INTERNATIONAL KNOWLEDGE MOBILITY AND GLOBAL INNOVATION

Eduardo Correia de Souza (IBMEC São Paulo)
& Jorge Chami Batista (IE-UFRJ)

ABSTRACT: In this paper we combine a model of Ricardian comparative advantages as in Dornbusch, Fisher and Samuelson (1977) with Grossman & Helpman's (1991) quality ladder model and derive the consequences of absence of international knowledge mobility (through firm's technology licensing) for the pattern of trade and the world rate of growth/innovation. Our analysis differs from that already made by Taylor (1994) in that the absence of knowledge mobility will here bring forth an infringement of comparative advantages which is by itself a factor of reduction in world growth. We also do some rough calibration of our model in order to compare it to the neoclassical growth model as to how big are the welfare losses from the absence of international capital mobility.

RESUMO: Neste trabalho nós combinamos um modelo de vantagens comparativas Ricardianas, como em Dornbush, Fisher and Samuelson (1977), com o modelo de "escada de qualidade" de Grossman&Helpman (1991), e analisamos as conseqüências da falta de mobilidade internacional do conhecimento (através do licenciamento das tecnologias das firmas) sobre o padrão de comércio e a taxa mundial de crescimento/inovação. Nossa análise difere da de Taylor (1994) em que aqui a falta de mobilidade internacional do conhecimento irá ocasionar uma violação das vantagens comparativas que é, em si mesma, um fator de redução na taxa de crescimento. Também fazemos uma calibração grosseira do nosso modelo a fim de compará-lo com o modelo neoclássico de crescimento quanto a quão grandes são as perdas de bem-estar devido à ausência de mobilidade internacional do capital.

KEYWORDS: endogenous growth, Ricardian trade, technology licensing, capital mobility

PALAVRAS-CHAVE: crescimento endógeno, comércio Ricardiano, licenciamento de tecnologia, mobilidade de capital

JEL classification: O31 , O33, O4 , O41

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1 - Introduction

Trade and international capital movements have fundamentally the same causes and effects. Nations different opportunity costs stand out among the principal causes. As a result, nations become more specialized and the world economy more efficient. But trade and capital movements, via foreign direct investment and licensing, are also the two main channels through which firms' knowledge moves internationally. As a consequence, world innovation and growth are also expected to benefit from trade and capital movements[1].

Historically, trade expansion, especially among developed countries, has been one of the major drives of world economic growth in the post-World War II period. The U.S. economy has played a leading role in this expansion as the largest producer and exporter of goods. But the U.S. share, both as a producer and exporter of goods, has declined as the counterpart of the rising shares of Japan, Germany, other European countries and, more recently, other Asian countries. In point of fact, U.S. exports accounted for 18 percent of total imports from other OECD countries in 1970, 16 percent between 1980 and 1984, and only 12 percent of world exports between 1992 and 1996[2]. However, the U.S. economy still revealed comparative advantage in almost half of the products traded internationally in this latter period[3], while the other nations tended to be much more specialized.

Indeed, natural and artificial trade barriers, despite the liberalization achieved by some rounds of multilateral trade agreements under the auspices of Gatt, remained a significant obstacle to the expansion of large exporting firms in the developed world. The problem was aggravated in the early 1980s by the world recession and the large trade imbalances in the world economy. The tensions generated by the large trade deficits of the U.S., on one side, the large trade surpluses of Japan and Germany, on the other, and secondarily, the need for some large indebted developing countries to generate substantial trade surpluses led to a more protectionist stance in the world. The response of the private sector did not take too long. Since the mid-1980s, the world economy has witnessed a very rapid increase in the international mobility of firms' capital and knowledge through foreign direct investment (FDI) and licensing.

Large Japanese firms that had focused their strategy in expanding export sales started a massive relocation of productive capacity, with heavy foreign direct investment in the U.S. and other developed countries. North-American and European firms followed suit. Singapore, the Republic of Korea and Taiwan (China) have also joined this club, first as recipients of capital and knowledge, but later as significant producers of technology and exporters of capital and knowledge[4]. During the course of this process of large flows of FDI, U.S. exports have become much more specialized, though their share in world exports has tended to stabilize. In fact, the share of U.S. exports in OECD imports was 13 percent between 2000 and 2004 compared to 12 percent between 1992 and 1996, while the number of products in which the U.S. revealed comparative advantage fell from 48 to 39 percent of all traded goods. It should also be noted that the U.S. has remained, over this whole period, the leading

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[1] See Madsen (2007) for empirical evidence that knowledge has been transmitted internationally through the channel of trade

[2] See Comtrade, United Nations or PcTas, Unctad.

[3] Out of 1030 four-digit products of the Standard International Trade Classification (SITC), the U.S. revealed comparative advantage (Ballassa's indicator) in 48% of them.

[4] Brahmbhatt and Hu (2007).

innovating nation, bringing together the largest number of researchers, spending the largest volume of resources in R&D and producing the largest number of patents.

The main purpose of this paper is to develop a theoretical model that accounts for the above mentioned stylized facts, allowing us to examine the effects of the movement in firms' knowledge among developed countries, through FDI and licensing, on their trade patterns, and on global innovation and growth. To do so we follow Taylor's (1994) approach, taking a Ricardian comparative advantage model, with a continuum of rising quality products, as our starting point.

This approach seems to make sense because, on the one hand, relative unitary labor costs in specific industries vary considerably among different countries, and the evidence presented by Carlin et al. (2001) shows very convincingly that this variable is crucial in explaining changes in export market shares of OECD countries by industries in their intra-trade. On the other hand, the use of an endogenous growth (quality ladder) model is in line with Gourinchas and Jeanne (2003) conclusion that "*if the benefits of international financial integration are large, they must occur through channels that are not in the standard neoclassical framework*".[5] While in the neoclassical growth model the distortion caused by the absence of capital mobility is of a transitory nature, in Taylor's setup asymmetric IPRs protection[6] will prevent capital mobility for R&D purposes, leading to a negative and permanent (steady-state) effect on the efficiency with which world resources are employed.

In Taylor's setup, international mobility for R&D purposes assumes three different forms: the first and perhaps most important is "licensing", when a domestic innovative firm authorizes other firm to produce a new good abroad in exchange for royalties payments. The second form is "international R&D financing", when home savings can hire skilled labour abroad to conduct research there, because wages are lower or research technology more productive - to illustrate, this might take the form of a world stock market for innovative firms. Thus we can have, in principle, international R&D financing without licensing and vice versa. Both concepts share the common feature that they promote higher returns to savings and involve some kind of international transferability[7], and this is why we will interchangeably speak here of "international capital mobility" or of "international knowledge mobility". Finally, there is "research technology transfer", that is when potential innovators can take their R&D technologies abroad and use them with foreign labor, so that one of the inefficiencies that may arise is due to the choice of less than best R&D techniques. Here we leave this latter form aside, and focus exclusively on the consequences of no capital mobility through specialization in trade and in R&D.

However, we depart from Taylor´s model with regard to its particular assumption that final goods production and R&D technologies, expressed in terms of labor inputs functions, bear a cross-goods and cross-countries identical proportion – so that if country A, in order to produce a given good, needs half the labor input that country B does, then it also requires half the labor input to quality-innovate this good with the same probability that country B. Though analytically attractive, this assumption

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[5] Gourinchas and Jeanne (2003), pg. 3

[6] Under asymmetric protection, foreign made innovations are not treated the same as domestic as each country only offers protection to domestically produced innovations." (Taylor, 1994, p.362)

[7] This transferability may take the form of knowledge mobility, when a good has been innovated in country A and is produced in country B by licensing; or it may take the form of financial resources mobility when country B's residents acquire claims on country A's production because this last country's savings are hiring skilled labor in country B to conduct research.

nonetheless appears to be somewhat at odds with the stylized fact (reported in the Appendix) that countries are more specialized in final goods production than in R&D activity: Taking OECD countries 2 by 2, with the United States always standing as the "big" partner, we find that countries differ much more in their relative trade positions (measured by Revealed Comparative Advantage coefficients) than in their relative patenting positions (measured by Patell & Pavitt's (1995) Revealed Technological Advantage coefficients).

