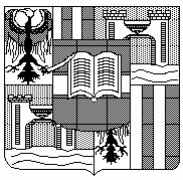

DEPARTMENT OF ECONOMICS
JOHANNES KEPLER UNIVERSITY OF LINZ

Specialization on a Technologically Stagnant Sector Need Not Be Bad for Growth

by

Gabriel J. Felbermayr

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Johannes Kepler University of Linz
Department of Economics
Altenberger Strasse 69
A-4040 Linz - Auhof, Austria
www.econ.jku.at

gabriel.felbermayr@jku.at
phone +43 (0)70 2468-8265

Specialization on a Technologically Stagnant Sector Need Not Be Bad for Growth

Gabriel J. Felbermayr*

Johannes Kepler University Linz, Austria,

and European University Institute Florence, Italy

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Abstract

This paper presents a simple North-South model of endogenous growth, based on learning by doing, which is consistent with the following empirical observations: (i) the price of investment goods relative to consumption goods has been falling for the last 40 years in most industrialized countries, (ii) poor countries are net importers of investment equipment and (iii) after a period of initial convergence, the sample of open economies exhibits remarkable stability of the per capita income distribution. In contrast to the research tradition started by Lucas (1988), in the proposed model, specialization on the technologically stagnant consumption sector does not entail a growth penalty.

Keywords: Endogenous growth, AK model, International Trade, Embodied Technical Change.

JEL classification: F43; O41.

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*Department of Economics, Johannes Kepler University Linz, Altenberger Strasse 69, A-4040 Linz-Auhof, Austria. E-mail: gabriel.felbermayr@jku.at. I thank seminar participants at the University of Linz, EUI, the 6th Workshop on International Economic Relations at the University of Göttingen and the LACEA 2002 conference in Madrid. Special thanks is due to Hartmut Egger, Omar Licandro and Wilhelm Kohler for helpful comments.

1 Introduction

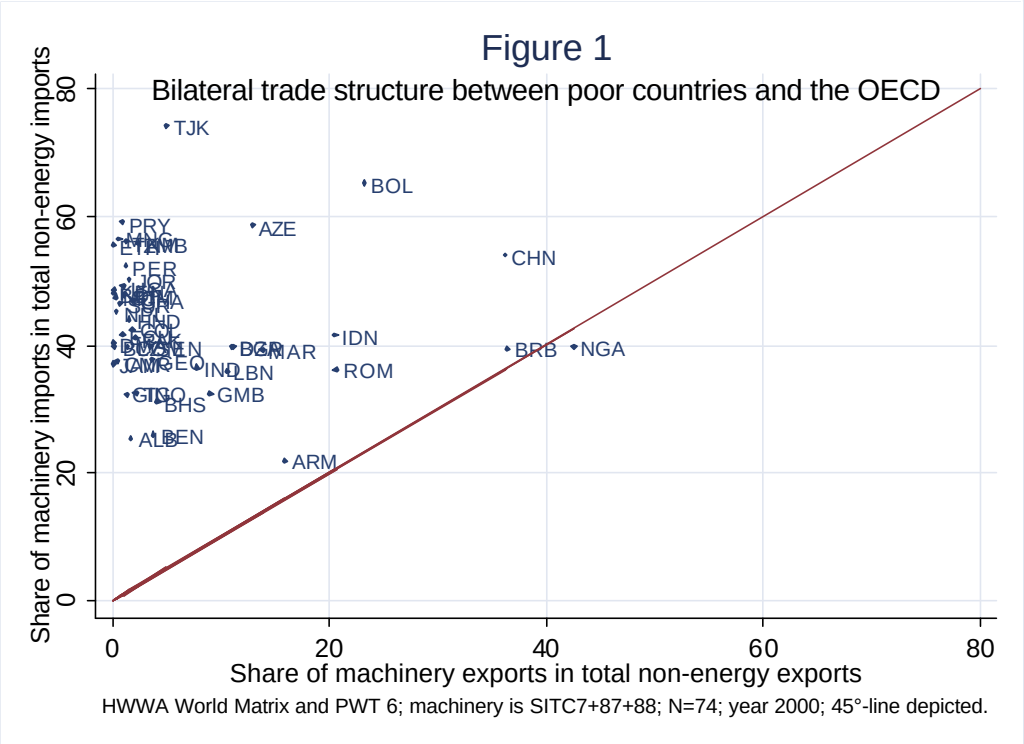
Lucas (1988), Stokey (1991) and Young (1991) have started a strand of research which argues that international trade may cause persistent cross-country differences in per capita real income growth. This result is derived in a framework where only consumption goods are traded internationally, there is *no physical capital*, and countries have identical preferences. Endogenous growth is due to unintentional sector specific learning by doing, the scope for which differs across sectors. Then, a country driven by static comparative advantage to specialize on a 'low-learning' sector, suffers a growth penalty and the global income distribution features divergence.

Many recent theoretical studies use variants of the above mechanism but differ with respect to the precise reason why some countries specialize on low-growth industries and others do not. However, they share the prediction that trade liberalization may trap some countries into a low-growth regime and that those unlucky countries are also likely to be found in the Southern hemisphere.

The present note argues that in a model with physical *and* human capital where investment *and* consumption goods are tradeable and technological change is embodied, specialization on the technologically stagnant consumption sector does not entail a growth penalty: the lack of own productivity growth is offset by a continuous decline in the relative price of the imported investment good. In contrast to Lucas-type models, this terms of trade trend improves domestic investment opportunities so that the pattern of specialization is irrelevant for real income growth and the global income distribution.

