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GLOBALIZATION, DIVERGENCE AND STAGNATION

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Abstract

In a world where poor countries provide weak protection for intellectual property rights, market integration will systematically shift technical change in favor of rich nations. For this reason, free trade can increase international income differences. At the same time, integration with countries where intellectual property rights are weakly protected can have a large adverse effect on the world growth rate. These results provide a strong rationale for global regulations, critical in a system of interdependent economies for sustaining innovation and reducing income inequality. Supportive empirical evidence is presented.

JEL classification: F14, F43, O33, O34, O41.

Keywords: Economic Growth, North-South Trade, Intellectual Property Rights, Cross-Country Income Differences, Innovation Diversion.

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1 Introduction

The past decades have witnessed a dramatic increase in the level of market integration across the globe. During the period 1960-1998, the average share of import plus export in GDP rose from 0.54 to 0.76 and the volume of world merchandize trade grew steadily at 10.7% per year.[1] A distinctive feature of this wave of globalization is the increasingly important role played by less developed countries (LDCs). Although trade between the US and non-OECD countries is still relatively small, it almost tripled during the period 1980-95 (Wood, 1998) and the same years have seen unprecedented episodes of market liberalization in LDCs (Sachs and Warner, 1995). In this scenario of increasing integration between more and less advanced economies, the cross-country income distribution is also changing. Many commentators claim that we live in an era of growing inequality. Quah (1993) documents that countries are diverging from the world mean.[2] Similarly, Pritchett (1997) argues that "divergence in relative productivity levels is the dominant feature of modern economic history".[3] Despite evidence of convergence among rich nations and falling poverty in world population,[4] a crude measure of cross-country inequality, the variance of log real per capita GDP, displays a disturbing upward trend, rising steadily from 0.7 in 1960 to more than 1.3 in 1998.[5] Observations like these stress the centrality of understanding the effects of trade on the world income distribution and raise the concern of a possible causal link from globalization to divergence. This concerns have recently been the subject of heated debates. Although it is well known that trade affects the world income distribution, only few models focus on how and why gains from trade may be systematically biased in favor of rich nations.[6]

[1] The trade share in GDP is from the Penn World Table, Mark 6.0; averages refer to a constant sample of 115 countries. World merchandize trade is from WTO data.

[2] Interestingly, Beaudry, Collard and David (2002) show that this phenomenon seems to be more pronounced among open countries.

[3] Pritchett (1997), using data from Maddison (1995), shows that, over the past century, advanced economies consistently grew faster than the less developed ones. Perhaps surprisingly, the average growth differential reaches a peak in the last two decades, characterized not olny by the globalization boom, but also by low productivity growth in advanced countries.

[4] See Sala-i-Martin (2002) on falling poverty in world population, a phenomenon mainly due to the good performance of two very populous countries, India and China. For the purpose of the paper, that is to relate different policies to economic prosperity, the country seems the relevant unit of analysis. See Acemoglu and Ventura (2003) on the relative stability of the world income distribution.

[5] Data form the Penn World Table 6.0 on a sample of 115 countries.

[6] The most common argument is based on the need to protect infant industry in LDCs. See Young (1991) and Acemoglu, Aghion and Zilibotti (2002) for recent applications.

By studying a specific market failure common in many developing countries, this paper argues that globalization may indeed amplify income disparities. First, it shows that North-South trade can generate divergence, through the endogenous response of technical change, if developing countries do not provide adequate protection of intellectual property rights (IPRs). Since innovators cannot fully appropriate the fruits of their work in developing countries, specialization in production due to trade opening translates into a shift of R&D effort towards the activities performed in rich economies only. Therefore, trade induces "innovation diversion", making the sectors in which poor countries enjoy a comparative advantage relatively less productive. Second, the paper shows that the uneven distribution of technical progress potentially brought about by trade can also undermine incentives to innovate, so that divergence can open the door to stagnation.

