labor skills, A^i, since these skills are equally applicable in both sectors. It is also independent of the elasticity of substitution between modern goods ($\frac{1}{1-\alpha}$) since this only matters for the number of modern firms, not for the size of the sector as a whole. As derived in (15), the number of modern firms is directly proportional to the labor share in the modern sector. In equilibrium, the total of modern goods is $N^i z^i = \alpha A^i \lambda^i L^i$ by (13) and (15). In addition, productivity growth exclusively stems from learning by doing in the modern sector. By (3), it equals $BN^i z^i$. The learning function thus takes the value $\dot{A}^i = A^i \cdot \alpha\theta B L^i/(\theta + (1-\theta)\gamma)$ in an autarky equilibrium.

3.4 Trade Equilibrium after Complete Liberalization

Now let both regions open up to free trade. Call the home region i and the foreign region $-i$. Assume that there are no transport costs or tariffs after trade liberalization. In order to keep the results simple I will restrict attention to an equilibrium in which all varieties produced in one region are sold at the same price world wide. All Southern goods sell at the same price p^S and all Northern goods sell at one price p^N.

All price relationships and market clearing conditions that applied to autarky must still hold in a world trade equilibrium—with only two exceptions: the market clearing condition for the agricultural good and the market clearing conditions for the manufactured commodities. There are three such conditions now: One for market clearing in the agricultural good, and two for market clearing of the modern goods. Market clearing of the agricultural good (17) generalizes to

$$C^i + C^{-i} = (1-\theta)\left(Y^i + Y^{-i}\right) \; = \; X^i + X^{-i}. \tag{25}$$

If specialization after trade liberalization is not complete, N^S modern firms will locate in the South and N^N firms will manufacture in the North. So, denote Southern consumers' demand for modern goods from region j by $d^{j,S}$. Equivalently, one could say that $d^{j,i}$ modern goods are delivered from region j to consumers in region i. Then, market clearing for for modern commodities manufactured in region j requires that $d^{j,i} + d^{j,-i} = z^j$ for $j = S, N$. Since all Southern goods sell at p^S and all Northern goods at p^N, demand (8) for modern goods from region j simplifies to

$$d^{j,i} = \frac{\theta Y^i}{\left[N^S(p^S)^{-\frac{\alpha}{1-\alpha}} + N^N(p^N)^{-\frac{\alpha}{1-\alpha}}\right]} \frac{1}{(p^j)^{\frac{1}{1-\alpha}}} \qquad j = S, N \tag{26}$$

in region i. Thus, market clearing for goods from region j can be written as

$$\begin{aligned} d^{j,S} + d^{j,N} &= \frac{\theta\left(Y^S + Y^N\right)}{\left[N^S(p^S)^{-\frac{\alpha}{1-\alpha}} + N^N(p^N)^{-\frac{\alpha}{1-\alpha}}\right]} \cdot \frac{1}{(p^j)^{\frac{1}{1-\alpha}}} \\ &= \frac{\alpha}{1-\alpha} L_0 \cdot A^j = z^j \qquad j = S, N. \end{aligned} \tag{27}$$

This immediately yields the price ratio in equilibrium

$$\frac{p^S}{p^N} = \left(\frac{A^N}{A^S}\right)^{1-\alpha}. \tag{28}$$

In addition to the three market clearing conditions (25) and (27), labor markets and capital markets must clear in both regions. As in autarky, expressing the equilibrium with labor shares λ^i and λ^{-i} implicitly imposes labor market clearing in both regions. Capital markets must clear in both countries by Walras' Law. Thus, the world trade equilibrium will be completely described if we impose the price relationships (18), (19), and (20) as in autarky, and the two income-expenditure relationships (14) and (21), which express income generated in the modern sector and income generated in the entire economy, respectively. Each of these conditions must hold for both regions i and $-i$. Together with market clearing for the agricultural good (25) and the modern commodities (26) (the latter applied to both region i and $-i$), these relationships constitute a system of thirteen equations in thirteen unknowns λ^i, λ^{-i}, N^i, N^{-i}, p^i, p^{-i}, w^i, w^{-i}, r^i, r^{-i}, Y^i, Y^{-i}, and P_X. The number of equations is odd because there is only one market clearing condition for the modern good. For convenience, I keep the agricultural good as *numéraire* so that $P_X \equiv 1$.

Just as for the derivation of the autarky equilibrium it again proves convenient to look at the economy from the income and spending side. World-wide revenues in the modern sector must equal world-wide spending on modern goods,

$$\begin{aligned} p^S N^S z^S + p^N N^N z^N &= \left(p^S N^S A^S + p^N N^N A^N\right) \frac{\alpha}{1-\alpha} L_0 \\ &= \theta \left(Y^S + Y^N\right). \end{aligned} \tag{29}$$

For convenience, the two market clearing conditions in (27) can be replaced by imposing the implied world price ratio (28) and income-expenditure relationship (29) instead. The unique world trade equilibrium—in the three equations (25), (28) and (29) along with the ten price and income relationships (18), (19), (20), (14), (21)—has an intuitive closed form.

Before stating it in proposition 2, let's define two handy variables and call them *specialization forces.* If country i is relatively abundantly endowed with labor, free trade will *ceteris paribus* cause an expansion in the modern sector. Similarly, if country i is relatively abundantly endowed with capital, its agricultural sector will expand after trade. Let Λ^i denote the specialization force from labor endowments that pushes country i to more agricultural production, and Γ^i denote the specialization force from capital endowments that pushes country i to more modern production. These specialization forces from labor endowments and from capital endowments can be defined rigorously as

$$\Lambda^i(t) \equiv 1 + \left(\frac{A^{-i}(t)}{A^i(t)}\right)^{\alpha} \frac{L^{-i}}{L^i} \quad \text{and} \quad \Gamma^i(t) \equiv 1 + \left(\frac{A^{-i}(t)}{A^i(t)}\right)^{\gamma\frac{1-\alpha}{1-\gamma}} \frac{K^{-i}}{K^i}, \tag{30}$$

respectively. The term $\frac{A^{-i}}{A^i}(t)$ is the *productivity gap* between the two regions $-i$ and i. It affects both specialization forces in this particular form due to monopolistic competition in the modern sector. With these definitions, the trade equilibrium can be expressed in the following manner.