Here we entirely disconnect final goods production and R&D technologies, assuming that the ranking of comparative advantages tends to be stable over time and heterogeneous across goods (as a result of stemming from permanent features such as the existence of specific natural resources, geographic location, climate and topology, or from historically developed factors such as labor skills and infrastructure for specific industries), while the labor inputs for innovation are uniform across goods and identical internationally, as in Grossman and Helpman (1991).

As a result of our assumptions, our model predicts that in the absence of firm's knowledge mobility through FDI and licensing, specialization according to Ricardian comparative advantage breaks down for a range of products. Ricardian heterogeneity on the production side implies that instantaneous profits from innovation are bigger for those goods in which a country has comparative advantage. However, what an innovative firm maximises is not instantaneous profit, but the "value" of its patent given by the present discounted value of a flow of monopolist instantaneous profits. This flow will be longer the more time it takes for that patent or vintage to become obsolete, that is, the smaller is the risk of obsolescence or innovative effort in that industry. Therefore, under rational expectations equilibrium, it will pay off for a relatively large and more innovative country (say, the U.S.) to "invade" the other country's comparative advantage range of goods to take advantage of smaller obsolescence risks there. Under international knowledge mobility, on the contrary, FDI and licensing would naturally prevent this "invasion" behaviour. This is consistent with our stylized fact regarding the change in the U.S. pattern of specialization during the recent boom in the flows of FDI. It is also interesting to notice how this "invasion effect" is reminiscent of the old "technology gaps" ideas from I.O. literature.[8] In turn, under Taylor's assumption that production and R&D technologies go along exactly together, even without capital mobility invasion would not occur because the incentive to invade the other country's comparative advantage range of goods (infinitesimally smaller instantaneous profits and discretely smaller obsolescence risks) is completely cancelled off by bigger research/innovation costs.

In our setup, the other consequence of no knowledge mobility is that more skilled labor will be allocated to final goods production and less to R&D activity. Given cross-countries and cross-goods identical productivities in research, it is possible to demonstrate that this unambiguously implies slower world growth or a smaller global quantity of innovation. Besides, since some final goods production will be carried over outside the range of comparative advantage where it would be efficient to produce, that extra amount of labor allocated to it will not imply a bigger instantaneous consumption. Summing up the two effects (slower growth and not bigger instantaneous consumption), we have that the absence of knowledge mobility is welfare reducing.

Our chief analytical contribution thus lies in showing that the efficient allocation of resources given by comparative advantages may break down for some products under the absence of international capital mobility, reducing innovation and growth. Therefore, ignoring this source of inefficiency, one tends to underestimate the positive effect of greater international financial integration. To support this

[8] For example, according to Dosi, Pavitt and Soete (1990, pg.11), "…the international composition of trade by countries within each sector appears to be essentially explained by technology gaps, while comparative advantage mechanisms appear to be of lesser importance."

statement we do some rough calibration and simulation exercises in order to assess how big the welfare gains from financial integration in our model are compared to analogous figures from the neoclassical model. We find that, when trading partners differ considerably in size (as is the case when we take the U.S. on one side and any other OECD country on the other), the welfare gain is equivalent to an almost 10% permanent increase in per capita consumption, considerably bigger than what Gourinchas and Jeanne (2003) or Mendoza and Tesar (1998) had found. So the story we tell in this paper perhaps helps explaining the divergence of the 80's and 90's, when rich countries increased their growth rates above most medium and low income countries – after all, that was also a period of increased capital and knowledge mobility, patent law harmonization, etc., among rich countries.

The paper is organized as follows: section 2 provides a description of our basic setup: a Ricardian trade model with a continuum of rising quality products. In section 3 we analyse the case of complete absence of international capital mobility, and the concomitant "invasion" phenomenon. In section 4 we formally prove that the equilibrium global quantity of innovation is bigger under international capital mobility, for what we still use a generalized function to describe production technologies in final goods (countries' relative labor inputs). In section 5 we impose a specific functional form to describe relative labor inputs and do the above mentioned calibration/simulation exercise. Section 6 concludes. The Appendix contains the empirical evidence on countries specialization in production and R&D.

2 - A Ricardian Model with a Continuum of Rising Quality Products (description of the assembled model)

Let us briefly review the basic characteristics of the quality ladder model in a closed economy and then combine it with a Ricardian trade model with a continuum of goods[9]. The demand side of the economy is determined by agents maximizing the following functional:

$$(1) \qquad U_t = \int_t^{\infty} e^{-\rho\cdot(\tau-t)} \cdot \ln D(\tau)\ \mathrm{d}\tau$$

with the instantaneous utility function given by

$$(2) \qquad \ln\ D(\tau) = \int_0^1 \ln\left[\sum_m q_m(z)\cdot x_{m,\tau}(z)\right]\ dz$$

,where $x_{m,\tau}(z)$ denotes the consumption of or the demand for the m^{th} quality or generation of good z at time τ, and $q_m(z)$ is an index of quality. It is assumed that $q_o = 1$ for every good z. Once the appropriate choices between qualities of the same good and between different goods are made, the instantaneous utility will vary along the equilibrium growth path according to increments in the quality indexes resulting from the innovation activity.

Two important properties of this instantaneous utility function are: 1) it follows from its maximization that the nominal amount spent on each good will be the same; and 2) once agents choose

[9] This section draws heavily on the Ricardian model presented in Dornbusch et al.(1977) and on the model of rising quality product presented in chapter 4 of Grossman and Helpman (1991).

among qualities or generations of the same good that one which brings the greater quality per unit of money, the elasticity of substitution between any pair of goods will be equal to 1.

At each point in time, income may be broken down into wages and instantaneous profits of monopolist firms, and is spent on consumption and acquisition of shares of prospective (innovating) firms. Therefore, aggregate saving is used to hire labor for innovative purposes.

The innovation process and the pattern of firms competition are intimately related: each successful attempt to innovate on good *z* will raise its quality by the exogenously given factor λ , so that $q_m(z) = \lambda^{m-n} \cdot q_{m-n}(z)$, $\lambda > 1$[10]. The different qualities of the same good are perfect substitutes of each other. Therefore, each new m^{th} generation of a good can be charged up to λ^{m-n} times the previous n^{th} generation. If it is charged any infinitesimal amount less than this, the producer of the previous generation will be driven out of the market. Admitting free-disposal, the limit-price for leaving the market is the unit-cost of final good *z*, or $a(z).W$, with *W* representing nominal wages and *a(z)* the labor input per unit of good *z*[11].

As Grossman&Helpman (1991) show, assuming free capital mobility for R&D purposes and perfectly non cumulative knowledge[12], then no quality leader will undertake research, and thus goods will be priced by a mark-up that is only one quality index λ over the unit cost:

$$\forall (z,m),\ p(z,m) = \lambda \cdot a(z) \cdot W = p(z)\ .$$[13]

The model is closed by two market clearing conditions and a free-entry condition in the R&D market: according to this last condition, a positive but limited level of R&D will occur only if the expected value of a new firm or blueprint be equal to the expected cost of performing an innovation. Equilibrium in the labor market requires the sum of demand for labor in manufacturing with that in the R&D sector to be equal to the labor endowment of the economy. Equilibrium in the assets market is expressed in terms of the usual condition that the expect return on any firm's stock be equal to the return on an equal size investment in a riskless bond. This is equivalent to the condition that firms be valued according to the "fundamentals", that is, the present discounted value of their flows of profits.