To make this argument, the paper builds a Ricardian model with endogenous, sector specific, technical change. Two sets of countries, the North and the South, are distinguished by exogenous sectoral productivity differences. Except for this Ricardian element, defining the pattern of comparative advantage, countries have access to the same pool of technologies, whose productivity can be increased by innovation. Innovation is financed by the rents it generates, but in the South some rents are dissipated due to imitation. The model is solved under autarky and free trade and the two equilibria are compared. In both cases, the equilibrium has a number of desirable properties: the world income distribution is stable, growth rates are equalized across sectors, countries with higher exogenous productivity levels are relatively richer. But the world income distribution depends crucially on the trade regime. With no commodity trade, each country produces the whole range of goods and therefore each innovator, serving the world economy, obtains both the high rents from the North and the smaller rents form the South. Under free trade, instead, each country specializes in the sectors where it has a comparative advantage and innovators obtain the rents from one location only. Since the rents from the South are smaller, the Southern sectors attract less innovation which, over time, reduces their productivity. This is the first result of the paper: in a world where poor countries provide weak protection for IPRs, market integration shifts technical change in favor of rich countries.

Is then North-South trade always beneficial for advanced economies? The somehow surprising answer, leading to the second result of the paper, is not necessarily: under free trade, weak IPRs have a strong potential to disrupt incentives for innovation, thereby hurting all countries. As the North becomes relatively richer, more sectors move to the South, where production costs are lower, and R&D becomes less attractive for a wider range of goods. Divergence can thus be followed by stagnation. In the limit case of no IPRs protection at all in the South, this process generates decreasing returns to innovation and growth eventually stops. Therefore, the model shows that in a world of interdependent economies, the regulatory policies of each country are crucial to sustain the growth rate of the entire global system.

These results have important implications. First, they provide strong arguments in favor of global protection of IPRs. In an era of falling trade barriers and increasing internationalization of production, the enforcement of IPRs in all parts of the world becomes critical for attracting and sustaining innovation. Second, that the desirability of IPRs depends on the trade regime can shed light on an observed change in attitudes of more and less advanced countries towards protection of intellectual property. The importance of defining common regulations in a global economy was recognized by the inclusion of the Agreement on Trade Related Intellectual Property Rights (TRIPS) in the statute of the WTO.[7] As the relocation of production in less developed countries can undermine growth in the entire system, rich economies have indeed a strong incentive to put pressure for a tightening of global regulations. Similarly, less advanced countries appear more willing to provide protection for IPRs in exchange for a better access to international markets. In this respect, this paper is the first to provide a rationale for linking trade liberalization to a tightening of IPRs and suggests that the TRIPS agreement, despite the criticism of the skeptics, may actually alleviate some undesirable distributional effects of globalization. Third, contrary to the view of industrial-policy advocates, suggesting that developing countries should try to target high growth sectors, the model warn that any sector can become stagnant if incentives to innovation become weak and that industrial targeting can be less effective than hoped.

The results of the paper are based on four assumptions: specialization driven by trade, sector-specific technical progress, imperfect appropriability of profits from innovation in developing countries and an elasticity of substitution between goods higher than one. All of them seem plausible and are shared by many models. That countries specialize in different sets of products, at least to some extent, appears reasonable. More specifically, the Ricardian model has proven to be useful in the

[7] The TRIPS agreement establishes minimum standards of protection for several categories of IPRs and a schedule for developing countries to adopt them.

literature on trade and technology and the absence of factor price equalization makes it suitable for analyzing the world income distribution. Several observations suggest that technical progress has a strong sectoral dimension. For example, R&D is mainly performed by large companies and therefore directed to their range of activities. Although innovation certainly generates spillovers, Jaffe et al. (1993) show that these are generally limited to products in similar technological categories.[8] Infringements of IPRs in developing countries is indeed a significant phenomenon, as proven by the many complaints of large companies based in industrial countries. In this respect, the US Chamber of Commerce estimated a profit loss for US firms of about $24 billion in 1988. Finally, gross substitutability between goods seem realistic, as it yields the sensible prediction that fast growing sectors and countries become relatively richer.