Proposition 2 *After trade liberalization, the equilibrium share of workers employed in agriculture is*

$$1 - \lambda^i_{trade}(t) = \frac{\gamma(1-\theta)}{\theta + \gamma(1-\theta)} \frac{\Lambda^i(t)}{\Gamma^i(t)}, \tag{31}$$

The size of the modern sector is given by the equilibrium number of modern firms

$$N^i_{trade}(t) = \frac{1-\alpha}{\theta + \gamma(1-\theta)} \frac{L^i}{L_0} \left(\theta + \gamma(1-\theta) \frac{\Gamma^i(t) - \Lambda^i(t)}{\Gamma^i(t)} \right), \tag{32}$$

so that productivity in country i grows at a rate

$$g^i_{A,trade}(t) \equiv \alpha B L^i \left(1 - \frac{\gamma(1-\theta)}{\theta + \gamma(1-\theta)} \frac{\Lambda^i(t)}{\Gamma^i(t)} \right). \tag{33}$$

The two factor price ratios are

$$\frac{w^{-i}_{trade}}{w^i_{trade}}(t) = \left(\frac{A^{-i}_{trade}(t)}{A^i_{trade}(t)} \right)^{\alpha} \quad \text{and} \quad \frac{r^{-i}_{trade}}{r^i_{trade}}(t) = \left(\frac{A^{-i}_{trade}(t)}{A^i_{trade}(t)} \right)^{\gamma \frac{\gamma}{1-\alpha}}, \tag{34}$$

respectively.

Corollary 2.1 *If there are no fixed costs in the modern sector ($L_0 = 0$), or if A^i is treated as total factor productivity in the agricultural sector (or both), then the respective specialization forces and factor price ratios are as in table 1.*

Corollary 2.2 *If capital is immobile across regions, no country can completely specialize in the modern sector.*

Corollary 2.3 *For $\frac{\Lambda^i(t)}{\Gamma^i(t)} \geq 1 + \frac{\theta}{\gamma(1-\theta)}$, region i completely specializes in agriculture and stops growing.*

Proof. In appendix B, p. 36. ∎

Table 1: TRADE EQUILIBRIA FOR DIFFERENT ECONOMIES

Type of Economy	Specialization Force		Factor Price Ratios		Elasticities	
	Λ^i	Γ^i	$\frac{w^{-i}}{w^i}$	$\frac{r^{-i}}{r^i}$	δ_L	δ_K
Classical economy						
A^i: L.-Prod.	$1+\frac{A^{-i}}{A^i}\frac{L^{-i}}{L^i}$	$1+\frac{K^{-i}}{K^i}$	$\frac{A^{-i}}{A^i}$	1	1	0
A^i: TFP	$1+\frac{A^{-i}}{A^i}\frac{L^{-i}}{L^i}$	$1+\frac{A^{-i}}{A^i}\frac{K^{-i}}{K^i}$	$\frac{A^{-i}}{A^i}$	$\frac{A^{-i}}{A^i}$	1	1
$(\alpha=1, L_0=0)$	>1	>1			$=1$	≤ 1
Modern economy						
A^i: L.-Prod.	$1+\left(\frac{A^{-i}}{A^i}\right)^{\alpha}\frac{L^{-i}}{L^i}$	$1+\left(\frac{A^{-i}}{A^i}\right)^{\gamma\frac{1-\alpha}{1-\gamma}}\frac{K^{-i}}{K^i}$	$\left(\frac{A^{-i}}{A^i}\right)^{\alpha}$	$\left(\frac{A^{-i}}{A^i}\right)^{\gamma\frac{1-\alpha}{1-\gamma}}$	α	$\gamma\frac{1-\alpha}{1-\gamma}\lessgtr 1$
A^i: TFP	$1+\left(\frac{A^{-i}}{A^i}\right)^{\alpha}\frac{L^{-i}}{L^i}$	$1+\left(\frac{A^{-i}}{A^i}\right)^{\frac{1-\alpha\gamma}{1-\gamma}}\frac{K^{-i}}{K^i}$	$\left(\frac{A^{-i}}{A^i}\right)^{\alpha}$	$\left(\frac{A^{-i}}{A^i}\right)^{\frac{1-\alpha\gamma}{1-\gamma}}$	α	$\frac{1-\alpha\gamma}{1-\gamma}>1$
$(\alpha\in(0,1), L_0>0)$	>1	>1			<1	$\neq 1$

After trade liberalization, the equilibrium labor share in agriculture differs from the autarky equilibrium by a factor of Λ^i/Γ^i. The higher Λ^i, that is, the higher the labor endowment abroad relative to the labor endowment at home, the more workers at home become employed in agriculture after trade. Similarly, the lower Γ^i, the more workers at home become employed in agriculture. The relative specialization forces change over time so that the two regional economies need no longer find themselves in steady states. To reap the full benefits of trade liberalization, factor markets in both regions must be sufficiently flexible and adjust to the possibly perpetual economic changes.

Note that the specialization forces for regions i and $-i$ are not the inverses of each other. Rather, $\Lambda^i = 1 + \frac{1}{\Lambda^{-i}-1}$ and $\Gamma^i = 1 + \frac{1}{\Gamma^{-i}-1}$. The factors, by which the relative labor and capital endowments in Λ^i and Γ^i are multiplied ($\left(\frac{A^{-i}}{A^i}\right)^{\alpha}$ and $\left(\frac{A^{-i}}{A^i}\right)^{(1-\alpha)\frac{\gamma}{1-\gamma}}$), equal the relative factor prices in equilibrium. They are concave or convex functions of the productivity gap A^{-i}/A^i, depending on the relative magnitude of the parameters α and γ.

Table 1 contrasts the economy mainly under consideration in this paper with related economies. The 'classical economies' have a manufacturing sector with constant returns to scale so that modern output is produced under technology $Z^i = A^i L^i$ ($L_0 = 0$). The equilibrium number of firms is indeterminate in such an economy, and can be set to $N^i = N^{-i} \equiv 1$ for convenience. The productivity coefficient A^i can be understood as *labor productivity* if agricultural production takes the form $X^i(t) = [A^i(t) L_X^i(t)]^{\gamma} [K^i(t)]^{1-\gamma}$ as in (1). It can be interpreted as *total factor productivity* (TFP) if we modify agricultural production to $X^i(t) = A^i(t) [L_X^i(t)]^{\gamma} [K^i(t)]^{1-\gamma}$.

In the absence of a productivity gap ($A^i = A^{-i}$), factor price equalization obtains as is well known from Heckscher-Ohlin trade theory. In this sense, the 'classical economy' with A^i being labor productivity seems to be a natural benchmark case. It results in factor price equalization for the interest rate, but not for the wage rate. One could call this 'conditional factor price equalization'—

conditional on productivity differences. Empirically, this is a typical pattern. Real interest rates are roughly equal across countries, even between richer and poorer regions, but real wages differ substantially. Thus, I generally choose to keep A^i as labor productivity when extending the 'classical economy' to a 'modern economy' with intraindustry trade. Intraindustry trade, however, ends with 'conditional factor price equalization' due to the price distortion from monopolistic competition (which is necessary for modern firms to recover their fixed cost). The international wage differential becomes $(A^{-i}/A^i)^\alpha < (A^{-i}/A^i)$, and, in the absence of international capital flows, interest rates do not equal across regions. This phenomenon will give rise to the possibility that convergence across regions occurs despite the fact that growth stems from a dynamic externality.