The proposed model predicts, in line with the data, that the income distribution within open countries exhibits remarkable stability. And it builds on two important empirical observations: first, in many industrialized countries the *price of investment goods relative to consumption goods has been falling rapidly* over the last decades, highlighting the relevance of embodied technological change (see Cummins and Violante, 2002, for US evidence). Second, *poor countries' are net-importers of investment goods and net-exporters of consumption good*. Figure 1 looks at bilateral trade in goods (excluding energy) between poor countries and the OECD as a whole in the year 2000. Plotting the share of machinery exports in total exports on the x-axis and the share of machinery imports on the y-axis, almost all poor

countries lie far north-west above the 45°−line[1]. Thus, their exports to OECD countries are heavily biased towards consumption goods (defined as non-investment goods) while their imports from OECD countries are mainly made up by investment goods. Moreover, it turns out that this pattern grows stronger the poorer the countries are[2].



To the extent that investment in poor and rich countries does not differ too dramatically in terms of composition, the above observations suggest that poor Southern countries face a continuous improvement of their terms of trade. Moreover, they appear to be close to complete specialization on consumption goods.

[1]The share of machiney exports in GDP is extremely low in outlier countries such as Nigeria (0.21%), Barbados (0.45%) or Armenia (0.95%). The share is more substantial in China or Indonesia.

[2]A simple regression exercise over a sample of 97 countries reveals that the difference between a country's share of machinery in non-energy imports and its share of machinery in non-energy exports is strongly declining in the log of per capita income. Doubling per capita income yields a decrease in the measure by over 8 percentage points. The estimate is fairly precise (with a t-value of 5.83) and the R^2 of the regression is 0.2306.

Building on the above facts, this paper presents a simple learning by doing model, isomorphic to Rebelo's (1991) two-sector AK model, and closely related to Boucekkine et al. (2003) who study embodied technical change in a closed economy. Within this framework, trade between a capital-rich North and a capital-poor South is analyzed. Despite South's specialization on the stagnant consumption sector, equilibrium growth rates are identical across countries, while per capita income inequality persists. In the present model, trade liberalization does not change the long-run growth rate of output in the North, while the long-run growth effect in the South is ambiguous. Finally, during the adjustment period to the new balanced growth path, the South grows faster than the North, but the catching-up process dampens off before real income levels are equalized.

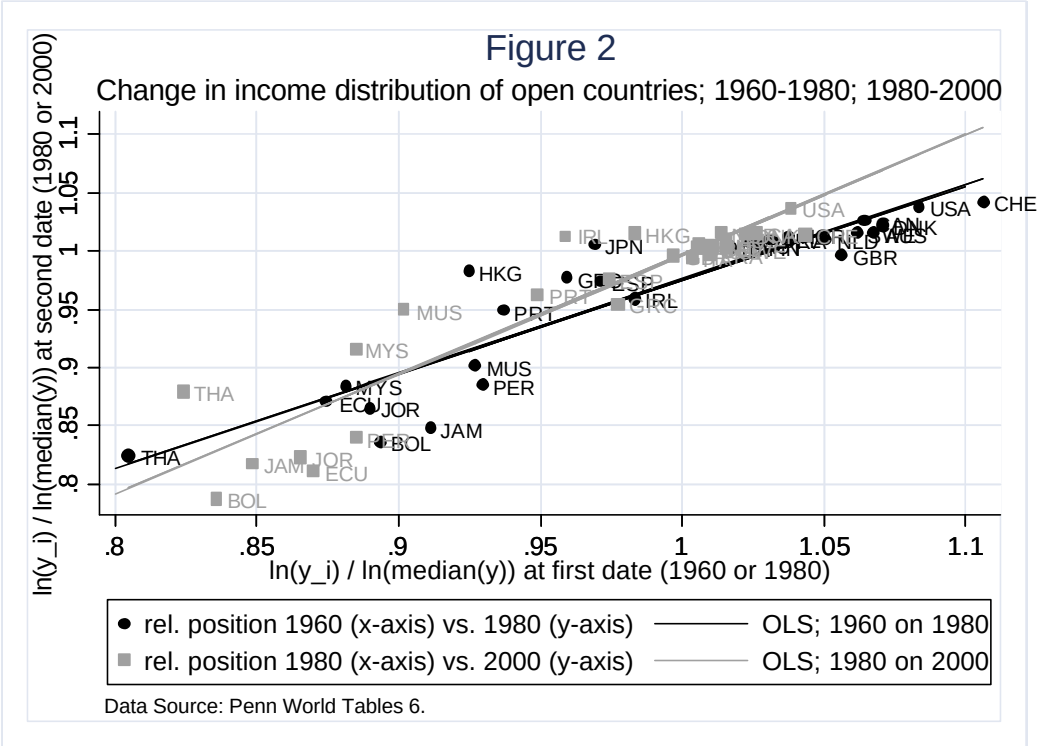
Figure 2 is similar to a picture in Acemoglu and Ventura (2002), but splits the time horizon into two sub-periods. It examines the evolution of the distribution in real per capita income within the sample of open economies. We define as open an economy that the Sachs and Warner's (1997) index classifies as open for at least 10 years within the period 1960 to 1980[3]; this is the case for 28 countries[4]. The data on income comes from the Penn World Tables (line rgdpch). The figure overlays two scatter plots: one where the x-axis depicts a country's income relative to the median in 1960 and the y-axis shows the same measure in 1980, and a second where the x-axis looks at the same measure in 1980 and the y-axis examines the year 2000. The first scatter plot is characterized by a cloud of black circles, the other by a cloud of grey squares.