The paper is related to the vast literature on endogenous growth and trade. The model with the closest setup to the present is perhaps the one suggested by Taylor (1994), who studies growth, IPRs and trade in a Ricardian model with sector-specific innovation. However, the assumption of a unit elasticity of substitution between goods prevents him from investigating distributional issues related to sectoral growth. Acemoglu and Ventura (2002) study how trade generates a stable world income distribution, but they do not analyze IPRs, innovation and imitation. Acemoglu and Zilibotti (2001) focus on factor-specific technical progress in a model where developing countries do not protect IPRs and show how this leads to the development of technologies not appropriate for the skill-endowment of the South. Despite the similar setup, in their model trade has quite different implications, as it generates productivity convergence and leaves the world growth rate unaffected.[9] The main reason for these contrasting resuts is that Acemoglu and Zilibotti use a Heckscher-Ohlin trade model, featuring factor price equalization. Closer to the spirit of the earlier endogenous growth approach, Young (1991) builds a model of learning by doing where trade can slow down the growth rate of a country that specializes in a sector with weak dynamic scale economies. The result of this paper is more general, as it shows that trade induces innovation diversion in favor of rich countries irrespective of the sector of specialization, because what matters for attracting

[8]Cross-sectoral spillovers can be included in the model without affecting the qualitative results as long as spillovers are less beneficial than a directed innovation.

[9]Acemolgu and Zilibotti (2001) claim, without proving it, that trade, by inducing skill-biased technical change, increases the North-South income gap. It turns out that this result holds only under special circumstances. What is general, in their model, is that the endogenous response of technology makes trade less beneficial for poor countries than would othewise be.

innovation is not a characteristic of sectors, but an institutional feature of countries.

The paper is also related to the formal literature on IPRs, imitation and welfare, that goes back to the product cycle Ricardian model of Krugman (1979). A number of papers used his approach to study several aspects of the issue, including the effects of licensing or FDI. The earlier contributions highlighted the negative effects of strong IPRs as they would restrict the efficient allocation of resources.[10] More recently, the view that IPRs can foster growth and stimulate the diffusion of technology has gained more consensus.[11] Abstracting from product cycles, this paper offers a complementary view based on cost-saving innovations that yields new results in favor of IPRs protection. An important virtue of this approach is that it incorporates the idea that technologies can be inappropriate for developing countries and that IPRs protection can play a role in attracting better technologies. These important considerations are absent in most of the product-cycle literature.[12] Further, these models do not usually deal with the effects of IPRs under different trade regimes. Another strand of literature focuses on the welfare effects of the monopoly distortion introduced by patent laws in a trading environment.[13] In comparison, this paper shows that different regulations across countries generate a new inefficiency, innovation diversion, that should be taken into account in designing an optimal system of international protection of intellectual property.

Finally, this analysis is complementary to Matsuyama (2000). He develops a Ricardian model where the North has a comparative advantage in high income elasticity goods. In his set up, a uniform and exogenous increase of world productivity results in a terms-of-trade deterioration for the South, because it raises the demand for the good in which the North has a comparative advantage. But Matsuyama's paper does not study the effects of the trade on technical progress, which is the main theme here.

The rest of the paper is organized as follows. Section 2 presents the basic two-country model, solves for the equilibrium under autarky and free trade and derives the two main results, that trade integration with a country where IPRs are weak can lead to divergence in income levels and slow down world growth. The analysis

[10] Among these models are Helpman (1993), Glass and Saggi (1995) and, more recently, Dinopoulos and Segerstrom (2003).

[11] Among these model, see Lai (1998), Yang and Maskus (2001) and Antras (2002).

[12] See, for example, Kremer (2002), Sachs (1999), Diwan and Rodrik (1991), and Acemoglu and Zilibotti (2002).