In the 'modern economy' after trade liberalization, the response of the labor allocation to an increase in productivity is ambiguous. It depends on the relative size of α and γ, which is to say it varies with the monopoly power of modern firms and the labor intensity of agricultural production. This is the key source of convergence in growth rates in this model.

4 Managing to Converge: The Technology Gap after Trade Liberalization

How do the productivity gap between countries, A^{-i}/A^i and the specialization force Λ^i/Γ^i evolve in world trade equilibrium over time? This section will show that the dynamics largely depend on the type of economies that participate in international trade. Regions that strongly engage in intraindustry trade tend to converge, whereas economies that concentrate in classical interindustry trade tend to diverge after trade liberalization. Since productivity growth is proportional to an economy's labor endowment, $g_A^i = \alpha B \lambda^i L^i$, there would be strong autonomous forces for divergence if $L^{-i} \neq L^i$ in this world economy. In order to concentrate on purely endogenous forces of divergence or convergence, I set $L^{-i} = L^i = 1$ in this section.

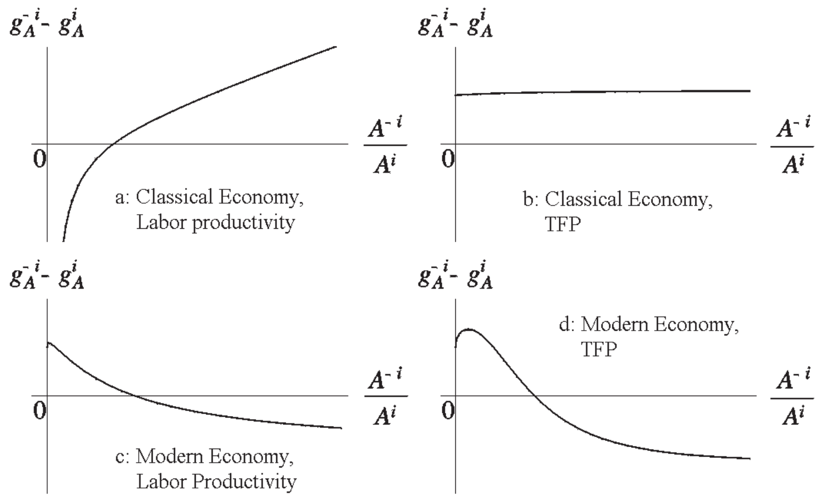

Figure 1: **Divergence and Convergence Patterns**

Proposition 3 *After trade liberalization, the productivity gap A^{-i}/A^i changes at a rate*

$$\left(\frac{\dot{A^{-i}}}{A^i}\right)/\left(\frac{A^{-i}}{A^i}\right) = g_A^{-i} - g_A^i = \frac{\alpha\gamma(1-\theta)B}{\theta+\gamma(1-\theta)}\left(\frac{\Lambda^i}{\Gamma^i} - \frac{\Lambda^{-i}}{\Gamma^{-i}}\right)$$
$$= \frac{\alpha\gamma(1-\theta)B}{\theta+\gamma(1-\theta)}\frac{\Lambda^i}{\Gamma^i}\left(1-\left(\frac{A^{-i}}{A^i}\right)^{\delta_K-\delta_L}\frac{K^{-i}}{K^i}\right) \quad (35)$$

for $L^{-i} = L^i$. The coefficients δ_K and δ_L are the elasticities of the factor price ratios with respect to the productivity gap, as given in table 1 (p. 19).

Proof. Taking the time-derivative of A^{-i}/A^i and using the equilibrium productivity growth rates (33) along with the definitions $\Lambda^i \equiv 1 + (A^{-i}/A^i)^{\delta_L}$ and $\Gamma^i \equiv 1 + (A^{-i}/A^i)^{\delta_K}(K^{-i}/K^i)$, yields (35). ■

The evolution of the international productivity gap as described in (35) allows for rich patterns of divergence or convergence. Divergence in productivity levels will occur if function (35) is increasing. Convergence can occur, on the other hand, if (35) is decreasing in a neighborhood of some steady-state technology gap A_0^{-i}/A_0^i. Figure 1 depicts some examples for the four types of economies in table 1

(p. 19).[3] In figure 1, the two 'classical economies' are depicted in the upper row. They diverge after trade liberalization, whereas 'modern economies,' as depicted in the lower row, converge in productivity levels. As will become clear soon, the examples in figure 1 are representative of more general cases.

For convergence to occur in a neighborhood of some A_0^{-i}/A_0^i, the right hand side of (35) must be decreasing. Taking the derivative with respect to the productivity gap and simplifying yields the following condition for *convergence*

$$\frac{\left(\frac{A_0^{-i}}{A_0^i}\right)^{\delta_K}\left(1+\left(\frac{A_0^{-i}}{A_0^i}\right)^{2\delta_L}\right)+\left(\frac{A_0^{-i}}{A_0^i}\right)^{2\delta_L}\frac{K^i}{K^{-i}}+\left(\frac{A_0^{-i}}{A_0^i}\right)^{2\delta_K}\frac{K^{-i}}{K^i}}{\left(\frac{A_0^{-i}}{A_0^i}\right)^{\delta_K}\left(1+\left(\frac{A_0^{-i}}{A_0^i}\right)^{2\delta_L}\right)+2\left(\frac{A_0^{-i}}{A_0^i}\right)^{\delta_L+\delta_K}}<\frac{\delta_K}{\delta_L}. \tag{36}$$

In the modern economy with A^i being labor productivity so that $\frac{\delta_K}{\delta_L}=\frac{\gamma}{\alpha}\frac{1-\alpha}{1-\gamma}$, condition (36) is more likely to hold if $\alpha<\gamma$. So world-wide convergence in productivity growth is likely to occur if monopoly power in the modern sector is relatively strong or agriculture makes relatively little use of the key factor to growth, or both.

The reason is that monopolistic competition drives a wedge between factor remuneration and factor productivity. The higher the monopoly power, the less modern goods $Z^i=N^iz^i=\alpha A^i\lambda^iL^i$ are produced in equilibrium since Z^i is falling in α. Thus, labor is a cheap factor when monopoly power is strong, because the modern sector is small, employs little labor, and the constant-returns-to-scale sector in the background (agriculture) has to employ a lot of labor in general equilibrium. This drives wages down. Simultaneously, monopolistic competition also weakens the specialization force stemming from labor endowments and strengthens the specialization force stemming from capital. The stronger monopoly power gets, that is the further α drops, the less important is the productivity gap in $\Lambda^i=1+(A^{-i}/A^i)^{\alpha}$, and the more impact has the productivity gap on $\Lambda^i=1+(A^{-i}/A^i)^{\gamma\frac{1-\alpha}{1-\gamma}}(K^{-i}/K^i)$. Thus, when the productivity gap widens

[3] The parameter choices in figures 1 and 2 are $\gamma=.65$, $\theta=.5$. In addition, $\frac{K^{-i}}{K^i}=.9$ while $\frac{L^{-i}}{L^i}=1$ so that region i tends to specialize in agriculture. In figure 1, $\alpha=\frac{2}{3}\gamma\approx.43$.