The figure also shows regression lines fitted to the scatter plots. For the period 1960 to 1980 the regression $\ln y_{1980}/median(\ln y_{1980}) = \alpha + \beta\,[\ln y_{1960}/median(\ln y_{1960})]$ was run, using OLS and correcting the standard errors for heteroskedasticity. It yields a coefficient $\hat{\beta} = 0.8074$ with a t-value of 13.89 and an R^2 statistic of 84.25. An F-test on $\beta = 1$ was run and the Null was rejected at the 1% level ($F(1, 26) = 10.97$). For the period 1980 to 2000 a similar regression was run. Now $\hat{\beta} = 1.0281$ with a t-value of 9.23 and the R^2 statistic

[3] We use the dataset provided in Easterly, Levine and Roodman (2003). Those authors updated the original Sachs-Warner index and corrected some mistakes.

[4] The countries are: Australia, Austria, Belgium, Bolivia, Canada, Denmark, Ecuador, Finland, France, Greece, Hong Kong, China, Ireland, Italy, Jamaica, Japan, Jordan, Malaysia, Mauritius, Netherlands, Norway, Peru, Portugal, Spain, Sweden, Switzerland, Thailand, United, Kingdom, United States. Out of this sample of 28 countries, in 1975 19 were OECD members.

shows a value of 0.8550. The F-test ($F(1,26) = 0.06$) cannot reject that $\beta = 1$. The slope β indicates whether there was convergence ($\beta < 1$), stability ($\beta = 1$) or divergence ($\beta > 1$) over the period in question. Thus, we are led to conclude that the period 1960-1980 looks as if there was convergence in real per capita incomes between open economies, while the period 1980-2000 was a period of stability.



The main reference of the paper is Lucas (1988) and the following endogenous growth literature that examines the effects on learning by doing and international specialization on the cross-country distribution of income. The proposed model is close to Acemoglu & Ventura (2002), who also study the implications of terms of trade movements on countries' incentives to accumulate capital. It is, however, different to their model, in that it brings the empirically relevant case of trade in investment goods together with well documented evidence on embodied technical change. The model is also close to dynamic two-country, two-sector, two-factor Heckscher-Ohlin models, see for example Chen (1992) or Ventura (1997) and the references therein. However, these papers consider diversified economies only and do not discuss the implications of embodied technical change in a free-trade environment.

The remainder of this paper comes in four sections: section 2 briefly reviews the Lucas mechanism, section 3 introduces the model and proofs the main proposition of the model, section 5 provides some discussion of the results and section 4 concludes.

2 The Lucas mechanism

Since the present paper makes major reference to Lucas (1988) (section V), a brief overview of his model seems valuable. In his model, there are two technologies, which are used to produce two distinct consumption goods. Technologies are linear in labor and there is no physical capital. It is easiest to understand his setting by alluding to a two country case, but generalizations are easily possible. In both countries, consumers have identical preferences and the technological description is given by

$$y^i_{s,t} = h^i_{s,0} e^{\delta_s t} N^i_{s,t} \text{ with } N^i_{1,t} + N^i_{2,t} = 1. \tag{1}$$

where countries are indicated by a superscript $i \in \{1,2\}$. The first subscript $s \in \{1,2\}$ refers to the sector, and the second, $t > 0$, to time. Sectoral output quantities are given by $y^i_{s,t}$, the share of labor allocated to sector s is $N^i_{s,t}$ and the total labor force in each country is normalized to unity. Sectoral productivity depends on unintentional learning by doing and is given by the amount of sector specific human capital given by $h^i_{s,0} e^{\delta_s t}$. While the initial stock $h^i_{s,0}$ differs across countries, the rate of learning, δ_s, is the same.

In autarky, each country produces both goods; in a trade equilibrium, the linearity of the sectoral production functions implies that countries will completely specialize on one good. This equilibrium is determinate, if $h^1_{s,0} \neq h^2_{s,0}$. In the remainder, we assume that $h^1_{1,0} > h^2_{1,0}$, so that country 1 specializes on good 1 and country 2 on good 2. Lucas assumes that the specialization pattern does not revert.

In each country, there is a representative consumer with identical CES preferences, characterized by an elasticity of substitution $\bar{\sigma} > 1$. Homotheticity implies that consumers hold nominal expenditure shares constant. Then, as the worldwide supply of good 1 grows faster than that of good 2, the relative price of good 1, p, has to fall over time. The rate of decline is just $\frac{\dot{p}}{p} = -\frac{\delta_1 - \delta_2}{\bar{\sigma}}$.

A country specializing on good 1 (country 1) sees its nominal income (in units of the numeraire, good 2) increase at rate $\delta_1 - \frac{\delta_1 - \delta_2}{\bar{\sigma}}$, while nominal income in the country specializing on good 2 (country 2) is δ_2. Denoting the expenditure share of good 1 by θ, the true price index evolves with rate $-\theta\left(\frac{\delta_1-\delta_2}{\bar{\sigma}}\right)$. Hence, real income in country 1 grows at rate $g_1 = \delta_1 - (1-\theta)\left(\frac{\delta_1-\delta_2}{\bar{\sigma}}\right)$ while it grows at rate $g_2 = \delta_2 - \theta\left(\frac{\delta_1-\delta_2}{\bar{\sigma}}\right)$ in country 2. Comparing these growth rates, it follows that $g_1 > g_2$. Hence, the country specializing on the stagnating sector 2 grows at a smaller rate than the other country.