These conditions determine the dynamics of the two endogenous variables, the aggregate intensity of research and the value of firms at each moment in time. They can be summarized by a differential equation and a contour condition that establishes whether the aggregate value of the firms is rising, falling or is constant. In determining the steady-state of the economy, rational expectations are used to rule out trajectories along which both the aggregate intensity of research and the value of firms tend to zero or the latter grows without bound while the former remains positive.

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[10] λ may also be determined endogenously, see Grossman and Helpman (1991), page 106

[11] *a(z)* is assumed to be equal to 1 for any good *z* in Grossman's & Helpman's version of the model.

[12] "Perfectly non cumulative knowledge" is an expression borrowed from Dosi (1984) regarding transmission of product specific knowledge. It means that in spite of property rights or costs which prevent imitation of current state-of-arts products and thus guarantee monopolistic rent to innovators, the current owner of a state-of-arts product has no advantage over other innovators in bringing forth a new vintage of that product. Actually, Dosi himself thinks to be a stylised fact about innovation some degree of cumulativeness. As we shall see at section II below, when transposed to international competition in R.&D. this assumption of perfectly non cumulative knowledge will play a fundamental role in determining the allocation of research efforts.

[13] In particular, in Grossman & Helpman's version of the model, with *a(z)* = 1 for every *z*, and with goods entering the utility function symmetrically, every good will be priced $\lambda.W$ in general equilibrium.

On the supply side, our version of the quality ladder model assumes that labor input is independent of product generation, but **Ricardian comparative advantages** make it depend upon the particular good being produced and the country which produces, so that:

(3) $\forall\, q_m(z),\ \ a(z,m) = a(z)$ and $a^*(z,m) = a^*(z)$

,where $q_m(z)$ stands for the quality of the m^{th} generation of product z

$a(z,m)$ is the labor input per unit produced of the m^{th} generation of product z in the domestic country, with the superscript "*" denoting "the rest of the world".

In an international context, we assume a pattern of price competition such that, whatever is the product or its generation, its price will be given by the quality parameter λ times the internationally minimum cost.[14]

(4) $\forall\,(z,m),\ \ p(z,m) = p(z) = \lambda \cdot \min(a(z)\cdot W, a^*(z)\cdot W^*)$

, with W and W^* representing nominal wages. Underlying expression (4) is a well defined **assumption regarding international knowledge spillovers**: Any firm in any country can produce any good z, at period *t*, with the pre-state-of-arts quality, e.g., max $(q_{t-1}(z), q^*_{t-1}(z))$. As a consequence, whenever an innovator produces a quality jump, he will be facing a competitive fringe which is able to produce the pre-state of the art version of that good at the international minimum cost, thus imposing an upper bound to his monopoly price.

World-wide consumption expenditure is normalized to E = 1. As a result, given the demand function for each good resulting from maximization of (2) subject to (4), profits may be calculated as:

(5)
$$\pi(z,m) = 1 - \frac{1}{\lambda \cdot \min(a(z)\cdot W, a^*(z)\cdot W^*)} \cdot a(z)\cdot W$$
$$\pi^*(z,m) = 1 - \frac{1}{\lambda \cdot \min(a(z)\cdot W, a^*(z)\cdot W^*)} \cdot a^*(z)\cdot W^*$$

,where $\pi(z,m)$ is the profits earned by the producer of the m^{th} generation of product z in the home country, and the term $[\lambda.\min(a(z).W,\ a^*(z).W^*)]^{-1} = p(z)^{-1}$ gives the demanded quantity.

Technology is assumed to be so smooth that, given a vector of nominal wages (domestic and international), there always exists a good $\tilde{z}$ for which domestic and international unitary costs are equal. Formally,

(6) given (W, W^*), $\exists\ \tilde{z}\ \ni\ a(\tilde{z})\cdot W = a^*(\tilde{z})\cdot W^*$

[14] This very pattern is assumed by Yang and Maskus (2001) when they say that "For the leading firm in the Northern market, its closest competitor is the Southern firm that can produce the second-level quality product" (pg. 177). Of course, they also assume there that the South has the lowest wage.

The set of goods Z = [0 , 1] may be reordered so that

$$(7) \qquad j < k \Rightarrow \frac{a(j)\cdot W}{a^*(j)\cdot W^*} \leq \frac{a(k)\cdot W}{a^*(k)\cdot W^*} \Rightarrow A(j) \equiv a^*(j)/a(j) \geq A(k) \equiv a^*(k)/a(k)$$

In what follows, we assume the $A(z)$ function to be strictly decreasing. So, according to (5),

$$(8) \qquad \pi(z) = 1 - \frac{1}{\lambda} \equiv \pi \quad \text{for } z \in [0, \tilde{z}] \text{ and}$$

$$\pi(z) = 1 - \frac{1}{\lambda}\cdot\frac{a(z)\cdot W}{a^*(z)\cdot W^*} = 1 - \frac{1}{\lambda}\cdot[A(z)]^{-1}\cdot w < \pi \quad \text{for } z \in (\tilde{z}, 1], \text{ where } w \equiv W/W^*.$$

Analogously,

$$\pi^*(z) = \pi \quad \text{for } z \in [\tilde{z}, 1] \text{ and } \pi^*(z) < \pi \quad \text{for } z \in [0, \tilde{z})$$

,that is, profits are smaller whenever a country produces outside its comparative advantage.

3 – the general case without international financial capital mobility

In a model in which there are both international R&D financing and licensing, as in Taylor (1993), research and production for each good are carried where they cost less. It is only international financial capital mobility that opens up the possibility that these two activities be conducted in separate locations. Notwithstanding this, in the particular case in which research costs are heterogeneous and exactly proportional to production costs in each country, even in the absence of international capital mobility the coinciding ranges of specialization in production and in R&D will be given by $\tilde{z}$ defined above, as in Taylor (1994)[15]: comparative advantages are not infringed, whether there is capital mobility or not. Here, we will assume that there are neither international R&D financing nor licensing. Also, as a form to capture the stylized fact (reported in the Appendix) that countries are much less specialized in R&D than in final goods production, we will follow Grossman & Helpman's (1991) uniform specification of research technology, so that in any country it takes $h.\iota$ units of labor for a firm targeting any good to succeed in innovating with probability ι ; while final goods production technologies are summarized by the strictly decreasing, continuous function *A(z)* described in the last section.

Those latter assumptions will blur the clear-cut patterns of specialization in production and in research found in Taylor (1994). In particular, it can be shown that two situations do not hold in a rational expectations equilibrium of our model: (i) it's not an equilibrium a situation in which each country produces and innovates inside its comparative advantages range as defined by $\tilde{z}$ above, except for the zero probability event that the two countries, by doing so, present the same equilibrium intensity

[15] See footnote 19 below. Notice that in his paper, Taylor (1994) calls the situation without financial capital mobility "asymmetric IPRs protection".

or probability of innovation; (ii) it's not an equilibrium a situation in which both countries target a same good to be innovated. [16]

To see why this must be so, let's begin by considering the standard non-arbitrage condition in the assets market, namely that instantaneous profits plus the change in the value of a firm less the expected value of a total loss due to obsolescence be equal to the instantaneous return to a riskless asset of equal value:

$$\pi(z)+\dot{v}(z)-\iota\cdot v(z)=r\cdot v(z) \tag{9}$$

,where *v(z)* denotes the discounted value of a firm's profits flow. With $r=\rho$, and in steady-state, (9) gives

$$v(z)=[\iota(z)+\rho]^{-1}\cdot\pi(z) \tag{9'}$$

Besides, if there is free-entry in the R&D activity and a finite amount of R&D expenditure, then the expected gain from innovation, namely the value of a firm, must be equal to the research cost. That latter being identical for all goods (due to the uniform specification of the R&D technology), in equilibrium the values of all firms in a national market must be the same.