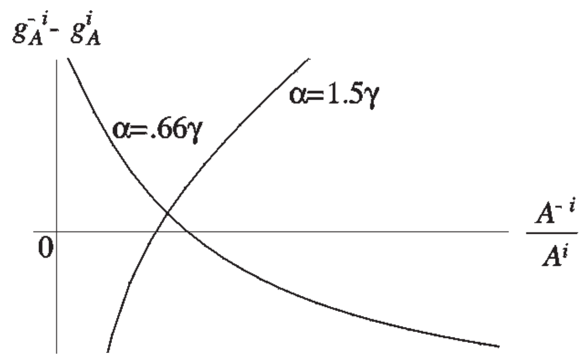

Figure 2: **Divergence and Convergence in the Modern Economy**

it now in fact strengthens the forces that make region i specialize in the modern sector because agricultural production becomes more attractive in the other region as Γ^i rises.

In figure 1, α is chosen to be relatively small relative to γ, $\alpha = \frac{2}{3}\gamma$. However, for $\alpha = \frac{3}{2}\gamma$, for example, divergence also occurs when modern economies start to trade. This is shown in figure 2. Proposition 4 states these findings in more general terms.

Proposition 4 *After trade liberalization, the four types of economies in table 1 (p.19) obey the following dynamics.*

1. *In any 'classical economy', divergence in productivity levels and growth occurs and the region whose specialization forces initially favor agriculture, $\frac{\Lambda^i(t_0)}{\Gamma^i(t_0)} > 1$, completely specializes in agriculture after finite time.*

2. *If there is a steady-state level for which the technology gap between regions i and $-i$ remains constant, it is unique and lies at:*

$$\frac{A_0^{-i}}{A_0^i} = \left(\frac{K^{-i}}{K^i}\right)^{\frac{1}{\delta_L - \delta_K}}. \qquad (37)$$

   The coefficients δ_K and δ_L are the elasticities of the factor price ratios with respect to the productivity gap, as given in table 1 (p. 19).

3. *Local convergence to the steady-state technology gap (37) occurs if $\delta_L < \delta_K$. This condition is satisfied in 'modern economies' if A^i is labor productivity and $\alpha < \gamma$. It is always satisfied in 'modern economies' if A^i is total factor productivity.*

Proof. In Appendix C, p. 37. ■

The first statement follows immediately from the fact that the change of the technology gap $g_A^{-i} - g_A^i$ must be an increasing function of the technology gap itself for any 'classical economy.' In general, a steady-state does not need to exist. In addition, the change in the technology gap $g_A^{-i} - g_A^i$ can be a non-monotonic function of A^{-i}/A^i. Figures 1b and 1d exhibit examples of both. If a steady-state exists, however, then it can only be stable in a 'modern economy.' Using the steady-state value of the technology gap (37) in the convergence condition (36) yields a value of one for the left-hand side of (36). Therefore, a steady-state is locally stable iff $\delta_K/\delta_L > 1$ or iff $\delta_L - \delta_K < 0$. For a modern economy with A^i being labor productivity $\delta_L - \delta_K = \frac{1-\gamma}{\gamma-\alpha}$ so that local convergence occurs for $\alpha < \gamma$. Most surprisingly, a modern economy with A^i being total factor productivity *always* has a stable steady-state to which it converges locally because $\delta_L - \delta_K = \frac{1-\alpha}{1-\gamma}$ is positive. Yet, local convergence is not to be confused with global convergence. As figure 1d shows, convergence would not occur in this case if the technology gap were severe and A^{-i}/A^i very small.

Policy advice—such as given by Rodrik (1999), for example— often stresses the importance of "making openness work" through sound domestic development policies so that an economy can successfully participate in the global market-place. The results of this section lend support to this view. Countries that are able to participate in intraindustry trade of advanced goods are likely to converge in productivity levels to their trading partners. Once they successfully prepared themselves domestically for the participation in intraindustry trade, these countries need not fear a negative impact of trade liberalization on their domestic growth.

4.1 Romer's (1990) economy as a further case

Romer's (1990) economy shares key features with the economy of this paper. It has been suggested that free trade between dissimilar regions in the Romer (1990) economy would result in divergence of growth rates. Rivera-Batiz and Romer (1991a), for example, are careful themselves to recommend free trade only for similar regions. I want to argue that divergence need not result in their models either because of the same reasons for which convergence occurs in the model of this paper.

Compared to the model proposed here, Romer's (1990) economy could be viewed as a one-sector economy in which the modern sector consists of three subsectors. Adopting notation used in this paper, the final production of the modern good in Romer' model takes the form $Z^i = (K_Z)^{1-\zeta} \int_0^{A^i(t)} (z_n^i)^\zeta \, \mathrm{d}n$ where K_Z is some sector-specific factor and z_n^i one variety of an intermediate capital good (for simplicity and without affecting the argument, I have suppressed a third factor in final production). The intermediate capital goods are supplied by a continuum of monopolistic competitors, each one selling one variety. In Romer's model, the capital to produce intermediate inputs is supplied through a savings decision and thus given at each instant. For the purpose of this argument it can also be considered a sector-specific input. Finally, designs for the varieties of capital goods are produced at a rate $\dot{A}^i(t) = B \cdot \lambda^i L^i A^i(t)$, where $\lambda^i L^i$ is the number of workers employed in R&D. Designs are then sold to the intermediate producers at a price so that all rents are shifted to the R&D sector. The modern sector therefore 'suffers' from a monopolistic distortion so that labor demand in R&D is reduced in a very similar way to the model in this paper. This, in turn, distorts factor prices and thus the specialization forces after trade—the first key element that the two models have in common.

A second common feature results once the model Romer is closed. One could either make the factor K_Z not subsector-specific but also turn it into labor, or one can add a second sector such as agriculture that competes for labor with the R&D

sector. To keep the similarities close, let's follow the second path, set $\zeta = 0$, and add agriculture with a production function $X^i = ((1-\lambda^i)L^i)^\gamma \left(\int_0^{A^i(t)} (z_n^i)\,\mathrm{d}n\right)^{1-\gamma}$. In equilibrium, each variety of capital goods is employed in the same proportion and the two production functions of the Romer (1990) model become $Z^i = A^i(t)\overline{z}^i$ and $X^i = (A^i)^{1-\gamma}((1-\lambda^i)L^i)^\gamma (\overline{z}^i)^{1-\gamma}$. Comparing these production functions with (1) and (2) shows that the production structures of the two models are closely related while the fact that $\overline{z}^i$ now also enters in agriculture adds an additional source of distortion in the Romer model. Therefore, convergence is to occur for large γ just as in the model of this paper.