Note that country 2 does benefit from technical progress in country 1 since its terms of trade are permanently improving. However, this trend is irrelevant for country's productive capacity and for the rate at which human capital is accumulated.

3 A learning by doing model with embodied technical change

3.1 Setup

The model features two goods, a consumption good, and an investment good. The consumption good is produced from capital and labor according to a Cobb-Douglas function and can be either consumed or used as an input in the production of investment equipment. We normalize the labor force to unity and write k_t for the total capital stock. c_t^s and i_t^s stand for supply of consumption and investment goods, respectively. Input into the investment sector is written x_t. The parameter $0 < \alpha < 1$ describes the output elasticity of capital, and $z > 0$ and $a_t > 0$ denote the states of know-how in the consumption and the investment sector. As usual, the subscript t refers to time. Hence, the description of technology is given by

$$k_t^\alpha = c_t^s + x_t \text{ and } i_t^s = a_t x_t. \tag{2}$$

By assumption, there is no technical progress in the consumption sector, whence z is a constant. In contrast, know-how in the investment goods sector increases with accumulated net investment at the rate $0 < \gamma < 1$:

ASSUMPTION 1

$$a_t = Ak_t^{\gamma} \text{ where } A > 0 \text{ if } x_\tau > 0 \text{ for all } \tau < t \text{ and } A = 0 \text{ otherwise.} \tag{3}$$

Thus, technical progress is embodied in new investment goods and investment sector specific knowledge A depreciates totally and immediately if production of investment goods is stopped. This is probably the simplest way to represent the idea that knowledge is at least partly sector specific. Weaker assumptions are easily possible at the cost of complication: all we really require is that sector specific knowledge depreciates fast enough when $x_t = 0$, so that the specialization pattern following trade liberalization is irreversible. In autarky, $A > 0$ for all t; see Lucas (1988).

Technology in (2) is equivalent to Cobb-Douglas technologies in both sectors with the same output elasticity α but different total factor productivities: unity in the consumption sector and a_t in the investment sector. Imposing the knife edge condition $\alpha + \gamma = 1$, we have

$$c_t = (k_t^c)^{\alpha} \text{ and } i_t = A\left(k_t - k_t^c\right), \tag{4}$$

where k_t^c denotes the capital stock allocated to the consumption sector. Thus, our learning-by-doing framework with embodied technical change is isomorphic to Rebelo's (1991) two-sector AK model.

Whether the externality γ is internalized or not, matters only for the *size* of equilibrium growth rates but is irrelevant for the international *comparison* of growth rates. Therefore, for simplicity, we work with the central planner version of the model, but assume that the central planner neglects the effect of her decisions on the international price ratio and the dynamic implications of static comparative advantage.

3.2 Autarky

Under Autarky, domestic supplies and demands coincide. Using tildes to denote these autarky values, the central planner maximizes intertemporal utility subject to technological and

capital accumulation constraints:

$$\max_{\tilde{c}_t,\tilde{k}_t} \int_0^\infty \frac{\tilde{c}_t^{1-\sigma}}{1-\sigma} e^{-\rho t} \mathrm{d}t \text{ s.t. } \tilde{c}_t = \left(\tilde{k}_t^c\right)^\alpha \text{ and } \dot{\tilde{k}}_t = (A-\delta)\,\tilde{k}_t - A\tilde{k}_t^c, \tilde{k}_0 > 0. \tag{5}$$

As usual, $\sigma > 0$ denotes the inverse of the intertemporal elasticity of substitution, $\rho > 0$ is the subjective time discount rate, and $\delta > 0$ is the depreciation rate. A dot over a variable denotes a time derivative. From now on, we assume that

ASSUMPTION 2

$$A - \delta > \rho > \alpha\,(1-\sigma)\,(A-\delta) \tag{6}$$

holds. This double condition delivers positive equilibrium growth rates and makes sure that the optimization problem is well-behaved.

Writing g_x for the proportional growth rate of variable x, optimal consumption growth and the transversality condition are

$$\tilde{g}_c = \frac{1}{\sigma}\,(A - \delta - \rho + \tilde{\pi}_t)\,, \tag{7}$$

$$\lim_{t\to\infty} e^{-(A-\delta)t}\tilde{k}_t = 0 \tag{8}$$

The term $\tilde{\pi}_t$ can be recognized as the proportional rate of change of the price of investment goods relative to consumption goods, $\tilde{q}_t$. The optimal sectoral allocation of capital requires that $\alpha\left(\tilde{k}_t^c\right)^{\alpha-1} = A\tilde{q}_t$ from where it follows that $\tilde{\pi}_t = -\,(1-\alpha)\,\tilde{g}_{k^c} < 0$. This negative trend in the relative price of investment goods entails capital losses which increase the user cost of capital and therefore slow down the rate of growth of consumption. As shown by Rebelo (1991), the model does not exhibit transitional dynamics and the sectoral capital allocation is stationary from $t = 0$ on, so that $\tilde{g}_{k^c} = \tilde{g}_k$. Using the fact that $\tilde{g}_c = \alpha\tilde{g}_k = \alpha\tilde{g}_i$ we can write $\tilde{\pi}_t = -\,(1-\alpha)\,\tilde{g}_c/\alpha$ and solve (7) for $\tilde{g}_c$:

$$\tilde{g}_c = \frac{\alpha}{1-\alpha\,(1-\sigma)}\,(A - \delta - \rho)\,. \tag{9}$$

Felbermayr and Licandro (2003) provide more details and discussion. In particular, under autarky, capital-rich countries feature a lower level of $\tilde{q}_t$ than capital-poor countries.