That being so, consider a situation in which the home country is targeting for innovation only $z\in[0,\tilde{z}]$ while the rest of the world is targeting $z\in[\tilde{z},1]$ and, without loss of generality, assume that the uniform equilibrium innovative efforts are such that $\iota>\iota^*$. [17] Call this situation (i), depicted in figure 1 below.

PROPOSITION : Situation (i) cannot hold.

PROOF: By (7) and (8) we know that the instantaneous profits corresponding to a given good $z'>\tilde{z}$, should the home country hold the patent for its production, will be smaller than those corresponding to a good inside the home country's comparative advantage range. However, from the point of view of a domestic firm,

$$v(z')=(\iota^*+\rho^*)^{-1}\cdot\pi(z')=(\iota^*+\rho^*)^{-1}\cdot\left[1-(A(z'))^{-1}\cdot w\cdot\frac{1}{\lambda}\right] \tag{10}$$

Because the function *A*(*z*) is continuous, with $A'(z)<0$ and $[A(\tilde{z})]^{-1}\cdot w=1$, then under $\rho=\rho^*$ and ι discretely bigger than ι^* there must exist a non zero measure connected set *Z'* of elements $z'>\tilde{z}$ such that $v(z')>v(\tilde{z})$. Therefore situation (i) cannot hold.

[16] Here we prove only the first statement. For a proof of the second, please refer to our MATHEMATICAL APPENDIX, available at the reader's request

[17] Without loss of generality because, except for particular parameter values, in general we will have $\iota\neq\iota^*$. Those innovative efforts must be uniform, that is, $\iota(z)=\iota$, $\forall z\in[0,\tilde{z}]$, because all goods inside the comparative advantages range are equally profitable and Grossman&Helpman assume that stockholders prefer portfolio diversification.

This implies that a "big" home country will also target some goods beyond its comparative advantage range. As the home country's innovative efforts move away from $\tilde{z}$, instantaneous profits as given by (8) above decay because the $A(z)$ function is strictly decreasing. In view of (9') this implies that equalization of all the home country's firms values will require the function $\iota(z')$ to be also strictly decreasing. That is, as the home country moves away from its comparative advantage, it invests less and less in innovation. Decaying instantaneous profits call for decaying obsolescence risks – it is for this reason that the rest of the world will not target any good in the home country's invasion range (see situation (ii) above): comparative advantages imply that the rest of the world's profits would be maximal and identical for all such goods, what would in turn require identical, constant obsolescence risks.

In the end, having rejected situations (i) and (ii) above, it follows that the rational expectations equilibrium picture of the world, which we call situation (iii) depicted in figure 2 below, is such that: the home country will alone target goods from 0 to $\hat{z} > \tilde{z}$, exhibiting an uniform intensity ι in $[0, \tilde{z}]$ and some positive, decreasing intensity $\iota\,(z')$ in $(\tilde{z}, \hat{z})$, while the rest of the world will exhibit an uniform ι^* for $z \geq \hat{z}$. The good $\hat{z}$ represents some threshold whereupon the home country will not invest.[18] Surprisingly perhaps, production costs heterogeneity and equalization of firms' values is enough to guarantee that the Ricardian model will not present any patent races between countries, for they will be targeting separated ranges of goods even without capital mobility.[19]

The labor market clearing conditions[20] are thus:

$$L = h \cdot \left[\iota \cdot \tilde{z} + \int_{\tilde{z}}^{\hat{z}} \iota(z') \cdot dz' \right] + \tilde{z} \cdot \frac{1}{\lambda \cdot W} + \int_{\tilde{z}}^{\hat{z}} \frac{1}{\lambda \cdot W^*} \cdot [A(z')]^{-1} \cdot dz' \qquad (11)$$

,where L is the home country's endowment of skilled labor; the first term on the right side of the equality is labor demand for R&D; the second is labor demand for goods production inside the comparative advantages range, and the last term is labor demand for production outside the comparative advantages range. For the rest of the world,

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[18] Accordingly, it must be

$v(z) = [\iota^*(\hat{z}) + \rho]^{-1} \cdot \left[1 - (A(\hat{z}))^{-1} \cdot \frac{w}{\lambda}\right]$, so that $\iota^*(\hat{z})$ is already the homogenous ι^*.

[19] In Taylor (1994), not only countries will be targeting separated sets of goods, as those will coincide with the comparative advantage ranges (sets). This is a consequence of the particular, perfect link he assumes to hold between production and research technologies: if $a(z)$ and $a^*(z)$ are the labor inputs to produce good z respectively at the home country and in the rest of the world, then the corresponding labor inputs for research are $a_I = \mu(z).a(z)$ and $a_I^* = \mu(z).a^*(z)$. Consider then a potential invading home country's firm were to devote a marginal innovation effort of size ι_i on a good z' > $\tilde{z}$. Because the free-entry condition holds in the rest of the world, this firm's expected return would be $\iota_i .W^*.a_I^* = \iota_i .W^*.\mu(z).a^*(z')$, while the cost would be $\iota_i .W.a_I = \iota_i .W.\mu(z).a(z')$. It follows from z' belonging to the rest of the world's comparative advantage range that $W^*.a^*(z') < W. a(z')$, and therefore that this cost is bigger than the expected return.

[20] Without international financial capital mobility, equilibrium in the labor markets implies equilibrium in the balance of payments, that is, in the balance of trade.

(11’) $$L^{*} = h \cdot \iota^{*} \cdot (1-\hat{z}) + (1-\hat{z}) \cdot \frac{1}{\lambda \cdot W^{*}}$$

,since the rest of the world is the “small country” which produces and innovates only inside a subset of its comparative advantage. Bearing in mind the above notation, one can establish the following non-arbitrage (N-A) and free entry conditions (F-E):

(12)

N-A: $$v(z) = (\rho + \iota)^{-1} \cdot \left(1 - \frac{1}{\lambda}\right) == v(z') = [\iota(z') + \rho]^{-1} \cdot \left[1 - (A(z'))^{-1} \cdot \frac{w}{\lambda}\right]$$

F-E : $$v(z) = W \cdot h$$

for $z \in [0, \tilde{z}]$ and $z' \in (\tilde{z}, \hat{z})$

, for the home country; and for the rest of the world,

(12’)

N-A : $$v^{*}(z) = (\rho^{*} + \iota^{*})^{-1} \cdot \left(1 - \frac{1}{\lambda}\right)$$

F-E : $$v^{*}(z) = W^{*} \cdot h$$

for $z \in [\hat{z}, 1]$

See also the descriptive figures:

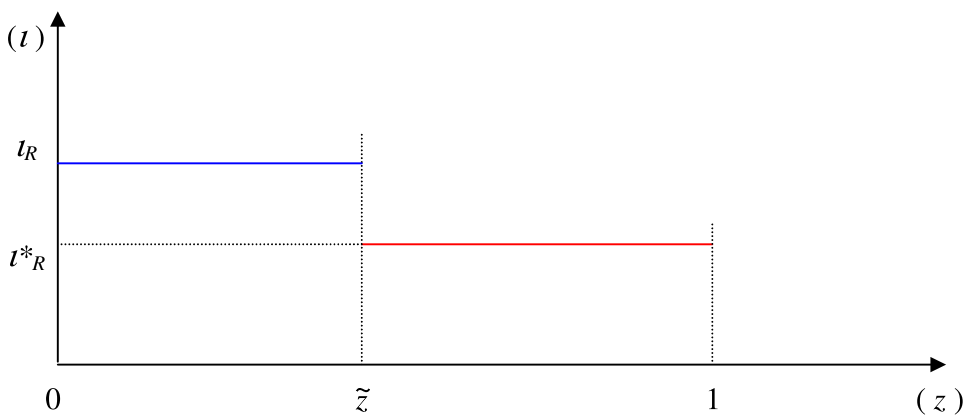

Figure 1: the pattern of R&D investment in a Ricardian World corresponding to the hypothetical situation (i) above. The home country’s investment function is drawn in blue, the rest of the world’s in red; the subscript “R” stands for Ricardian.