5 Agreeing to Diverge: A Dynamic Welfare Analysis

Following Romer (1990), Young (1991), Rivera-Batiz and Romer (1991b), Aghion and Howitt (1998, Ch. 10), or Xie (1999) much attention has been paid to a possibly harmful effect of international trade on growth when regions start to trade which widely differ in factor endowments or initial productivity levels. Some of these approaches such as Young (1991) or Xie (1999) only consider a partial equilibrium, and may therefore miss forces that result in convergence as in section 4. In addition, while stressing welfare gains from free trade verbally, these approaches do not explicitly compare welfare losses from slower growth with welfare gains from increased trade. This section provides an explicit welfare analysis. I consider the initial reduced framework where the dynamic externality of learning by doing is not even partly internalized and where welfare gains from free trade only stem from concavity of utility—neglecting any additional welfare effects from the availability of additional varieties. By overstressing dynamic losses and understating repeated static gains in this manner, the model shows that traditional arguments for free trade still carry strong weight, even under conditions of endogenous growth theory.

5.1 Welfare analysis and two common fallacies

To derive a concise welfare measure, first consider output and relative prices. Lemma 1 assembles their levels before and after trade liberalization.

Lemma 1 *For all economies in table 1 (p. 19), after trade liberalization and* incomplete *specialization output in region i becomes*

$$Y^i_{trade}(t) \quad = \quad \frac{X^i_{trade}(t)}{1-\theta}\left(1+[\theta+\gamma(1-\theta)]\,\frac{\Gamma^i(t)-\Lambda^i(t)}{\Lambda^i(t)}\right) \tag{38}$$

in terms of agricultural production, whereas it was

$$Y^i_{aut}(t) = \frac{X^i_{aut}(t)}{1-\theta} \tag{39}$$

in autarky. Similarly, the world-wide price index P for modern goods (5) becomes

$$P_{trade}(t) \quad = \quad V\,\frac{\Gamma^i}{[A^i(t)^\alpha L^i + A^{-i}(t)^\alpha L^{-i}]^{\frac{1}{\alpha}}}\,\frac{X^i_{trade}(t)}{1-\theta}, \tag{40}$$

after trade, whereas it was

$$P_{aut}(t) = V\,\frac{1}{[A^i(t)^\alpha L^i]^{\frac{1}{\alpha}}}\,\frac{X^i_{aut}(t)}{1-\theta} \tag{41}$$

in autarky. $V \equiv \frac{1}{\alpha}(L_0)^{\frac{1-\alpha}{\alpha}}[\theta+\gamma(1-\theta)]^{\frac{1}{\alpha}}/(1-\alpha)^{\frac{1-\alpha}{\alpha}}\theta^{\frac{1-\alpha}{\alpha}}$.

Proof. In appendix D, p. 38. ■

Agricultural output after trade liberalization X^i_{trade} is determined by the labor allocation after trade $1-\lambda^i_{trade}$ (proposition 2), whereas X^i_{aut} was determined by $1-\lambda^i_{aut}$ (proposition 1). With these results at hand, the welfare gains or losses from free trade can simply be inferred from utility levels. Indirect utility is given by (10).

Proposition 5 *For all economies in table 1 (p. 19), utility attains a level of*

$$\begin{aligned} u^i_{trade}(t) \quad = \quad & T\left(\frac{X^i_{trade}(t)}{1-\theta}\right)^{1-\theta} \times \left(1+[\theta+\gamma(1-\theta)]\,\frac{\Gamma^i(t)-\Lambda^i(t)}{\Lambda^i(t)}\right)^{-\theta} \\ & \times V^{-\theta}\left(\frac{1}{[A^i(t)^\alpha L^i + A^{-i}(t)^\alpha L^{-i}]^{\frac{1}{\alpha}}}\right)^{-\theta}\left(\Gamma^i(t)\right)^{-\theta} \end{aligned} \tag{42}$$

after trade liberalization, while it was

$$u^i_{aut}(t) = T\left(\frac{X^i_{aut}(t)}{1-\theta}\right)^{1-\theta} \times 1 \times V^{-\theta}\left(\frac{1}{[A^i(t)^\alpha L^i]^{\frac{1}{\alpha}}}\right)^{-\theta} \tag{43}$$

in autarky. Thus, the ratio of post- and pre-trade utility becomes

$$\begin{aligned}\frac{u^i_{trade}}{u^i_{aut}}(t) &= \Bigg((1-\gamma)(1-\theta)\left(\frac{\Lambda^i(t)}{\Gamma^i(t)}\right)^{\theta+\gamma(1-\theta)} \\ &\qquad + [\theta+\gamma(1-\theta)]\left(\frac{\Gamma^i(t)}{\Lambda^i(t)}\right)^{(1-\gamma)(1-\theta)}\Bigg) \cdot \left(\Lambda^i(t)\right)^{\frac{1-\alpha}{\alpha}\theta}.\end{aligned} \tag{44}$$

Proof. Using the results of lemma 1 in indirect utility $u^i = T\,Y^i P^{-\theta}$ yields (42) and (43). Dividing (42) by (43) and simplifying yields (44). ■

The three terms in (42) have intuitive interpretations. Neglecting the constant T, the first factor, $(X^i_{trade}/1-\theta)^{1-\theta}$, captures the *reallocation effect* of trade liberalization. Depending on the specialization forces that shift the labor allocation under free trade, this term is larger or smaller than the corresponding term under autarky. It indicates whether agricultural output increases or falls after trade liberalization. The *reallocation effect* works through both output and prices as can be seen from (38) and (40). Hence, the power of $1-\theta$. The second term in (42) only appears in utility after trade, but not in utility before trade. We could call it, somewhat euphemistically, the '*output effect.*' In fact, this is no real effect at all because the true *reallocation effect* has been entirely captured by the previous term. The nominal '*output effect*' arises merely because I the agricultural good is the *numéraire*. Were the modern the *numéraire*, it would work in the opposite direction. The third term in (42) exclusively captures the *price effect* of trade liberalization. Depending on whether the foreign region can produce more productively than the home region, and depending on how strongly the specialization force from capital endowments Γ^i shifts employment, the average price of modern goods will fall or rise from the view point of region i. Only the product of all three effects, the *reallocation*, '*output*,' and *price effect*, correctly accounts for the increase in welfare. The *price effect* will offset all nominal '*output effects*' so that the true welfare gains from trade are captured. As a result, each region shares in the growth of the other region through an improvement of its own term of trade.

Static welfare increases with trade liberalization iff $u^i_{trade}/u^i_{aut} > 1$ in (44). In 'classical economies,' $\alpha = 1$ so that the second factor in expression (44) $\Lambda^i(t)^{\frac{1-\alpha}{\alpha}\theta}$ drops out. That term captures the utility that individuals derive from varieties in 'modern economies.'Since these gains derive from the particular form of utility that was imposed and go beyond gains that stem from concavity, I will disregard these extra-gains in the following arguments.