3.3 Trade

At $t = 0$ countries switch unexpectedly from a state of perfect autarky to a situation where goods prices are determined internationally. At that point in time, North and South differ only with respect to their capital stocks and, possibly, investment sector efficiency A. Otherwise they are identical. While goods market are integrated, there is no international capital mobility. Thus, cross ownerships of capital stocks is ruled out, but part (or all) of the installed capital stock may have been produced abroad[5]. In the remainder, first we study the situation in a generic country and distinguish North and South by superscripts N and S only when we proceed to cross-country comparison. Moreover, international equilibrium magnitudes are identified by an asterisk.

In the integrated equilibrium the sectoral allocation of capital does not determine the equilibrium demand for consumption or investment goods. The planner therefore has two control variables: k_t^c and c_t where the first determines the sectoral allocation of capital and the second regulates the time path of the state variable, k_t. In making her choices, we assume that the planner takes the time path of the relative price of investment goods relative to consumption goods as given. This is an important assumption, since the planner could use commercial policy to influence domestic welfare and enter in a strategic game with the planner in the other country. For the sake of simplicity this kind of strategic behavior is not modelled. Note, however, that for the purpose of our main proposition, we need not assume that goods prices are completely equalized across countries. The result goes through as long as proportional changes in q_t are the same across countries, i.e. if the *relative law of one price* holds. Thus, our analysis is compatible with arbitrary trade costs (including optimal tariffs) as long as they are multiplicative (such as iceberg transportation costs or tariffs) and constant over time[6]. Thus, in the integrated equilibrium we allow that that $q_t^{N*} \leq q_t^{S*}$, while $\pi_t^N = \pi_t^S = \pi_t^*$. Thus, the main result of the paper is consistent with the fact established by Restuccia and Urrutia (2001), who show that q_t^S is still much higher than q_t^N.

[5] Obstfeld and Taylor (2003) document for 1997 that more than 80% of the world stock of foreign capital is invested in countries whose per capita income is above 60% of the US level.

[6] In the remaining analysis, we assume that trade costs are of the iceberg type. This avoids complications arising from tariff generated income.

We also assume that the planner does not internalize the implications of assumption (3), by which complete specialization is irreversible. This assumption avoids the technicalities associated with the discrete loss of investment sector specific expertise that specialization on the consumption goods sector entails. As long as $A^N \geq A^S$ it is inconsequential, because the planner would not be able to implement a better allocation if he took the loss of expertise into account. Moreover, the assumption is in line with Lucas (1988), where the long-run implications of irreversible specialization are not internalized neither.

In the trade equilibrium, domestic demands no longer need to equal domestic supplies. We label domestic demand for consumption and investment goods by c_t and i_t, while output supplies are given by $(k_t^c)^\alpha$ and $A(k_t - k_t^c)$, respectively. Trade is balanced, so that the value of domestic demand has to equal the value of domestic production (GDP), i.e. $c_t + q_t i_t = q_t A(k_t - k_t^c) + (k_t^c)^\alpha$ for all t. For the ease of presentation, it proofs convenient to split the planner problem into a static part determining the sectoral capital allocation k_t^c, and a dynamic part which sets c_t. [7]

The optimal capital allocation maximizes the country's GDP. Thus, we define the GDP function (a maximum value function)

$$y(k_t, q_t) = \max_{k_t^c} \left\{ q_t A(k_t - k_t^c) + (k_t^c)^\alpha \middle| \, k_t \geq k_t^c \right\}. \tag{10}$$

At the time of trade liberalization ($t = 0$), if the planner chooses to close down the investment sector, i.e. $k_0^c = k_0$, assumption (3) entails that investment sector specific know-how A falls to zero and remains nil. Hence, for all $t \geq 0$, we have $k_t^c = k_t$. Hence, depending on k_0 and q_0, the pattern of sectoral capital allocation obeys

$$\text{If } k_0 \leq \tilde{k}(q_0) = \left(\frac{\alpha}{q_0 A}\right)^{\frac{1}{1-\alpha}} \Longrightarrow k_t^c = k_t \text{ for all } t \geq 0, \tag{11a}$$

$$\text{If } k_0 > \tilde{k}(q_0) \Longrightarrow k_t^c = \tilde{k}(q_t) = \left(\frac{\alpha}{q_t A}\right)^{\frac{1}{1-\alpha}} < k_t \text{ for all } t \geq 0. \tag{11b}$$

[7] It is of course possible to nest the static and the dynamic problem into one single planner problem. This yields exactly the same first order conditions, but dealing with the possible corner solution in the capital allocation of the South becomes more cumbersome.

We are free to choose initial conditions k_0^S and k_0^N to make sure that the equilibrium level of q_0^* satisfies $k_0^S \leq \tilde{k}\left(q_0^*\right) < \left(\bar{k}_0 - k_0^S\right)$. Under this condition, the global endowment of capital is distributed over South and North such that South lies outside the diversification cone and completely specializes on the consumption sector. We will see below, that such a situation may be an equilibrium outcome.

