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

Marc-Andreas Muendler†

University of California, San Diego and CESifo

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Abstract

The impact of international trade on domestic growth is revisited in a model with dynamic externalities and static increasing returns to scale. The model embraces features of both classical and new growth and trade theories, allows for learning by doing, 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-Vanek type specialization forces through monopolistic competition. Less developed regions can therefore manage to converge by participating in intraindustry trade. 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. JEL: F43, F12, O41

If a pure trade theorist were to advise a less developed country about whether and to what extent it should open up to free trade, she would have to reconcile a large and partly contradictory array of results. Ricardian or Heckscher-Ohlin-Vanek (HOV) models mandate trade liberalization unconditionally. Open up

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†muendler@ucsd.edu (*www.econ.ucsd.edu/muendler*)

to free trade, the trade theorist would conclude, no matter what your production technologies or factor endowments look like, world markets will start to work so that your comparatively more efficient or endowment-intensive sectors will become export industries, and your 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 consumers or firms benefit from added varieties of goods, open up to trade and your economy will be better off because consumers and firms benefit from the choice. Here, things already become difficult because the location of industries can be indeterminate, but may matter. Finally, an advisor who adheres to new growth theory will warn: Be careful. If your industries are likely to specialize in low-growth sectors, you may be worse off after liberalization. If you cannot rapidly implement knowledge that is created by other means than learning by doing, or elsewhere, you may become locked into low-tech production and that forever. After all, the advisor won't know.

This paper sets out to present a simple but comprehensive theoretical framework. The model allows for the four sources of specialization that a trade theorist such as the one above has in mind: international productivity gaps, differences in factor endowments, benefits from variety, and dynamic externalities from knowledge creation. The location of firms is determined endogenously. By construction, it is a worst-case model for a less developed country (LDC). Above all, learning-by-doing externalities will be the only source of productivity growth so that a less advanced region can suffer dynamic losses from trade as argued so often in the past decade. The model is kept simple by assuming explicit functional forms that will give rise to close-form solutions. It may not seem insightful at first to model so much. As wisdom has it, our 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.

So far, researchers mostly argued that diverging growth rates would result when dynamic externalities are present in factor accumulation or productivity change. This need not be the case. Eicher (1999) shows in a setting of human capital accumulation that convergence in growth rates (β-convergence) may in fact come about. The present paper argues, using simple closed-form solutions, that convergence can arise in many models of trade and endogenous growth under imperfect competition. The reason is that monopolistic competition distorts the old-style specialization forces. This effect is overlooked in partial equilibrium approaches. The model shares several features with Matsuyama's (1992) and Peletier's (1998) two-sector economies but addresses different questions. Beyond the analysis of an open economy's growth path, the present paper focuses on the evolution of the international productivity gap and on trade forces that affect it.

In the present general-equilibrium framework, an explicit welfare analysis can be added 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 keeping in mind. 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 outweigh dynamic losses from slower growth for wide ranges of parameters.

Recently, the impact of trade on growth has been reassessed under the auspices of endogenous trade theory and regional economics. Endogenous growth theory seems to make globalization little desirable for LDCs. Young (1991), Stokey (1991), and Peletier (1998) show that trade liberalization may inhibit learning by doing and knowledge creation in LDCs. The reason is that liberalization could induce LDCs to specialize in product lines where the learning potential has been largely exhausted. 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.

A line of argument in regional economics stresses that innovative 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 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 across 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 paper proceeds as follows. Section 1 spells out the model, and section 2 derives the unique autarky and the unique free-trade equilibrium. Section 3 analyzes the dynamics of the 'global economy' and the technology gap between rich and poor regions. Section 4 investigates under what conditions free trade can be desirable for a less developed country that has to specialize in low-growth sectors. Section 5 concludes.

1 The Model

There are two regions called 'North' and 'South' for simplicity. Both regions employ two homogeneous factors of production, capital and skilled labor. Labor is assumed to be perfectly mobile within one region but immobile across borders.Capital is taken to be internationally immobile, too, in order to focus on pure effects of commodity trade. There are two sectors in each region, one 'traditional' and one 'modern' sector. For convenience, call the traditional sector agriculture.This sector makes relatively intensive use of capital (or land). The second sector is manufacturing. Manufacturers employ skilled labor more intensively. They heavily rely 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.