The purely 'classical gains' from trade are expressed in the first factor in (44). For $\Lambda^i(t) \neq \Gamma^i(t)$, this term strictly exceeds unity for it takes the form $a \cdot x^{1-a} + (1-a) \cdot x^{-a}$, and $a \in (0, 1)$, $x \in (0, \infty)$. Since both specialization forces, $\Lambda^i(t)$ and $\Gamma^i(t)$, always exceed one, their ratio cannot become negative and $x \in (0, \infty)$. Figure 3 plots the utility ratio as a function of the specialization forces. The 'classical gains' from the first factor in (44) are depicted by the thick curve. There are no gains from trade when the two specialization forces are exactly offsetting each other so that their ratio equals one. As is well known since David Ricardo, there are never any static losses from trade. In fact, as differentiation shows, the gains from trade increase more than proportionally when the two regions become less similar.

If the representative agent in country i only considered these static gains, a region would always choose to liberalize trade. The horizontal axis measures zero-gains from trade and thus represents the utility level in autarky. Any move away from point '1' on this axis will increase welfare beyond the autarky level. But what if there are dynamic losses that offset the static gains? What if the two countries diverge after free trade and the productivity gap A^{-i}/A^i widens?

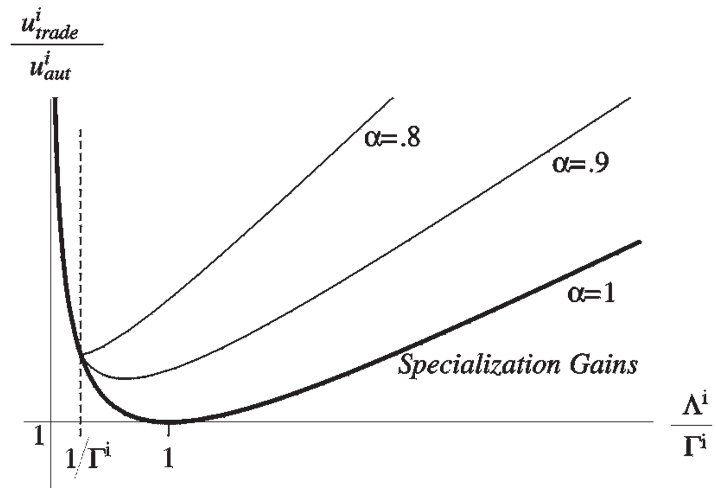

Figure 3: **Gains from Trade**

5.2 Dynamic welfare analysis

To analyze the trade-off between repeated static gains from trade and potential dynamic losses, we need to derive a 'dynamic criterion' beyond (44). When deciding whether to open up to free trade at time t_0, the representative agent faces the choice between receiving the autarky utility forever, $\int_{t_0}^{\infty} e^{-\rho(\tau-t)}\, u^i_{aut}(\tau)\, \mathrm{d}\tau$, or the utility from free trade forever $\int_{t_0}^{\infty} e^{-\rho(\tau-t)}\, u^i_{trade}(\tau)\, \mathrm{d}\tau$. The specialization forces in this model are not reverting or cyclical so that the agent is not concerned about temporary trade liberalization. If it pays to liberalize at some point t_0, then it always pays to liberalize.

Corollary 5.1 *The appropriate welfare criterion for trade liberalization under dynamic considerations is*

$$\left[\rho - (\theta + \gamma(1-\theta))g^i_{A,aut}\right] \int_{t_0}^{\infty} e^{-\int_{t_0}^{\tau}\left[\rho-(\theta+\gamma(1-\theta))g^i_{A,trade}(s)\right]ds}\, \frac{u^i_{trade}}{u^i_{aut}}(\tau)\, d\tau > 1. \tag{45}$$

Proof. Expression (45) follows from

$$\frac{\int_{t_0}^{\infty} e^{-\rho(\tau-t_0)}\, u^i_{trade}(\tau)\,\mathrm{d}\tau}{\int_{t_0}^{\infty} e^{-\rho(\tau-t_0)}\, u^i_{aut}(\tau)\,\mathrm{d}\tau} > 1$$

$$\Leftrightarrow \quad \frac{\int_{t_0}^{\infty} e^{-\rho(\tau-t_0)}\, [A^i_{trade}(\tau)]^{\theta+\gamma(1-\theta)}\, \frac{u^i_{trade}}{u^i_{aut}}(\tau)\,\mathrm{d}\tau}{\int_{t_0}^{\infty} e^{-\rho(\tau-t_0)}\, [A^i_{aut}(\tau)]^{\theta+\gamma(1-\theta)}\,\mathrm{d}\tau} > 1.$$

The first equivalence holds because labor and capital endowments do not change over time. The equivalence with (45) follows from the facts that $A^i(\tau) = A^i(t) \cdot e^{\int_{t_0}^{\tau} g^i_A(s)\mathrm{d}s}$ and $g^i_{A,aut} = const$. It requires that $\frac{\rho}{\theta+\gamma(1-\theta)} > \int_{t_0}^{\tau} g^i_A(s)\,\mathrm{d}s$, otherwise the integrals do not take a finite value. ∎

If (45) exceeds unity, the region is better off liberalizing. If it is less than one, the region prefers to remain autark. To gain an understanding of the criterion, consider the extreme case in which region i completely specializes in agriculture after trade and thus stops growing, $g^i_{A,trade} = 0$. If there were no static gains from trade, criterion (45) would become $\rho - g^i_{A,aut} < \rho$, and the representative agent would refuse to liberalize to free trade. There are static gains from trade, however, and they occur each period forever. Over time, they sum up to large benefits. If the specialization forces did not change over time, a sufficient condition for trade liberalization would be

$$\begin{aligned} \frac{u^i_{trade}}{u^i_{aut}} &= (1-\gamma)(1-\theta)\left(\frac{\Lambda^i}{\Gamma^i}\right)^{\theta+\gamma(1-\theta)} + [\theta+\gamma(1-\theta)]\left(\frac{\Gamma^i}{\Lambda^i}\right)^{(1-\gamma)(1-\theta)} \\ &> \frac{\rho}{\rho - g^i_{A,aut}}. \end{aligned} \qquad (46)$$

This implicitly defines some lower bound on the specialization force ratio Λ^i/Γ^i beyond which free trade is desirable. If the specialization force ratio is not fixed but grows over time, as is the case for all 'classical economies,' the lower bound beyond which trade is desirable will be even smaller because additional future gains from trade make up for some of the losses in growth.