The dynamic part of the planner's problem consists in choosing the optimal demand structure and the path of k_t:

$$\max_{\tilde{c}_t, \tilde{k}_t} \int_0^\infty \frac{c_t^{1-\sigma}}{1-\sigma} e^{-\rho t} \mathrm{d}t \text{ s.t. } c_t + q_t i_t = y\left(q_t, k_t\right) \text{ and } \dot{k}_t = i - \delta k_t, k_0 > 0. \tag{12}$$

The optimal growth rate of consumption and the transversality condition associated with the above program are

$$g_{c,t} = \frac{1}{\sigma}\left[R_t - \rho - \delta + \pi_t\right], \tag{13}$$

$$\lim_{t\to\infty} e^{-\int_0^t (R_\tau - \delta)\mathrm{d}\tau t} k_t = 0, \tag{14}$$

where $R_t \equiv \left(\partial y / \partial k_t\right) / q_t$ is the rental price of capital.

Using condition (11) and distinguishing between North and South by superscripts N and S, consumption growth rates can be written as

$$g_{c,t}^N = \frac{1}{\sigma}\left[A^N - \rho - \delta + \pi_t\right], \tag{15a}$$

$$g_{c,t}^S = \frac{1}{\sigma}\left[\frac{\alpha}{q_t^S}\left(k_t^S\right)^{\alpha-1} - \rho - \delta + \pi_t\right], \tag{15b}$$

where investment sector efficiency may differ across countries $\left(A^N \neq A^S\right)$ and international goods price arbitrage may be hindered by the existence of (constant) ad valorem tariffs, subsidies and / or multiplicative trade costs. In contrast to the autarky situation, the rental rate of the South depends on the state variable, since, $g_{c,t}^S$ now exhibits transitional dynamics. Because these dynamics have repercussions on the time path of π_t, there will also be transitional dynamics in $g_{c,t}^S$ .During the adjustment period, the specialized South experiences faster growth than the diversified North and π_t falls faster than along the balanced growth path.

Before moving to the main proposition of the paper, it is necessary to show that a market clearing relative price does indeed exist. Defining the average rate of change of the relative price of investment goods between times 0 and t as $\bar{\pi}_t = \frac{1}{t}\int_0^t \pi_z dz$, we have $q_t = q_0 e^{\bar{\pi}_t t}$. In order to identify the equilibrium level of q_t^*, we need to find the consumption functions in each country. Those can be recovered from the Euler equation (13) and the law of motion of capital. For simpler notation, we may define an interest rate as $r_t = R_t - \delta + \pi_t$ and consider the average interest rate between times 0 and $t : \bar{r}(t) = \frac{1}{t}\int_0^t r_z dz$. Writing w_t for the wage rate, integrating the law of motion of the capital stock and using the transversality condition (14), an intertemporal budget constraint can be derived which reads

$$\int_0^\infty c_t e^{-\bar{r}(t)t}\mathrm{d}t = q_0 k_0 + \int_0^\infty w_t e^{-\bar{r}(t)t}\mathrm{d}t. \tag{16}$$

This is just the usual requirement, that the present value of consumption equals wealth, defined as the sum of initial assets, $q_0 k_0$ plus the present value of wage income.

Integrating the Euler equation (13) between 0 and t yields

$$c_t = c_0 e^{\frac{1}{\sigma}(\bar{r}_t - \rho)t}. \tag{17}$$

Using this result in the intertemporal budget constraint, initial consumption is

$$c_0 = \left[\int_0^\infty e^{\frac{1}{\sigma}(\bar{r}_t - \rho - \bar{r}_t\rho)t}\mathrm{d}t\right]^{-1}\left(q_0 k_0 + \int_0^\infty w_t e^{-\bar{r}(t)t}\mathrm{d}t\right) \tag{18}$$

where the inverted square bracket denotes the propensity to consume out of wealth. Since $\bar{r}_t$ is a function of $\bar{\pi}_t$, for any $t > 0$ an international market clearing condition for the consumption good can be written as

$$X^c\left(q_0^*, \bar{\pi}_t^*; k_0^S, k_0^N\right) = \left[\left(k_0^S e^{\bar{g}_{k,t}^S}\right)^\alpha + \left(\frac{\alpha}{q_0^* A}e^{-\bar{\pi}_t^* t}\right)^{\frac{\alpha}{1-\alpha}}\right] - \left[c\left(q_0^*, \bar{\pi}_t^*; k_0^S\right) + c\left(q_0^*, \bar{\pi}_t^*; k_0^N\right)\right] = 0 \tag{19}$$

where $X^c(\cdot)$ denotes the global excess supply for good c and an asterisk denotes an international equilibrium price level or rate of change. The first square bracket denotes global supply for the consumption good, while the second square bracket denotes the sum of the national consumption functions. Note that $\bar{g}_k^S$ is itself a function of $\bar{\pi}_t$. By Walras law, once condition

(19) is met, the investment goods market also clears.

Clearly, both square brackets are positive, continuous and increasing functions in q_0 so that equation (19) has a solution q_0^*. The below proposition remains intact if we allow for deviations from free trade, e.g. in form of iceberg transport costs or other trade costs. In this case, $q_t^{N*} = q_t^*/\tau < q_t^* < \tau q_t^* = q_t^{S*}$, where $\tau > 1$ parametrizes the (symmetric costs) of shipping goods from North to South and vice-versa.