1.1 Production

Let 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:

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

The variable A^i denotes the economy-wide labor productivity. L_X^i 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 of N^i firms. (N^i will be determined endogenously in equilibrium.) Each single firm n manufactures a quantity z_n^i

[1] Earlier drafts of this paper allowed for capital accumulation without a change in the main results.

of goods under an identical increasing-returns-to-scale production technology that uses skilled labor as its only input:

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

L_n^i 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.

The above production technologies embody two classical and one modern source of trade specialization. First, since labor productivity A^i may differ between North and South and $\gamma < 1$, Ricardian trade theory predicts that the region with the higher labor productivity A^i specializes in modern goods production, all else equal. Second, HOV theory predicts that the region with the higher capital-labor ratio will *ceteris paribus* specialize in agriculture. HOV theory also predicts that the specialization after trade will be incomplete when the two regions are sufficiently similar. Third, 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. This component gives rise to the primary concern here: Does trade hurt the South?

1.2 Technological change

Workers employed in manufacturing learn from every unit they manufacture. However, modern firms do not internalize this knowledge creation. It is a byproduct of their manufacturing activity and, as such, a 'dynamic externality'. Similar externalities were elaborated in Arrow (1962) and, more recently, P. Romer (1986). Many forms of endogenous growth stem from sources that cannot be internalized completely by markets because knowledge is a public good so that its creation is generally underpriced. Under the assumption that there will be a continuum of modern firms, each producing exactly one variety, knowledge creation can be given the following form of a pure externality:

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

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 more rapidly, 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 main results of the model as long as learning by doing is faster in industry.

1.3 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

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

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

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

[2] θ has to lie between zero and one for $u(\cdot)$ to be a well-defined utility function. The requirement that α not exceed unity can be justified from the implied elasticities of substi-

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 the agricultural good is the *numéraire* with $P_X \equiv 1$, while p_n is the unit price of variety n of the modern good. For the consumer's 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.

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

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

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 to 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 becomes

$$u(\tau) = T\; Y^i(\tau)\, P(\tau)^{-\theta}, \tag{10}$$

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

2 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:

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

tution. In a 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 $1/(1-\alpha)$. In order to obtain stronger substitutability among modern goods than between them and the agricultural product, $1/(1-\alpha) \in (1, \infty)$ is needed, i.e. $\alpha \in (0, 1)$.

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

In this section, two convenient equilibrium relationships are derived first: the equilibrium scale of production of modern firms and the equilibrium number of modern firms. They take the same functional form under autarky and free trade. Then, the autarky equilibrium and finally the world trade equilibrium will be derived. For ease of notation, the time variable is dropped 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.

2.1 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. Under 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 drive profits down to zero. Given production technology (2), each firm's cost function is $C(w^i, z_n^i) = w^i z_n^i / A^i + w^i L_0$. A firm n finds it optimal to employ $L_n^i = z_n^i / A^i + L_0$ 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. 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. So, the optimal quantity z_n^i is determined by the profit maximizing condition that marginal revenue equal marginal cost $p_n^i\,(1 - \epsilon_{p_n,d_n}) = w^i / A^i$.

Neglecting equilibria in which varieties are sold at different prices, one can follow Dixit and Norman (1980) and Krugman (1980) and assume that the equilibrium is symmetric. This simplifies the 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 $1/\alpha$ approximately derives from demand elasticity (9) for a large measure of firms. The approximation $1-\epsilon_{p_n,d_n} \approx 1-1/\epsilon_{d_n,p_n} \approx \alpha$ only implies 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 to the modern sector, λ^i, will not depend on this simplification.

In an unregulated market, entry will occur until profits are driven down to zero: $\pi^i_n = (p^i_n - w^i/A^i)\, z^i_n - w^i L_0 = 0$. 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 $L^i = L_0/(1-\alpha)$ workers in a symmetric equilibrium. Were firms not able to charge a premium over 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).