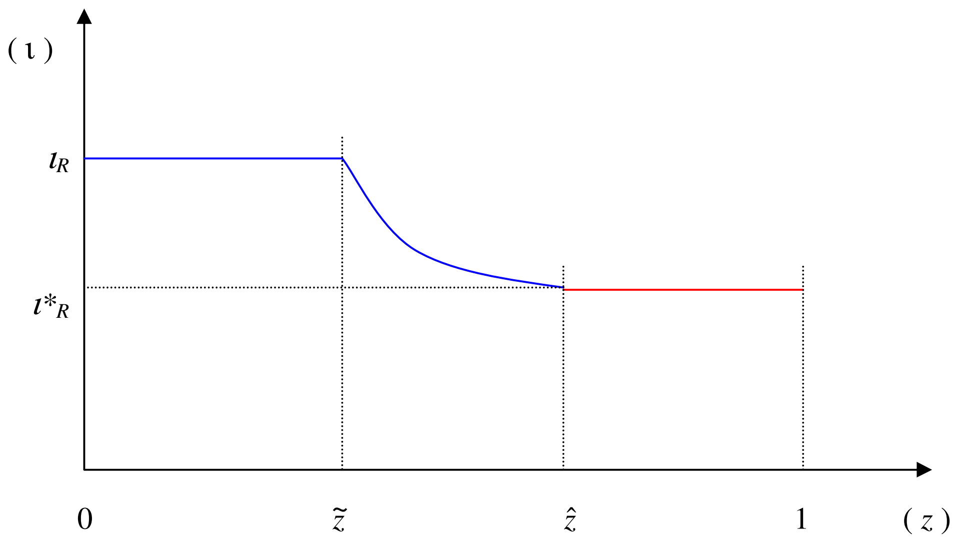

Figure 2: the true pattern of R&D investment in a Ricardian World without capital mobility, corresponding to situation (iii) above. The home country's investment function is drawn in blue, the rest of the world's in red. Notice there is no duplication of R&D efforts.

4 - the global quantity of innovation

Here we show that whatever the functional form describing the strictly decreasing relative labor inputs function *A(z)*, the Ricardian trade model will display a smaller global quantity of innovation, and therefore slower growth, in the absence of international capital mobility. To do this, we will compare the global quantity of innovation emerging from the general case described in the last section with that emerging from a world where there are both international R&D financing and licensing and, besides, both countries remain doing some research activity ("diversification in R&D" assumption). Given identical innovation technologies across countries, this latter assumption amounts to Factor Price Equalization (FPE) − otherwise there would be a cheapest location where all the R&D activity would be conducted. Notwithstanding the apparent loss of generality, as Taylor (1994) shows, FPE is not, by far, a zero probability event in our class of models, occurring whenever countries do not differ too much in relative sizes and relative advantages.[21]

Let's begin with the international capital mobility case, for it is very straightforward. First notice that in this case comparative advantages are not violated, that is, all final goods are produced where it is cheaper. Call $\tilde{z}$, as before, the last final good in which the home country has comparative advantage, and $\bar{z}$ the last good in which it conducts R&D. Under FPE, *W* denotes the wage rate in both countries. The common interest rate is denoted by ρ. Equilibrium in labor markets can then be expressed as:

$$(13) \qquad \bar{z} \cdot h \cdot \iota_M + \frac{E_M}{\lambda \cdot W} \cdot \tilde{z} = L$$

[21] The proof specific to our setup is given in the MATHEMATIC APPENDIX available at the reader's request. The case for FPE is also made more acceptable when one bears in mind that in this model the only production factor is "skilled labor", something like an engineer or scientist who can move from research to production and who could, conceivably, move from one country to another.

(13’) $$(1-\bar{z})\cdot h\cdot\iota_M+\frac{E_M}{\lambda\cdot W}\cdot(1-\tilde{z})=L^*$$

,where ι_M and E_M are respectively the uniform intensity of innovation and the worldwide consumption expenditure under capital mobility. The first term on the left side of each equality is labor demand for R&D purposes, and the second is the amount of labor employed in final goods production. Summing (13) and (13'), and bearing in mind that by the free-entry condition it must be $v_M=W\cdot h$ and that by the non-arbitrage condition it must be $v_M=(1-\lambda^{-1})/(\iota_M+\rho)$, we arrive at

(14) $$\iota_M=\frac{\lambda-1}{\lambda}\cdot\frac{L+L^*}{h}-\frac{\rho}{\lambda}$$

, the equilibrium uniform intensity of innovation under capital mobility and FPE. The global quantity of innovation, or expected number of innovations, is simply given by ι_M times 1, the measure of the final goods’ set.

To derive the global quantity of innovation without capital mobility, consider again the system comprising (11), (11'), (12) and (12'). Notice we can write the relative labor input function as:

(15) $$A(z')=\alpha(z')\cdot A(\tilde{z})\ ,\quad \alpha(\tilde{z})=1\,,\ \alpha'<0\ ,\ z'\in[\tilde{z},1]$$

Then by (11) the amount of labor the home country spends for final goods production in the range where it invades the rest of the world's comparative advantage is

(16) $$L_{pi}\equiv\int_{\tilde{z}}^{\hat{z}}\frac{1}{\lambda\cdot W^*}\cdot[A(z')]^{-1}\cdot dz'=\int_{\tilde{z}}^{\hat{z}}\frac{1}{\lambda\cdot W}\cdot\frac{1}{\alpha(z')}\cdot dz'=$$
$$=\frac{1}{\lambda\cdot W}\cdot(\hat{z}-\tilde{z})+D,\ \ D>0$$

, since, by definition of $\tilde{z}$ in (6) and (7), $[A(\tilde{z})]^{-1}\cdot\frac{W}{W^*}=1$. D represents the integral of the changes (augments, actually) in the labor requisite for producing final goods as one moves away from the home country's comparative advantage.[22]

[22] That the labor requisite increases with z’ can be easily seen by taking the total differential $d\left(\frac{1}{\lambda\cdot W}\cdot\frac{1}{\alpha(z'')}\right)=\frac{\partial(\bullet)}{\partial\alpha(z'')}\cdot\frac{\partial\alpha(z'')}{\partial z''}\cdot dz''$. In the right side of this last equality, both derivatives are negative and therefore the total differential is positive. As to the second derivative, it depends on the functional form chosen to describe the α (that is, the relative labor input *A*) function. Working with a general, non-specified, function, all we can say is the steeper is α the bigger the additional amount of labor the home country will spend for producing final goods in an invasion range of a given measure. For a rigorous formula for the term *D*, we ask the reader, again, to refer to the MATHEMATICAL APPENDIX.