Focusing on the balanced growth path, we are now ready to state the main proposition of the paper:

PROPOSITION *Along the balanced growth path (BGP), if the 'relative law of one price' is valid, and the South specializes on the technologically stagnant consumption sector*
(i) cross country growth rates are identical and equal to

$$g_c = \frac{\alpha}{1-\alpha(1-\sigma)}\left(A^N - \delta - \rho\right), g_i = g_c/\alpha; \tag{20}$$

(ii) the proportional North-South income gap is non-zero and constant;
(iii) moving from autarky to free trade leaves the long-run growth rate in the diversified economy unchanged, while the specialized economy's growth rate may be higher or lower under free trade.

PROOF (i) Along the BGP, growth rates (including π_t), the nominal saving rate s_t, and the sectoral capital allocation are constant. Moreover, since $c_t = (1-s)\,y_t$ and $i_t = sy_t/q_t$, we have that $g_k = g_i = g_c - \pi$. For North to remain diversified for all $t > 0$, (11) requires that $\alpha\left(k_t^{c,N}\right)^{\alpha-1} = q_t^N A^N$ must hold; thus $g_k^N = -\pi^N/(1-\alpha)$. From expression (15b) it follows that along a balanced growth path g_c^S can be constant only if $g_k^S = -\pi^S/(1-\alpha)$. Thus, if the relative law of one price is valid, $\pi^N = \pi^S = \pi^*$, it also must hold that $g_k^N = g_k^S$. Moreover, since $g_c = g_k + \pi^*$ it follows that $g_c^S = g_c^N$.
The growth rate of consumption is found by substituting $\pi^* = -(1-\alpha)(g_c - \pi^*) \Longrightarrow \pi^* = -(1-\alpha)\,g_c/\alpha$ into (15a).

(ii) Comparing (15a) and (15b) shows that along the BGP the equality $g_c^S = g_c^N$ implies $\alpha\left(k_t^S\right)^{\alpha-1} = q_t^S A^N$. Moreover, a diversified production structure in North requires

$\alpha\left(k_t^{c,N}\right)^{\alpha-1} = q_t^N A^N$. Since $q_t^S \geq q_t^N$, it must be true that $k_t^S \leq k_t^{c,N} < k_t^N$. so that the Southern capital intensity remains always below the Northern one. Hence, in terms of the numéraire, per capita income in South will always be lower than in North $y_t^S = \left(k_t^S\right)^\alpha < q_t^N A^N \left(k_t^N - k_t^{c,N}\right) + \left(k_t^{c,N}\right)^\alpha = y_t^N$. Moreover, the proportional gap $\left(y^N - y^S\right)/y^S$ can be expressed as $q_t A^N \left(\frac{k_t^N - k_t^{c,N}}{\left(k_t^S\right)^\alpha}\right) + \left(\frac{k_t^{c,N}}{k_t^S}\right)^\alpha - 1$ which is a constant since $g_k^N = g_k^S$ $\pi = -(1-\alpha) g_k^S = -(1-\alpha) g_k^N$ and $g_k^N = g_k^S$.[8]

(iii) As (20) shows, only the diversified economy's level of A matters for the common growth rate. If $A^N < A^S$ and South is so capital-poor that it still specializes on the consumption sector, $\tilde{g}_c^S > g_c$ while $\tilde{g}_c^N = g_c$. In the opposite case where $A^N > A^S$ it holds that $\tilde{g}_c^S < g_c$ while $\tilde{g}_c^N = g_c$.

4 Discussion

On the measurement of growth across countries. Penn World Tables provide real GDP in purchasing power parities. In the above proposition, we have shown consumption grows at the same rate in North and South. Moreover, $g_c = g_y$, where y is in units of the consumption good. Since there is no change in the cost of living over time (the price of consumption goods has been chosen as the numeraire), we can directly interpret g_y as that growth rate computed in the Penn World Tables. This is also the measure that underlies our figure 2.

Note that in the model, even if trade does not completely eradicate international differences in the relative price of investment goods, along the balanced growth path the *rental rate of capital* is equalized over the two countries. Since both countries share the same isoelastic preferences of the CRRA family, the saving rate does not depend on the level of income or wealth. Hence, North and South share the same saving rate. Applying NIPA's methodology by which the growth rate of real output is a weighted average of the growth rate of investment and consumption, with the saving rate serving as weight, we derive identical growth rates

[8] Wheter q^N is used in valuing Northern output, or q^S or any other relative price does not matter for this part of the proof, as long as the relative law of one price holds.

in both countries. Hence, the result is robust to this change in the definition of real GDP growth.

However, if we compare an index of industrial output across North and South, the model trivially predicts that this index grows faster in the North than in the South.

No case for protectionism. Part (iii) in the proposition yields a rationale for an infant industry protectionist policy. If $A^N < A^S$, the South grows faster under autarky than the North, accumulating capital at a greater pace. By assumption, at time 0, the South lies outside the diversification cone if free trade were to be allowed. However, if trade liberalization is postponed sufficiently far, the difference between the Southern and the Northern capital-labor ratio might become so narrow, that the free trade equilibrium no longer entails specialization of the South. In this case, the factor price equalization theorem would hold, and both countries would grow at an identical rate because they would face the same accumulation incentives. This common growth rate would be a convex combination of $\tilde{g}_c^N$ and $\tilde{g}_c^S$, so that the North would benefit and the South would still be harmed. If liberalization is postponed even further, the South will be so much more capital rich than the North, that it will be the North that falls outside the diversification cone. Thus, trade liberalization at a later time might increase the Northern growth rate and lead to higher global growth.