2.2 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 looking 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 the fixed amount of labor L_0 or the higher the monopoly power of firms (the lower α), the more firms enter. Independent of the concrete parameter values, entering firms will compete all rents away.

2.3 Autarky equilibrium

Four markets 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:

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

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, labor market clearing was implicitly imposed: $L_N^i + L_X^i = L^i$. The last among the four markets—the capital market—must clear by Walras' Law.

The interest rate r^i is such that the agricultural sector finds it optimal to employ all supplied capital. The labor market clears at a wage rate w^i equal to the marginal product in both sectors, the market for modern goods clears at a price p^i given by (12), and the agricultural good sells at a price of $P_X = 1$. So,

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

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

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

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 a period can be expressed as functions of the labor share λ^i. What 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 can be expressed with 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. 29. ■

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 ($1/(1-\alpha)$) since it only matters for the number of modern firms, not for the size of the sector as a whole. In general equilibrium, the number of modern firms is directly proportional to the labor share in the modern sector by (15). The total of modern goods is $N^i z^i = \alpha A^i \lambda^i L^i$ by (13) and (15). Productivity growth stems exclusively from learning by doing in the modern sector. By (3), it equals $BN^i z^i$. The learning function thus takes the value $\dot{A}^i = A^i\,\alpha\theta B L^i/(\theta+(1-\theta)\gamma)$ in an autarky equilibrium.

2.4 Equilibrium under free trade

Let both regions open up completely 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 results simple, restrict attention to an equilibrium in which all varieties from one region sell at the same price world wide. All Southern goods sell at price p^S and all Northern goods at p^N.

The price relationships and market clearing conditions that applied to autarky continue to hold in a world trade equilibrium—with three exceptions:

the market clearing condition for the agricultural good and the market clearing conditions for the Southern and Northern 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. Denote Southern consumers' demand for modern goods from region j by $d^{j,S}$. More generally, $d^{j,i}$ modern goods are delivered from region j to consumers in region i. Then, market clearing 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

$$\begin{aligned} d^{j,S}+d^{j,N} &= \frac{\theta\left(Y^{S}+Y^{N}\right)}{\left[N^{S}(p^{S})^{-\frac{\alpha}{1-\alpha}}+N^{N}(p^{N})^{-\frac{\alpha}{1-\alpha}}\right]}\cdot\frac{1}{(p^{j})^{\frac{1}{1-\alpha}}} \\ &= \frac{\alpha}{1-\alpha}L_{0}\cdot A^{j}=z^{j} \qquad j=S,N. \end{aligned} \tag{27}$$

Dividing (27) for the North by (27) for the South, 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 can be described by 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 agricultural good.

Just as for the derivation of autarky equilibrium, it 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, define two handy variables called *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 the same 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 $A^{-i}/A^i(t)$ is the *productivity gap* between the two regions $-i$ and i. The factors $(A^{-i}/A^i)^{\alpha}$ and $(A^{-i}/A^i)^{(1-\alpha)\frac{\gamma}{1-\gamma}}$ affect both specialization forces in this particular form due to monopolistic competition in the modern sector. The factors 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. So, α and γ in the powers on A^{-i}/A^i determine the behavior of the specialization forces. Their presence will be the key to growth convergence.

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

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

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

Corollary 2.3 *Since capital is immobile across regions, each region will host an agricultural sector and cannot specialize completely in the modern sector.*

Proof. In appendix B, p. 29. ∎

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 ongoing economic changes. Note that the specialization forces for regions i and $-i$ are not the inverses of each other. Rather, $\Lambda^i = 1 + 1/(\Lambda^{-i} - 1)$ and $\Gamma^i = 1 + 1/(\Gamma^{-i} - 1)$.

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

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	$\neq 1$

technology $Z^i = A^i L^i$ (and $L_0 = 0$). 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 agricultural production is modified 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 in HOV 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. So, it seems slightly more appropriate in the present context to view A^i to mean labor productivity.

Intraindustry trade ends with simple '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 $(A^{-i}/A^i)^\alpha < (A^{-i}/A^i)$. This distortion gives rise to the possibility that convergence across regions can occur even though growth stems from a dynamic externality.