Consider now the amount of labor the home country spends to perform innovation in the invasion range,

(17) $$L_{ii} \equiv \int_{\tilde{z}}^{\hat{z}} h \cdot \iota(z') \cdot dz'$$

Using (15) and the definition of $\tilde{z}$ in (6), we can solve (12, N-A) for $\iota(z')$ as a function of the uniform ι:

(18) $$\iota(z') = \frac{\lambda - [\alpha(z')]^{-1}}{\lambda - 1} \cdot \iota - \frac{[\alpha(z')]^{-1} - 1}{\lambda - 1} \cdot \rho$$

So that the intensity of innovation decreases as one advances into the invasion range. If, on the contrary, the α function were constant with $\alpha(z') = \alpha(\tilde{z}) = 1$, then $\iota(z') = \iota$. Thus we can write:

(17') $$L_{ii} = h \cdot \iota \cdot (\hat{z} - \tilde{z}) - C \quad , \; C > 0 \qquad \text{with} \quad C = -\int_{\tilde{z}}^{\hat{z}} \int_{\tilde{z}}^{z'} d\left(h \cdot \iota(z'')\right) dz'$$

, that is, *C* is the absolute value of the integral of the negative changes in the amount of labor spent for innovative purposes as one moves away from the home country's comparative advantage.

Thanks to Grossman&Helpman's (1991) special functional forms, our model displays the interesting feature that, independent from the functional form of the α function, *C* = *D*, that is, the amount of labor which is saved through smaller innovation intensities in the invasion range is exactly equal to the additional amount of labor spent in final goods production. [23] So we can rewrite (11) as

(19) $$L = h \cdot \iota \cdot \tilde{z} + L_{ii} + \tilde{z} \cdot \frac{1}{\lambda \cdot W} + L_{pi} = h \cdot \iota \cdot \hat{z} + \hat{z} \cdot \frac{1}{\lambda \cdot W}$$

Solving (19), (11'), (12) and (12') for the uniform intensities of innovation, and assuming $\rho^* = \rho$, comes

(20) $$\iota = \frac{\lambda - 1}{\lambda} \cdot \frac{L}{h \cdot \hat{z}} - \frac{\rho}{\lambda} \qquad \text{and} \qquad \iota^* = \frac{\lambda - 1}{\lambda} \cdot \frac{L^*}{h \cdot (1 - \hat{z})} - \frac{\rho}{\lambda}$$

In the invasion range, using (17'), the quantity of innovation can be calculated as

(20') $$I_i \equiv \frac{L_{ii}}{h} = \iota \cdot (\hat{z} - \tilde{z}) - \frac{C}{h}$$

So the global quantity of innovation without capital mobility is

[23] This result, involving some more tedious calculations, is demonstrated in the MATHEMATICAL APPENDIX

(21) $$GQI \equiv \iota \cdot \tilde{z} + I_i + \iota^* \cdot (1-\hat{z}) = \frac{\lambda - 1}{\lambda} \cdot \frac{L + L^*}{h} - \frac{\rho}{\lambda} - \frac{C}{h} = \iota_M - \frac{C}{h}$$

, where ι_M is given by (14). Therefore we have just proved that the global quantity of innovation is necessarily bigger under capital mobility. The intuition for this result involves both the standard Schumpeterian effect "less competition → bigger potential monopolist profits → more innovation", and a general equilibrium, allocative effect. The first effect follows from the fact that without capital mobility and outside the comparative advantages range smaller instantaneous profits will accrue to "invading firms" (see expression 8 above); and since financial capital remains mobile inside their country, equalization of returns to R&D investments calls for smaller innovative efforts in the invasion range[24]. Under international capital mobility, on the contrary, instantaneous profits are maximal through all the set of final goods. The allocative effect follows from the fact that, having to face a sharp foreign competitive fringe (recall the paragraph below expression 4) invading firms will set "low" prices on final goods, reflecting in a high demand. But being outside the comparative advantage range means that, given a vector of wages[25], it takes more labor input to meet that demand. What's more, here we saw how these two effects combine: none of the labour drawn away from the R&D activity in the invasion range will flow into more intense innovation inside the comparative advantages range – it will be all sunken into inefficient final goods production inside the very invasion range.

5 - a quantitative assessment of the effects of the absence of international capital mobility

Gourinchas and Jeanne (2003) use a Ramsey-Cass-Koopman model with a logarithmic instantaneous utility, as in our equation (1) above, to estimate the impact of financial integration (physical capital mobility) on the welfare (infinite lifetime utility) of a non-OECD country. Developing countries have a smaller initial capital *per capita* level than developed countries that are assumed to have already achieved the steady-state (that is, with no capital gap). Under financial integration, physical capital will flow from countries where it is abundant to countries where it is scarce because in those latter the marginal product of capital is bigger than the world interest rate. However, inasmuch as developed countries are already in steady-state, the world interest rate is equal to the natural rate of interest which is the same for all countries, reflecting common parameters such as the long run growth rate in labor productivity and the intertemporal discount rate. That being so, financial integration will not "tilt" permanently consumption profiles. For a given country, the long run levels of output and consumption *per capita* will be the same under autarky and financial integration. Therefore, the effect of free physical capital mobility is transitory: to accelerate poor countries' convergence to the steady-state, making a smoothing in consumption profiles possible. In the end, Gourinchas and Jeanne find small welfare gains from financial integration despite substantial initial capital gaps: the average non-OECD country will enjoy a Hicksian equivalent variation (defined as the percentage increase in autarky

[24] As Antweiler (1995) points, according to the usual non-arbitrage condition on the research activity what one expects to observe is an inverse relation between innovation intensities and relative production or research costs across industries. His chief concern, however, is with microeconomic incentives for conducting R&D explaining international differences in growth performance; roughly speaking, following the logic of the "inverse relation" countries whose economic policies impose high costs on R&D will undergo low rates of innovation.

[25] That in this situation W < W* follows immediately from (12) and (12') with $\iota > \iota^*$

consumption at each point of time that brings welfare up to its level under financial integration) around 1,24.[26]

Compared to this, how big can be the gains from financial integration in our endogenous growth model? The answer of course depends on relative countries sizes and the functional form of the relative labor input *A(z)* function: if countries are practically the same size and *A(z)* is flat (weak comparative advantages), then what we called the invasion range will be small and inside it final goods production will not require so much more labor input than inside the comparative advantage range, so that we may expect quite small losses from the absence of capital mobility. However, a presumption that under fairly general conditions the gains from financial integration are big rests on the fact that, unlike the neoclassical growth model, in our class of models we are dealing with steady-state, permanent effects.

For our simulation exercise we chose the hyperbolic functional form $A(z) = A_0 / z$, $z \in [0,1]$ because it renders calculations in the Mathematica® program tolerably simple. For example, inside the invasion range, $A(z') = \frac{\tilde{z}}{z'} \cdot A(\tilde{z})$. Also, we normalize the parameter A_0 so that comparative advantages be symmetrical, that is $A^{-1}(1) = 0{,}5 \Rightarrow A_0 = 0{,}5$. Then the home country will invade the rest of the world's comparative advantage if and only if $L > L^*$.