[13] See Chin and Grossman (1990), Deardorff (1992) and recently Grossman and Lai (2002).

ends with some extensions and a list of empirical predictions. Section 3 shows some supportive empirical evidence. Section 4 concludes.

2 The Model

2.1 Autarky

Consider first the set N of rich countries (the North). The North is assumed to be a collection of perfectly integrated economies with similar characteristics, whose total population is L_N. The subscript N is suppressed where it causes no confusion. Consumers have identical isoelastic preferences:

$$U = \int_0^\infty \ln c(t)\, e^{-\rho t} dt.$$

There is a continuum $[0,1]$ of sectors, indexed by i. Output of each sector, $y(i)$, is aggregated in bundle Y used both for consumption and investment:

$$Y = \left[\int_0^1 y(i)^{\frac{\epsilon-1}{\epsilon}}\, di\right]^{\frac{\epsilon}{\epsilon-1}}, \tag{1}$$

where $\epsilon > 1$ is the elasticity of substitution between any two goods. The relative demand obtained by maximizing (1) is:

$$\frac{p(i)}{p(j)} = \left[\frac{y(i)}{y(j)}\right]^{-1/\epsilon}. \tag{2}$$

The aggregate Y is taken as the numeraire and its price index is therefore set equal to one:

$$P = \left[\int_0^1 p(i)^{1-\epsilon}\, di\right]^{\frac{1}{1-\epsilon}} = 1. \tag{3}$$

Each good $y(i)$ is homogeneous and produced by competitive firms using machines $x(i)$ and labor $l(i)$:

$$y(i) = A(i)^\beta\, x(i)^{1-\beta}\, l(i)^\beta, \tag{4}$$

where $A(i)$ is an index of machine productivity in sector i. Machines are sector-specific, non tradeable and depreciate fully after use. Demand for machine $x(i)$

derived from (4) is:

$$x(i) = [(1-\beta) p(i) / \chi(i)]^{1/\beta} A(i) l(i), \tag{5}$$

where $\chi(i)$ is the price of machine $x(i)$. Machines in each sector are produced by a monopolist. The unit cost of producing any machine is normalized to $(1-\beta)^2$. Together with isoelastic demand (2), this implies that the monopolist in each sector charges a constant price, $\chi(i) = (1-\beta)$. Substituting $\chi(i)$ and (5) into (4), yields the quantity produced in sector i as a linear function of the level of technology $A(i)$ and employed labor $l(i)$:

$$y(i) = p(i)^{(1-\beta)/\beta} A(i) l(i). \tag{6}$$

The linearity of $y(i)$ in $A(i)$ is crucial for endogenous growth, but it is not a sufficient condition. As it will become clear later on, an expansion of $y(i)$ can reduce its price $p(i)$ and this can effectively generate decreasing returns. Given the Cobb-Douglas specification in (4), the wage bill in each sector is a fraction β of sectoral output. Therefore, equation (6) can be used to find the relation between equilibrium prices and the wage:

$$w = \beta p(i)^{1/\beta} A(i). \tag{7}$$

Since there is perfect mobility of labor across sectors, the wage rate has to be equalized in the economy. Dividing equation (7) by its counterpart in sector j delivers the equilibrium relative price of any two varieties:

$$\frac{p(i)}{p(j)} = \left[\frac{A(j)}{A(i)}\right]^{\beta}. \tag{8}$$

Intuitively, sectors with higher productivity have lower prices. Using (7), integrating over the interval $[0,1]$ and making use of (3) shows that the equilibrium wage rate is a CES function of sectoral productivity:

$$w = \beta \left[\int_0^1 A(i)^{\beta(\epsilon-1)} di\right]^{1/\beta(\epsilon-1)}. \tag{9}$$