3 Managing to Converge: The Technology Gap under Free Trade

How does the specialization force Λ^i/Γ^i and how does the productivity gap between countries A^{-i}/A^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, set $L^{-i} = L^i = 1$ for the discussion in this section.

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

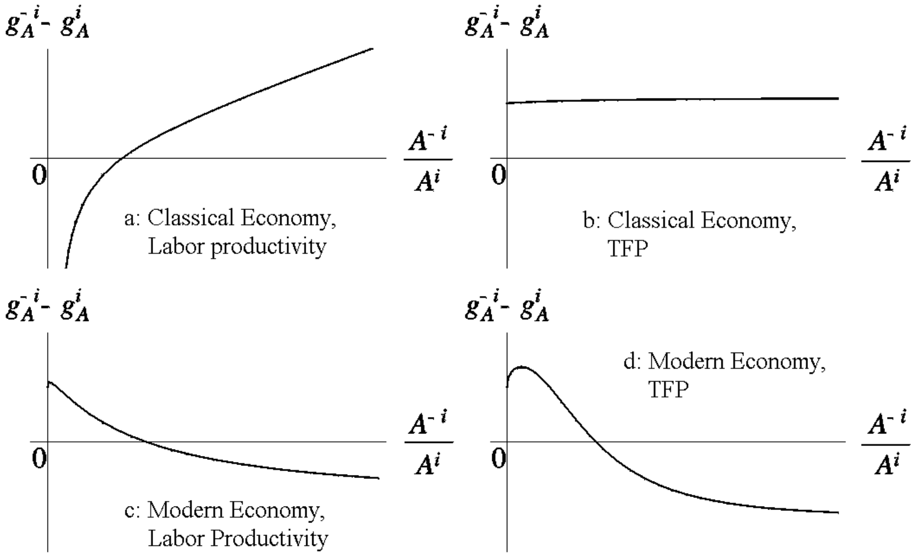

Figure 1: **Divergence and Convergence Patterns**

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. 15).

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. 15).[3] In figure 1, the two 'classical economies' are depicted in the upper row. They diverge after trade liberalization, whereas 'modern economies' converge in productivity levels as depicted in the lower row. The examples in figure 1 are representative of more general cases to be derived below.

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*

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

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 $\alpha<\gamma$ (proposition 4 below will formalize this). 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 monopoly power, the less modern goods $Z^i = N^i z^i = \alpha A^i \lambda^i L^i$ 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 productivity gap has more impact on $\Lambda^i = 1 + (A^{-i}/A^i)^{\gamma\frac{1-\alpha}{1-\gamma}}(K^{-i}/K^i)$. A widening of the productivity gap A^{-i}/A^i 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. When the productivity gap opens, it has a reverting effect because factor remuneration of skilled workers makes modern production less desirable in a region with a productivity advantage beyond the steady-state level.

[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, $\alpha = \frac{2}{3}\gamma \approx .43$.

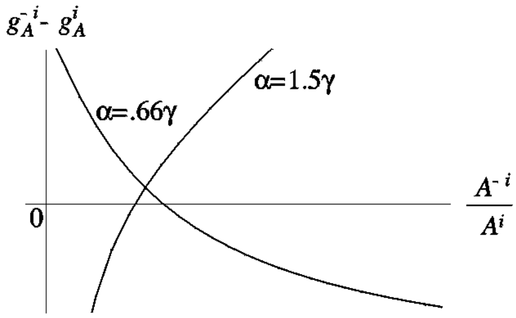

Figure 2: **Divergence and Convergence in the Modern Economy**

In figure 1, α is chosen to be relatively small relative to γ ($\alpha = \frac{2}{3}\gamma$). However, for relatively large α ($\alpha = \frac{3}{2}\gamma$), divergence can also occur for modern economies. This is depicted 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.15) 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:*

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

   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. 15).

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. 30. ■

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 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 initial technology gap were severe and A^{-i}/A^i very small.