A few comments are due on the rough calibration work we did: Gourinchas and Jeanne adopt the parameter value $\beta = 0{,}96$ for the intertemporal discount rate in the discrete time functional $U_t = \sum_{s=t}^{\infty} \beta^{s-t} \cdot \ln c_s$, where c_s is consumption at time *s*. Thus our corresponding continuous time parameter must be $\rho = -\ln \beta \cong 0{,}04$. Next we take the contribution of Total Factors Productivity (TFP) to the observable growth rate in output per worker for OECD countries over the period 1960-1985 found in Hall and Jones (1999): a 0,86% per year TFP component in an overall mean growth rate of 2,23% per year, and assume that this is the outcome of a situation without international capital mobility. This figure will correspond to the growth rate of the "consumption index" in Grossman&Helpman's quality ladder model[27], whereby a relation between the endogenous variable "Global Quantity of Innovation without capital mobility" (*GQI*) and the quality upgrade λ parameter is established:

$$(22) \qquad g_D \equiv \log D(t) - \log D(t-1) = GQI \cdot \log \lambda \ \rightarrow \ 0{,}0086 = GQI \cdot \log \lambda$$

,where g_D denotes the growth rate in the consumption index in equation (1) above. So, setting a markup value (value for parameter λ) implicitly determines the *GQI* value that the model without capital mobility must return in order to meet the observable $g_D = 0{,}0086$.

Next, for a given *GQI* value, we use the normalization $L + L^* = 100$ [28], and then calculate the implicit parameter *h* value. Finally, given an estimate of *h*, we can use an expression analogous to (14) above to calculate what the global quantity of innovation would be under capital mobility (ι_M). Using

[26] Further evidence on transitional dynamics perhaps not being so important in neoclassical growth models can be found in the estimates by Caselli, Esquivel and Lefort (1996): the average time an economy spends to cover half of the distance between its initial position and its steady-state is about 7 years instead of 30 years as implied by earlier studies.

[27] see Grossman&Helpman (1991), pg.97

[28] A sensitivity analysis using the Mathematica program has proved that this normalization is harmless.

the estimates of *GQI* and ι_M thus obtained, it is straightforward comparing welfare levels and calculating the Hicksian equivalent variation, for what we assume the dynamics to start already in steady-state.[29]

In table 1 below we report our findings for a case in which labor endowments don't differ much (L = 60 , L^* = 40) and for a case where the home country is much bigger (L = 80 , L^* = 20). In both cases we decided to calculate the Hicksian variation for several possible values of the parameter λ, which can then be thought of as representing markups for different industries. However, since we are interested on (aggregate) economic growth we should consider Hall's (1986) estimate that price is at least 1,28 times total marginal cost for the U.S. manufacturing industry as a whole, and take λ = 1,3 below as a benchmark.[30]

λ (markup value)	**Hicksian equivalent % variation (L = 60 , L* = 40)**	**Hicksian equivalent % variation (L = 80 , L* = 20)**
1,01	0,039	0,236
1,05	0,317	1,460
1,10	0,290	2,651
1,20	0,686	5,999
1,30	1,085	9,579
1,40	1,495	12,948
1,50	1,746	16,544
1,60	2,069	19,659
1,70	2,378	23,363
1,80	2,534	25,644
1,90	2,727	28,201
2	2,848	30,871
3	3,799	43,760
4	4,364	47,426

(table 1: markup values and Hicksian equivalent variations)

[29] For details on this calculation, we ask the reader (again) to look at the corresponding section of our MATHEMATICAL APPENDIX. Notice also that we speak here of an expression **analogous** to (14) to calculate what the global quantity of innovation would be under capital mobility. This is because in this section we do not necessarily assume FPE under capital mobility. Given our assumption that $A^{-1}(1) = 0{,}5$, we will be typically considering cases such that $L > L^*$ and therefore $W < W^*$, so that the home country performs all the R&D activity under capital mobility. To see why this must be so, see section II of our Mathematical Appendix.

[30] Maybe it would be more in the spirit of the quality ladder model to consider, instead of the markup for the manufacturing industry as a whole, only the average markup for "high-dif" (highly differentiated) goods, as defined by Chami Batista (2004): "If the long run price elasticity of substitution between US imports of the same good from 2 different countries is found to be positive or if no long run relationship is found between relative prices and quantities, the product is classified as HIGH-DIF. This means that international competition in these products is not predominantly based on price differences" The reader may also find it interesting to report here some of Hall's estimated markups for 2-digit industries: chemicals (1,62) , petroleum refining (1,1) , primary metals (1,28), fabricated metals (1,15) , machinery and instruments (around 1,17), communication (1,675), textiles (1,32) , electricity and gas generation (1,94).

Inspecting table 1 we see that in the first case, when countries' sizes are practically equal, the impact of capital mobility in our endogenous growth trade model is about the same as that found by Gourinchas and Jeanne (2003) for the neoclassical growth model : a Hicksian variation of 1,085% for λ = 1,3 . In contrast, when countries sizes are significantly different, we get a Hicksian variation of 9,57% for λ = 1,3, and up to 19,65% (for a markup around 1,6 as in the chemicals industry) or 30% (for a markup around 2, as in gas and electricity generation).

6 - conclusions

We have seen how the absence of international capital mobility (understood as licensing plus international R&D financing) reduces the global quantity of innovation or the growth rate in the Ricardian trade model with endogenous growth. In explaining why this happens, we highlighted the "invasion" phenomenon by which specialisation in R&D and production according to comparative advantages breaks down for some industries. For Grossman&Helpman's functional forms, which made our model simple and computable, all the skilled labor diverted from innovation in the invasion range where profits are smaller is absorbed by final goods (inefficient) production inside the very invasion range.

Our analysis also shows that the loss due to absence of international capital mobility is expected to be greater when trading partners differ much in market sizes / skilled labor endowments, or in comparative advantages in final goods production. This, together with the Ricardian specification of final goods technologies may incidentally give the reader a flavor of North-South relations-type analysis, but here we should note that with only one production factor (skilled labor), all international productivity differences must necessarily appear in a Ricardian fashion. Inspecting the Appendix, one will realize that the picture of the world that we had in mind suggests rather a North-North-type analysis, with the United States featuring as the big country and the other major OECD countries standing for the small partners. To the conceivable ensuing objection that international financial capital mobility has always been a problem of minor importance among OECD countries, we respond that this is not exactly so in what concerns IPRs, so much so that the agreement between the World Intellectual Property Organization and the World Trade Organization regardind TRIPs dates from 1995, to take one example. In our view, as the “stylized facts” reported in the introduction suggest, the transition towards full capital/knowledge mobility among OECD countries is characteristic of the period mid-80’s and 90’s.

Appendix – patterns of specialization in production and in R&D

Although the real world counterpart of our final goods production technology could perhaps be recovered using measurements of “unitary labor costs”[31], there is no such corresponding figure for research technology that we know of. So here we take the more roundabout approach of examining patterns of specialization in **world exports** and **patenting**. This is a sound approach because Taylor’s (1994) assumption that production and research technologies bear a perfect correspondence would lead to the prediction that, for a given country, both the “intensity” and the “extent” of specialization in trade and innovation go along together: for recall that prices are given by $p(z) = \lambda \cdot a(z) \cdot W$, and

[31] See, for example, the variables listed in Carlin et alli (1999)

demand for good z is simply the inverse of price, so that a country's level of production, if it has comparative advantage and produces good z, is inversely proportional to its labor input requisite $a(z)$. Now the equilibrium intensity of innovation is given by expression (14) above, which, adapted to Taylor's assumption, becomes $\iota(z)=\frac{\lambda-1}{\lambda}\cdot\frac{L+L^*}{h(z)}-\frac{\rho}{\lambda}=\frac{\lambda-1}{\lambda}\cdot\frac{L+L^*}{a(z)\cdot\mu}-\frac{\rho}{\lambda}$, where $h(z)$ is the research labor input and μ is a constant of proportionality as in footnote 21 above. Thus, as a country moves away from its comparative advantage in production, its intensity of innovation decays. Furthermore, as can be seen in the last formula, this intensity decays more than proportionally to the increase in the labor input requisite. Therefore, in Taylor's setup the intensity of innovation decays faster than the volume of production as a country moves away from its comparative advantage.[32] So we would expect countries to be more specialized in research than in production, what we next show not to hold when we examine patterns of specialization in world exports and patenting.