This lower bound on the specialization force ratio, however, varies heavily with the choice of the discount factor and the autarky growth rate. Therefore, a more useful quantity to look at is the ratio $g^i_{A,aut}/\rho$. For (46) to be satisfied,

Table 2: LOWER BOUNDS ON $\frac{g_{A,aut}}{\rho}$ FOR TRADE LIBERALIZATION

$(1 - \frac{u_{aut}}{u_{trade}}\Big\vert_{\frac{\Lambda}{\Gamma}=1+\frac{\theta}{\gamma(1-\theta)}})$	$\theta = .3$	$\theta = .5$	$\theta = .7$
$\gamma = .1$	.23	.47	.68
$\gamma = .3$	.09	.23	.40
$\gamma = .5$	.04	.12	.24
$\gamma = .7$	.02	.06	.12

this ratio must not exceed $1 - \frac{u^i_{aut}}{u^i_{trade}}$. To evaluate $\frac{u^i_{aut}}{u^i_{trade}}$, I choose the point of complete specialization in agriculture as reference value: $\frac{\Lambda^i_0}{\Gamma^i_0} = 1 + \frac{\theta}{\theta+\gamma(1-\theta)}$. At this point, region i will stop growing. Table 2 reports values of $1 - \frac{u^i_{aut}}{u^i_{trade}}$ for different parameter choices. As long as the ratio $\frac{g^i_{A,aut}}{\rho}$ is less than or equal to the values reported, region i prefers to liberalize to free trade. Suppose region i would grow at a rate of 5% in autarky. Then, the representative agent has to be at least patient enough so that $\rho \geq .07$ for $\theta = .7$ and $\gamma = .1$, or $\rho \geq .22$ for $\theta = .5$ and $\gamma = .3$. For $\theta = .3$ and $\gamma = .7$, however, the agent would have to be extremely patient with $\rho \geq 2.45$.

The estimates are conservative. Firstly, to keep calculations simple, the more advanced foreign region $-i$ has been assumed to not grow after trade liberalization. The model, however, predicts increased growth in the more advanced region after trade liberalization and the less advanced region shares in this growth through improving terms of trade. Secondly, the less advanced region has been assumed to stop growing immediately, while there would be a transition period of slowing, but non-zero growth in which the static gains from trade are not yet fully reaped. These two opposing effects are likely to cancel. Finally, an average growth rate of 5% for ever is high even for very successful developing regions (Sachs and Warner 1995).

So, for a reasonably broad range of parameter values, regions would strictly prefer trade over autarky even if they subsequently grew more slowly. The calculations have an immediate implication especially for poor regions with relatively low productivity levels and autarky growth prospects. Call such a place Antarctica, say. If the potential trading partners are raising their productivity at a relatively fast rate, the specialization forces that would prevail if Antarctica were to open up to free trade get stronger and stronger. They surpass the boundary level at some point. Thus, a country with low growth prospects will always agree to trade liberalization after some point in time, and prefer trade and divergence over autarky. In this sense, the less developed region *agrees to diverge* while the faster growing region welcomes divergence anyway. Even fast growing less developed regions will prefer free trade over isolation if the factor endowments between the regions differ so strongly that the gains from trade outweigh dynamic losses from divergence. These countries will *agree to diverge* as well.

6 Conclusion

This paper has analyzed the implications of new trade and new growth theory for welfare and convergence after trade liberalization. For this purpose, it has considered four types of economies. They were characterized by two types of productivity change—labor and total factor productivity growth—and two types of competition in the sector that determined productivity growth—perfect competition under constant returns to scale and monopolistic competition under increasing returns to scale. The main insights of the paper are twofold.

Firstly, and in contrast to previous findings of new growth theory, if the innovative sector is characterized by monopolistic competition free trade can result in international growth convergence. The reason is that monopolistic competition can revert the forces of specialization that prevailed in classic trade theory. It is thus likely that countries, which manage to participate in intraindustry trade for advanced products after trade liberalization, converge to the growth rates of richer countries. An extension of the present model that resembles Romer's (1990) model would exhibit very similar distortion patterns so that convergence can result in that model, too.

Secondly, gains from international trade and specialization are static gains, repeatedly realized in every instant, and thus sum up to large benefits over time. These benefits can outweigh dynamic losses from slower growth after trade liberalization, and can make free trade desirable despite international income divergence. In this sense, countries may choose free trade over isolation even if trade causes income divergence. The slower growing regions share in the wealth creation of the faster growing regions through improving terms of trade. For non-trivial ranges of parameters, trade and divergence is better than isolation.

Due to monopolistic competition, there are no rents to be shifted across regions. In this static sense, the location of industry does not matter. It matters severely, however, for the dynamic externality stemming from learning by doing. Because labor is immobile across regions, the more modern firms a region hosts the more benefits from this externality accrue in the region.

Even though these results speak strongly for trade liberalization, trade liberalization should not be seen as an unconditionally desirable policy. A country with permanently low growth prospects in autarky may want to liberalize international trade, accept even slower future growth, and reap the repeated static gains from free trade. Yet, in the light of the convergence result, a country may also choose to pursue a different development policy. The results in this paper do lend support to temporary trade restrictions. Under these restrictions, a country may prepare its domestic industries for their successful participation in intraindustry trade at a later stage, open up to free trade once the modern sector is able to successfully compete with foreign firms, and then benefit from convergence under international trade.

Appendix

A Autarky equilibrium

Proof. The two market clearing conditions, (16) and (17) in the text, the three price equations (18), (19), and (20), along with the income-expenditure relationship (21), constitute a system of six equations in six unknowns λ^i, N^i, p^i, w^i, r^i, Y^i.

To derive the equilibrium, start with market clearing in the modern sector: Using the three price relationships—(18), (19), (20)—in (21), income (16) can be rewritten as

$$Y^i = N^i p^i z^i = \frac{\gamma X^i}{1-\lambda^i} + (1-\gamma)X^i. \tag{47}$$

In the text, (15), I have shown that the equilibrium number of firms $N^i = (1-\alpha)L^i\lambda^i/L_0$ can be immediately derived from (20) and (14). Using this, again along with the price for modern goods (20), $N^i p^i z^i$ becomes $N^i p^i z^i = \gamma X^i \lambda^i/(1-\lambda^i)$. Substituting for $N^i p^i z^i$ in (47) and solving out for λ^i yields (22) in the text. Similarly, we could depart from market clearing in the agricultural sector and find the same relationship. The equilibrium number of firms (23) and productivity growth (24) follow readily. ■

B Trade equilibrium

Proof. The three market clearing conditions, (25), (28) and (29) along with the six $(3\cdot 2)$ price equations (18), (19), (20), and the four $(2\cdot 2)$ income relationships (14) and (21) constitute an equation system in thirteen equations and thirteen unknowns: λ^i, λ^{-i}, N^i, N^{-i}, p^i, p^{-i}, w^i, w^{-i}, r^i, r^{-i}, Y^i, Y^{-i}, and P_X. One equation is redundant so that the price of the agricultural good can be set equal to unity.