Policy advice—such as Rodrik (1999) provides, for instance—often stresses the importance of "making openness work" through sound domestic development policies so that an economy can successfully participate in the global marketplace. 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 growth to their trading partners. Once they have successfully prepared themselves for the participation in intraindustry trade, these countries need not fear a negative impact of trade liberalization on their domestic growth. After trade liberalization, dynamic externalities will not widen but reduce the technology gap between South and North to a steady-state level. However, trade will not go further than that. The steady-state level of the technology gap itself can only be reduced through own knowledge creation or knowledge transfers.

3.1 P. Romer's (1990) economy

Even though close-form solutions are hard to obtain in more elaborate growth models, it is conceivable that similar forces as in the present model prevail and close the technology gap to a steady-state level. P. Romer's (1990) economy, for instance, 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) are careful to recommend free trade only for similar regions. It is likely, however, that divergence need not result in their models because of the same reasons for which convergence occurs in the present model.

Compared to the present model, Romer's (1990) economy could be viewed as a one-sector version 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, a third factor in final production was suppressed). 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 given 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 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 Romer (1990) model is closed. One can 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, 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 model become $X^i = (A^i)^{1-\gamma} ((1-\lambda^i)L^i)^\gamma (\overline{z}^i)^{1-\gamma}$ and $Z^i = A^i(t)\overline{z}^i$. Comparing these production functions to (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 to the Romer model. Therefore, convergence is likely to occur for large γ just as in the model of the present paper.

4 Agreeing to Diverge: A Dynamic Welfare Analysis

Following P. 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 that widely differ in factor endowments or initial productivity start to trade. Some of these approaches, such as Young (1991) or Xie (1999), consider a partial equilibrium, and may therefore miss forces that result in growth convergence as in section 3. Moreover, an explicit comparison of welfare losses from slower growth to welfare gains from increased trade seems necessary for normative conclusions. This section provides a dynamic welfare analysis. For this comparison, learning by doing is assumed not to be internalized at all. In addition, only welfare gains that stem from concavity of utility are considered here—neglecting any additional welfare effects from the availability of more 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.

4.1 Repeated static gains

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

Lemma 1 *For all economies in table 1 (p. 15), 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. Here, $V \equiv \frac{1}{\alpha}(L_0)^{\frac{1-\alpha}{\alpha}}[\theta+\gamma(1-\theta)]^{\frac{1}{\alpha}}/(1-\alpha)^{\frac{1-\alpha}{\alpha}}\theta^{\frac{1-\alpha}{\alpha}}$.

Proof. In appendix D, p. 31. ■

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). An open economy's terms of trade determine its access to wealth and are an important aspect of its welfare. The welfare gains or losses from free trade can be inferred from the representative agent's utility levels. Indirect utility is given by (10).

Proposition 5 *For all economies in table 1 (p. 15), utility attains a level of*

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

after trade liberalization, while it was

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

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

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

Proof. Using the results of lemma 1 in indirect utility $u^i = TY^iP^{-\theta}$ from (10) 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. One could call it, somewhat euphemistically, the '*output effect*'. In fact, this is no real effect because the true *reallocation effect* was captured entirely by the previous term. The nominal '*output effect*' arises because the agricultural good is the *numéraire*. Were the modern good the *numéraire*, the effect would work differently.

The third term in (42) exclusively captures the *price effect* of trade liberalization. Its moves incorporate the terms-of-trade effect: A slowly growing region can share in the growth of the other region through an improvement of its terms of trade. 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 nominal '*output effects*' so that the true welfare gains from trade are captured. The analysis highlights that, in an open economy, welfare gains of the representative agent cannot be inferred directly from changes in output.

An economy gains from trade liberalization in static terms iff u^i_{trade}/u^i_{aut} exceeds unity in (44). In 'classical economies', $\alpha = 1$ so that the factor $\Lambda^i(t)^{\frac{1-\alpha}{\alpha}\theta}$ in expression (44) drops out. The term captures the utility that consumers derive from varieties in 'modern economies'. Since these gains stem from the particular form of utility that was imposed and go beyond gains from concavity, these extra-gains will be disregarded in the following arguments.