We measure specialization in trade at sectors level using RCA ("revealed comparative advantage") coefficients: for a given country and a given product, the corresponding RCA coefficient is defined as that country's share in world total exports of that product, divided by the country's share in world total exports over all products. Therefore, a RCA coefficient bigger (smaller) than one means that that country is relatively much (little) specialized in that industry. Notice that RCA measures adjust for "country specific effects", such as countries sizes and openness to trade, that might otherwise invalidate international comparisons. For patenting, we use the analogous concept of RTA ("revealed technological advantage") as in Patel and Pavitt (1995), only that the units of measurement are not values but numbers of patents granted.

Since we are particularly interested on the phenomenon by which a "big" country invades a smaller country's comparative advantage, it seems natural to perform here comparisons of RCA and RTA patterns taking countries two by two, with the United States (U.S.) representing always the big country. So, call the other country " i " and consider industry "j". The measures of U.S. relative trade and patenting specialization with relation to country i in industry j are given respectively by

$$rrca_{ij}\equiv\frac{RCA_{US\,\mathrm{j}}}{RCA_{i\,\mathrm{j}}}\qquad\text{and}\qquad rrta_{i\,\mathrm{j}}\equiv\frac{RTA_{US\,\mathrm{j}}}{RTA_{i\,\mathrm{j}}}$$

Next, taking 3-digit data on patenting from the USPTO regrouped into 2-digit according to Hall et alli (2000) classification, and 2-digit data on exports from STAN-OECD database, we construct independent, decreasing, $rrca_i$ and $rrta_i$ schedules by reordering exported goods and classes of patents.[33] If, say, the resulting $rrca_i$ schedule is very steep, that means that the U.S. and country i are

[32] For example, take two goods, j and k, such that $a(k) = 2.a(j)$. The volume of production of good j is twice the volume of production of k. However, $\iota(k)=\frac{\lambda-1}{\lambda}\cdot\frac{L+L^*}{2\cdot a(j)}-\frac{\rho}{\lambda}<\frac{\lambda-1}{\lambda}\cdot\frac{L+L^*}{2\cdot a(j)\cdot\mu}-\frac{1}{2}\cdot\frac{\rho}{\lambda}=\frac{1}{2}\cdot\iota(j)$

[33] We speak of "independent" schedules because, when we match "goods" and "patent classes", the *rrca* and *rrta* orderings are, in general, quite different for the same country i : in real world situations, the correspondence between RCAs and RTAs is not only not perfect, as in Taylor, but even not monotonic – put another way, if we were to keep the same ordering of goods we got from the decreasing *rrca* schedule and plot the corresponding *rrta* schedule, that latter might very well be increasing in some ranges of z. A regression analysis we performed elsewhere shows that, although the correlation between RTAs and RCAs is unambiguously positive, it is only of the order of 40%.

radically specialized in trade. If, further, the $rrta_i$ schedule is less steep, we may conclude that the U.S. and country *i* are more specialized in final goods production (trade) than in R&D activity (patenting). Finally, the steep of our schedules is estimated as a "logarithmic decay rate", according to

$$rrca_{i\,j} = rrca_{i\,0} \cdot (1+d)^j$$

, where "0" stands for the good or industry with the highest coefficient and *j* is the (j + 1)st good in the ordering; *d* is the necessarily non-positive rate of decay. Taking logs on both sides of last expression allows us to use OLS estimation. An entirely analogous procedure applies for *rrta* coefficients.

We report below our findings about *rrca* and *rrta* decay rates for the pairs (U.S., *i*), with *i* = (France, Japan, UK, Germany, Italy):

	(US, France)	(US, Japan)	(US, UK)	(US,Germany)	(US, Italy)
d_{rrca} (trade)	-0,0865 (0,0098)	-0,1885 (0,0192)	-0,079 (0,0078)	-0,0752 (0,00547)	-0,1823 (0,0254)
d_{rrta} (patents)	-0,0633 (0,0073)	-0,1078 (0,0117)	-0,0547 (0,0037)	-0,0546 (0,0037)	-0,0857 (0,0049)

Note: standard errors in parenthesis

For all the five pairs of countries we find that *rrta* schedules are significantly less steep than *rrca* schedules, what constitutes evidence of less specialization in R&D (patents) than in final goods production (trade).

REFERENCES

1) Antweiler Jr., Werner – "International Differences in R&D: an Empirical Investigation of a 'Quality Ladder' Implication" – university of Toronto, 1994

2) Brahmbhatt, M. and Hu, A. – "Ideas and Innovation in East Asia" - *World Bank Policy Research Working Paper No. 4403*, 2007

3) Carlin,W , Glyn, A. and Van Reenen,J. - "Export Market Performance of OECD Countries: An Empirical Examination of the Role of Cost Competitiveness" – IFS (The Institute for Fiscal Studies) Working Paper W99/21, London, 1999

4) Caselli, F. , Esquivel, G. and Lefort, F. – "Reopening the Convergence Debate: A New Look at Cross-Country Growth Empirics" - Journal of Economic Growth, September 1996

5) Chami Batista, J. – "Latin American Export Specialization in Resource-Based Products: implications for growth" – The Developing Economies XLII-3, September 2004

6) Dornbush, R., Fischer, S. and P.A.Samuelson - "Comparative Advantage, Trade, and Payments in a Ricardian Model with a Continuum of Goods" - American Economic Review, December 1977

7) Dosi, G. - “Technical Change and Industrial Transformation” - London, Macmillan, 1984

8) Dosi, G. , Pavitt, K. and Soete, L. – “The Economics of Technical Change and International Trade” – NYU Press 1990

9) Gourinchas, P.-O., and Jeanne, O. - "The Elusive Gains from International Financial Integration" - NBER Working Paper 9684, May 2003

10) Grossman,G. & Helpman, E. – “ Innovation and Growth in the Global Economy” - MIT Press 1991

11) Grossman, G. and Lai, E. - "International Protection of Intellectual Property" - NBER Working Paper 8704, January 2002

12) Hall, B. , A.Jaffe and M.Trajtenberg - "The NBER/Case Western Patents Data File: A Guided Tour", May 2000

13) Hall, R. - "The Relation Between Price and Marginal Cost in U.S. Industry" - NBER Working Paper 1785, January 1986

14) Hall, R. and Jones, C. - "Why do Some Countries Produce so Much More Output per Worker than Others" - Quarterly Journal of Economics, February 1999

15) Madsen, J. – “Technology spillover through trade and TFP convergence: 135 years of evidence for the OECD countries” – Journal of International Economics 72 (2007)

16) Mendoza, Enrique and Linda Tesar – “The International Ramifications of Tax Reforms: Supply-Side Economics in a Global Economy” – American Economic Review, vol.88 (1), 1998

17) Patel,P. and K.Pavitt – “Patterns of Technological Activity: their measurement and Interpretation” in the HANDBOOK OF THE ECONOMICS OF INNOVATION AND TECHNOLOGICAL CHANGE (organized by Paul Stoneman, Blackwell 1995)

18) Romer, Paul M. - "Endogenous Technological Change" - Journal of Political Economy, No. 98, 1990

19) Taylor, Scott, M. – “ ‘Quality Ladders’ and Ricardian Trade” – Journal of International Economics 34 (1993)

_ “Trips, Trade and Growth” – International Economic Review, vol. 35, 1994

20) Yang, Guifang and Maskus, Keith - "Intellectual property rights, licensing, and innovation in na endogenous product-cycle model" - Journal of International Economics, 53, 2001