Using the three price relationships once for market clearing in the modern sector and once for market clearing in agriculture, we can solve out for λ^i in terms of agricultural output, and find

$$1-\lambda^i = \frac{\gamma(1-\theta)}{\theta+\gamma(1-\theta)}\left(1+\left(\frac{A^{-i}}{A^i}\right)^{\delta_L}\frac{L^{-i}}{L^i}\right)\frac{X^i}{X^i+X^{-i}}. \tag{48}$$

Relationship (48) must also hold for economy $-i$, so that

$$\frac{1-\lambda^i}{1-\lambda^{-i}} = \frac{1+\left(\frac{A^{-i}}{A^i}\right)^{\delta_L}\frac{L^{-i}}{L^i}}{1+\left(\frac{A^{i}}{A^{-i}}\right)^{\delta_L}\frac{L^{i}}{L^{-i}}}\frac{X^i}{X^{-i}} = \left(\frac{A^{-i}}{A^i}\right)^{\delta_L}\frac{L^{-i}}{L^i}\frac{X^i}{X^{-i}}. \tag{49}$$

By (1),

$$\frac{X^i}{X^{-i}} = \left(\frac{A^i}{A^{-i}}\right)^{\delta_A}\left(\frac{1-\lambda^i}{1-\lambda^{-i}}\right)^{\gamma}\left(\frac{L^i}{L^{-i}}\right)^{\gamma}\left(\frac{K^i}{K^{-i}}\right)^{1-\gamma}, \tag{50}$$

where $\delta \in \{\gamma, 1\}$. Using (50) in (49) and solving out for $\frac{1-\lambda^i}{1-\lambda^{-i}}$ yields

$$\frac{1-\lambda^i}{1-\lambda^{-i}} = \left(\frac{A^{-i}}{A^i}\right)^{\frac{\delta_L-\delta_A}{1-\gamma}} \frac{L^{-i}}{L^i}\frac{K^i}{K^{-i}}.$$

Using this in (50) again, we find

$$\frac{X^{-i}}{X^i} = \left(\frac{A^{-i}}{A^i}\right)^{\frac{\delta_A-\gamma\delta_L}{1-\gamma}} \frac{K^{-i}}{K^i}$$

so that, by (48),

$$1-\lambda^i = \frac{1+\left(\frac{A^{-i}}{A^i}\right)^{\delta_L}\frac{L^{-i}}{L^i}}{1+\left(\frac{A^{-i}}{A^i}\right)^{\delta_K}\frac{K^{-i}}{K^i}} \frac{\gamma(1-\theta)}{\theta+\gamma(1-\theta)}, \tag{51}$$

where $\delta_K \equiv \frac{\delta_A-\gamma\delta_L}{1-\gamma}$. This establishes proposition 2 and corollary 2.1 for $\delta_A \in \{\gamma, 1\}$ and $\delta_L \in \{\alpha, 1\}$.

For a proof of corollary 2.2, suppose that $\lambda^i = 1$. Then capital in region i is unemployed if it cannot flow to region $-i$, and the marginal product of capital is infinite, as is the interest rate. This cannot be an equilibrium. More formally, $\lambda^i = 1$ implies $\frac{\Lambda^i}{\Gamma^i} \leq 0$ by (31), which is impossible. Corollary 2.3 immediately follows from (31) with $\lambda^i = 0$. ■

C Convergence Conditions

Proof. For ease of notation, denote the productivity gap by $a_0 \equiv \frac{A_0^{-i}}{A_0^i}$, the ratio of capital stocks by $k \equiv \frac{K^{-i}}{K^i}$ and the ratio of labor endowments by $l \equiv \frac{L^{-i}}{L^i}$. For a 'classical economy' first consider the case of A^i being labor productivity ($\delta_L = 1$, $\delta_K = 0$). Then condition (36) implies that the change in the productivity gap, $g_A^{-i} - g_A^i$, is an increasing function of the productivity gap $a \equiv \frac{A^{-i}}{A^i}$ in a neighborhood of a_0 iff ${a_0}^2\left[(1+k^{-1})+(1+k)\right]/\left[1+2a_0(1+a_0)\right] \geq 0$. This is always satisfied. Thus, convergence cannot occur in this case. Similarly for the case of a 'classical economy' where A^i is total factor productivity ($\delta_L = \delta_K = 1$), condition (36) implies that $g_A^{-i} - g_A^i$ is an increasing function in the productivity gap a at a_0 iff $\left[a_0(1+{a_0}^2)+{a_0}^2(k^{-1}+k)\right]/\left[a_0(1+{a_0}^2)+2{a_0}^2\right] \geq 1$, i.e. iff $k^{-1}+k \geq 2$. This is always satisfied and convergence cannot occur in this case either. In 'classical economies', a widening productivity gap causes the ratio of specialization forces to increase over time in the region that specializes in agriculture. Taking the partial derivative, it is easy to show that $\partial\left(\frac{\Lambda^i}{\Gamma^i}\right)/\partial\left(\frac{A^{-i}}{A^i}\right) \geq 0$ iff $a^{\delta_L-\delta_K} l\left(1+ka^{\delta_K}\right)/k\left(1+la^{\delta_L}\right) \geq \frac{\delta_K}{\delta_L}$. Since $\frac{\delta_K}{\delta_L} = 0$ for A^i being labor productivity, this condition is trivially satisfied, and it reduces to $\frac{l}{k} \geq 1$ for A^i being total factor productivity. So, statement 1 in proposition 4 is true.

In order to derive the behavior of 'modern economies', observe that the steady-state technology gap is unique if it exists. That is, for $g_A^{-i} = g_A^i$ to hold, (35) immediately implies that $k_0 = a_0^{\delta_L-\delta_K}$, or $a_0 = k_0^{-\frac{1}{\delta_K-\delta_L}}$. This proves statement 2 in proposition 4.

Moreover, there is a unique zero-intercept of the function $g_A^{-i} - g_A^i$, if it exists. Thus, convergence occurs in a neighborhood of a_0 if convergence condition (36) is satisfied at a_0. Using the steady state relationship $k_0 = a_0^{\delta_L - \delta_K}$ in condition (36) shows that the left-hand side of (36) must equal one so that convergence occurs iff $\delta_K/\delta_L > 1$. For a 'modern economy', $\delta_L = \alpha$. Using $\delta_K = \frac{\gamma - \alpha\gamma}{1-\gamma}$ for A^i being labor productivity and $\delta_K = \frac{1-\alpha\gamma}{1-\gamma}$ for A^i being total factor productivity establishes the third statement in the proposition. ■

D Comparison between trade and autarky equilibrium

Solving the equation system underlying proposition 2 (appendix B) yields

$$Y^i_{trade} = X^i_{trade}\left[(1-\gamma) + \frac{\theta + \gamma(1-\theta)}{1-\theta}\frac{1 + \frac{X^{-i}_{trade}}{X^i_{trade}}}{\Lambda^i}\right],$$

which implies (38) in the text, for specialization forces as defined in (30). The price of modern goods from region j is

$$p^j = \frac{\theta + \gamma(1-\theta)}{\alpha A^j}\frac{X^j}{L^j}\frac{\Gamma^j}{\Lambda^j}.$$

Using the latter relationship along with the equilibrium number of firms in the two regions (32) and plugging both into the definition of the price index (5) yields (40) after a round of simplifications. Similar steps for the autarky equilibrium yield (39) and (41).

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