The first factor in (44) expresses conventional static gains from trade. 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 unity, their ratio cannot become negative and $x \in (0,\infty)$. Figure 3 plots the utility ratio as a function of the specialization forces. Conventional 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 so that their ratio equals one. As is well known since David Ricardo, there are no static losses from trade. In fact, as the concave curve in figure 3 illustrates and 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 represents the utility level in autarky. Any move away from unity on this axis increases 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?

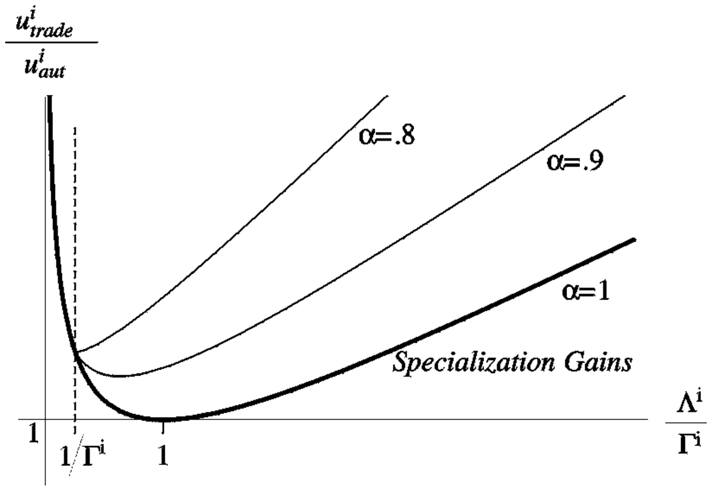

Figure 3: **Gains from Trade**

4.2 Dynamic welfare analysis

To analyze the trade-off between repeated static gains from trade and potential dynamic losses, a dynamic criterion beyond (44) is needed. 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

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

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

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

This implicitly defines a 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, this ratio must not exceed $1 - u^i_{aut}/u^i_{trade}$. To evaluate u^i_{aut}/u^i_{trade}, one can choose the point of complete specialization in agriculture as reference value: $\Lambda^i_0/\Gamma^i_0 = 1 + \theta/[\theta+\gamma(1-\theta)]$. At that point, region i stops growing and incurs the worst dynamic loss possible. Table 2 reports values of $1 - u^i_{aut}/u^i_{trade}$ for different parameter choices. As long as the ratio $g^i_{A,aut}/\rho$ is less than or equal to the values reported, region i prefers 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. A region chooses free trade if the condition in table 2 is satisfied but not only in that case. First, to keep calculations simple, the more advanced foreign region $-i$ was assumed not to grow after

Table 2: Lower Bounds on $g_{A,aut}/\rho$ for Trade Liberalization

$\left(1-\frac{u_{aut}}{u_{trade}}\Big\vert_{\frac{\Lambda}{\Gamma}=1+\frac{\theta}{\gamma(1-\theta)}}\right)$	$\theta=.3$	$\theta=.5$	$\theta=.7$
$\gamma=.1$	.228	.464	.676
$\gamma=.3$	.091	.229	.401
$\gamma=.5$	.045	.123	.237
$\gamma=.7$	.020	.059	.122

Criterion: Free trade iff $\frac{g_{A,aut}}{\rho} \leq 1-\frac{u_{aut}}{u_{trade}}\Big\vert_{\frac{\Lambda}{\Gamma}=1+\frac{\theta}{\gamma(1-\theta)}}\Big)$

trade liberalization. The model, however, predicts increased growth in the more advanced region after trade liberalization and the less advanced region can share in this growth through improving terms of trade. Second, the less advanced region was assumed to stop growing immediately. However, there is a transition period of slowing but non-zero growth. On both accounts, the LDC would benefit. Finally, an average growth rate of 5% *forever* is high even for successful developing regions (Sachs and Warner 1995).

So, for a reasonably broad range of parameter values, regions strictly prefer trade over autarky even if they subsequently grow more slowly. The calculations have an immediate implication especially for a poor economy with relatively low productivity levels and autarky growth prospects. Call such a place Antarctica, say. If potential trading partners raise their productivity at a relatively fast rate, the specialization forces that would prevail if Antarctica opened up to free trade get stronger and stronger. They surpass the boundary level at some point. Thus, a country with lastingly 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 may 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.