However, this possibility is not sensible, both on theoretical and empirical grounds. The theoretical problem is that a narrow focus on growth rates neglects the instantaneous beneficial *welfare* effects of trade liberalization. Given the long time span that it needs for the South to outgrow the North by so much, that the new equilibrium reverses the specialization pattern, discounting will have made the future possibility of higher growth almost meaningless. Moreover, recent evidence presented by Hall and Jones (1999) shows that poor countries have much lower TFP than rich ones, so that the case $A^N < A^S$ is anyway unrealistic.

We have stressed above, that multiplicative and constant trade costs to not affect the main result of the paper and that only a *relative law of one price* is required. Of course, the irrelevance of trade costs for long-run growth rates does not imply that those costs are irrelevant altogether. They constitute distortions which affect the *levels* of equilibrium quantities, and keep the gains from trade that the countries reap below the level that obtains under completely free trade. Note also, that in the above model, any country might want to ma-

nipulate its terms of trade by means of an optimal tariff. If both countries chose to do so, they end up in an inferior situation regarding the static gains from trade. However, dynamic considerations are again unaffected, as long as tariffs do not change over time.

On the relative law of one price. One key assumption in the model is that trade equalizes the rate of change of the relative price of investment goods. If capital is homogenous, this is a rather weak requirement. The available evidence shows that poor countries tend to import and invest used capital goods while rich countries invest into state of the art equipment. If machinery of more recent vintage is more productive than older machinery, but otherwise identical, this fact does not constitute any problem an the relative price of old machinery declines in line with the relative price of frontier equipment.

If, however, capital goods are heterogenous, and different types of capital are used in different sectors, it may well be that the type of capital goods imported by poor countries exhibits a smaller decline rate of its relative price than those capital goods used in rich countries. This issue warrants further investigation.

A similar point relates to the wide-spread presumption that poor countries' terms of trade have been deteriorating over the last 40 years instead of improving, as in the present paper (see the extensive literature on the *Prebisch-Singer* hypothesis, e.g. Grilli and Yang, 2000). This literature is mostly concerned with the price of a basket of commodities (including minerals, ores, coffee, cotton, etc.) relative to the price of manufactured goods exports of western countries to proxy for poor countries import prices. This measure has indeed declined considerably over the last 40 years. Note however, that the western export prices used in this literature do not account for quality improvements and the arrival of new goods. Thus, they will overstate price inflation. Using the price index of US exports computed in the US NIPA tables, which accounts for the quality bias, a different picture emerges, and the computed time series looks much more stationary.[9]

[9]The Grilli-Yang index, as used in the literature, is the price of a commodity basket relative to the unit value of manufactured goods exports from the US. An alternative index would be the price of the same commodity basket relative to the NIPA price index for US exports. Conducting an augmented Dickey-Fuller test for unit roots in these time series (1970 to 1999), the Null of a unit root cannot be rejected (at the 1% level) if the Grilli-Yang index is used while it can be rejected (at the 2% level) if the alternative index is used. (The underlying DGP involves one lag (chosen with help of the Akaike Information Criterion) and a constant; results are robust to using different procedures, such as the Philips-Perron test).

Extensions. One possible extension to remedy the above criticism would be to allow for the South to export raw materials. However, it would be very difficult to generate an endogenous long-term terms of trade deterioration for poor countries, because the commodities discussed in the Prebisch-Singer literature are either products from the mining or the agricultural sector, in both of which productivity growth seems rather low compared to investment goods. As long as capital plays a role in these sectors, the above mechanism will not be affected. It may be that the observed terms of trade deterioration is driven by the entry of new producers into the market, which is a temporary event and does not constitute a long-run trend that a growth model should be able to replicate.

Another long-run property of the model may be more problematic but also more straightforward to remedy. Along the balanced growth path, the model predicts factor price equalization. In the standard Heckscher-Ohlin framework with capital accumulation, factor prices would be equalized immediately upon trade liberalization. In that sense, the proposed paper is more realistic. However, factor price equalization defies the empirically well-supported *Balassa-Samuelson* hypothesis, by which richer countries have higher price levels. To account for this fact, it would be desirable to include a non-tradeable consumption good, whose production requires labor as an input. The richer the country, the stronger will demand for this non-traded good be. It is unlikely that this extension changes the core result of the present paper.

5 Concluding Remarks

Many recent theoretical and empirical studies allude to the basic mechanism of Lucas (1988), by which international trade can lead to uneven growth as static comparative advantage leads countries to specialize on industries with different scope for productivity increases. The present paper shows that this result depends crucially on the omission of trade in investment goods and capital accumulation.

We show that countries specializing on the technologically stagnant consumption sector face a continuous decline in the relative price of investment goods, which constitutes itself an engine of growth. If the relative law of one price holds, long-run growth rates of output are equalized across countries. Moreover, in line with evidence, proportional differences in per

capita income levels persist over time and remain constant. Finally, while trade liberalization does not affect the long-run growth rate of output in the North, the long-run growth effects in the South are ambiguous. Interestingly, these results require the law of one price to hold only in differences, not in levels.

The model is consistent with the following empirical observations: (i) the price of investment goods relative to consumption goods has been falling for the last 40 years in most industrialized countries, (ii) poor countries are net importers of investment equipment and (iii) after a period of initial convergence, the sample of open economies exhibits remarkable stability of the per capita income distribution.

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