The cases considered are worst-case scenarios for LDCs. The only source of growth is a not even partly internalized dynamic externality. Even under such conditions, the dynamic losses from trade may be small compared to repeated static gains. In practice, own R&D efforts and knowledge transfers help nurture innovative and growth promoting sectors so that the worst case is unlikely to apply.

5 Conclusion

What do new trade and new growth theory imply for welfare and growth convergence after trade liberalization? Four types of economies are considered in the present paper. They exhibit two types of productivity change—labor and total factor productivity growth—, and two types of competition in the sector that determines growth—perfect competition under constant returns to scale and monopolistic competition under increasing returns to scale. Both perfect competition and monopolistic competition leave no rents to be shifted across regions. So, industry location does not matter in this static sense. It matters heavily, however, for the dynamic externality from learning by doing. When labor is immobile across regions, the more modern firms a region hosts the more it benefits from this growth externality.

The main insights of the paper are twofold. First, and in contrast to previous arguments in new growth theory, if the innovative sector is characterized by monopolistic competition, then free trade can result in international growth convergence. The reason is that monopolistic competition can revert the forces of specialization that prevail in classic trade theory. Countries that manage to participate in intraindustry trade for advanced goods after trade liberalization are likely to converge to the growth rates of richer countries. Specialization in low-growth sectors will not make these countries fall behind.

Second, gains from international trade and specialization are static gains, repeatedly realized in every instant, and sum up to large benefits over time. These benefits can outweigh dynamic losses from slower growth after trade liberalization, and countries may choose free trade over isolation even if trade causes divergence. In addition, the slower growing regions can share in the wealth creation of the faster growing regions through improving terms of trade. As a consequence, trade and divergence can be better than isolation for substantial ranges of parameters.

Even though these results speak strongly for trade liberalization, it should not be seen as an unconditionally desirable policy. In the light of the convergence result, a country may also choose to pursue temporary trade restrictions, prepare its domestic industries for their successful participation in intraindustry trade, open up to free trade as soon as the modern sector is able to compete successfully with foreign firms, and then benefit from convergence under international trade. In this sense, developing countries can engage world markets on their own terms.

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

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

By (15) in the text, 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. 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 (3·2) price equations (18), (19), (20), and the four (2·2) 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 to unity.

Using the three price relationships once for market clearing in the modern sector and once for market clearing in agriculture, λ^i can be expressed in terms of agricultural output. That yields

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

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 yields

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

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 2.3, 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 2.2 immediately follows from (31) with $\lambda^i = 0$. ∎

C Convergence Conditions

Proof. For ease of notation, denote the productivity gap by $a_0 \equiv A_0^{-i}/A_0^i$, the ratio of capital stocks by $k \equiv K^{-i}/K^i$ 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 $a \equiv A^{-i}/A^i$ 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 $\left[a_0(1+a_0{}^2) + a_0{}^2(k^{-1}+k)\right] / \left[a_0(1+a_0{}^2) + 2a_0{}^2\right] \geq 1$, 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 $\partial\left(\Lambda^i/\Gamma^i\right)/\partial\left(A^{-i}/A^i\right) \geq 0$ iff $a^{\delta_L - \delta_K} l \left(1 + k a^{\delta_K}\right) / k \left(1 + l a^{\delta_L}\right) \geq \delta_K/\delta_L$. Since $\delta_K/\delta_L = 0$ 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 holds.

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 $k_0 = a_0^{\delta_L - \delta_K}$. 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 $\delta_K = (\gamma - \alpha\gamma)/(1-\gamma)$ for A^i being labor productivity and $\delta_K = (1-\alpha\gamma)/(1-\gamma)$ 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

$$Y_{trade}^i = X_{trade}^i \left[(1-\gamma) + \frac{\theta + \gamma(1-\theta)}{1-\theta} \frac{1 + \frac{X_{trade}^{-i}}{X_{trade}^i}}{\Lambda^i} \right],$$

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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