Using (6) and (8) in (2) yields the optimal allocation of workers across sectors. Integrating over the interval $[0, 1]$ gives:

$$l\left(i\right)=L\frac{A\left(i\right)^{\beta(\epsilon-1)}}{\int_0^1 A\left(j\right)^{\beta(\epsilon-1)}dj}. \tag{10}$$

Note that more productive sectors attract more workers (as long as $\epsilon > 1$) because the value of marginal productivity of labor has to be equalized. Profits generated by the sale of machine i are a fraction $\beta\left(1-\beta\right)$ of the value of sectoral output:

$$\pi\left(i\right)=\beta\left(1-\beta\right)p\left(i\right)^{1/\beta}A\left(i\right)l\left(i\right). \tag{11}$$

The evolution of technology combines Ricardian elements with endogenous technical change. The productivity index $A(i)$ in each sector is the product of two components, an exogenously given productivity parameter, $\phi\left(i\right)$, and the level of current technology in use in sector i, $a\left(i\right)$:

$$A\left(i\right)=a\left(i\right)\phi\left(i\right).$$

While $\phi\left(i\right)$ is fixed and determined by purely exogenous factors, such as the specific environment of a country, $a\left(i\right)$ can be increased by technical progress. For simplicity, the model assumes that all the countries in the North share the same productivity schedule $\phi=\left(\phi\left(i\right)\right)$. Innovation is directed and sector specific. To simplify, without loss of generality, innovation is modelled as incremental:[14] in the R&D sector, μ units of the numeraire can increase the productivity of machine i by $\partial a\left(i\right)$. Once an innovation is discovered, the innovator is granted a perpetual monopoly over its use. The patent is then sold to the producer of machine i. Free-entry in the R&D sector drives the price of any innovation down to its marginal cost μ. The monopolist decides how much innovation to buy by equating the marginal value of the quality improvement, the present discounted value of the infinite stream of profits generated by the innovation, to its cost. Along the balanced growth path, where $\partial\pi\left(i\right)/\partial a\left(i\right)$

[14] This description of innovation is equivalent to the expanding variety approach of Romer (1990). See Gancia and Zilibotti (2003) for more details on growth through expanding variety of intermediates and how to rewrite the present model in that context.

and r are constant, this condition is:

$$\frac{\partial \pi(i)}{\partial a(i)}\frac{1}{r}=\mu.$$

Using (11), (10), (7) and normalizing $\mu=\sigma(1-\beta)\beta$, the previous expression reduces to:[15]

$$L\phi(i)\left[\frac{\beta w}{A(i)}\right]^{1-\beta(\epsilon-1)}=r. \tag{12}$$

For the remainder of the paper, define $\sigma\equiv\beta(\epsilon-1)$ and assume $\sigma\in(0,1)$. On the one hand, the assumption $\sigma>0$ (equivalent to $\epsilon>1$) rules out Bahgwati (1958) immiserizing growth: the fact that a sector (later on a country) growing faster than the others would become poorer. On the other hand, the restriction $\sigma<1$ is required to have a stable income distribution across sectors: it implies that if a sector grows more than another, its relative profitability would fall, discouraging further innovation.[16] If violated, it would be profitable to innovate in one sector only and all the other sectors would disappear, a case that does not seem realistic. From this discussion, it is clear that along the balanced growth path R&D is performed for all the machines and all the sectors grow at the same rate. But for this to be the case, the incentive to innovate has to be equalized across sectors. Therefore, imposing condition (12) for all i, it is possible to characterize the equilibrium profile of relative productivity across sectors:

$$\frac{A(i)}{A(j)}=\frac{a(i)\phi(i)}{a(j)\phi(j)}=\left[\frac{\phi(i)}{\phi(j)}\right]^{\frac{1}{1-\sigma}}. \tag{13}$$

Equation (13) shows that, as long as $\sigma>0$ (i.e., $\epsilon>1$), sector specific innovations amplify the exogenously given productivity differences $\phi(i)/\phi(j)$. As for labor mobility, in order to equalize the returns to innovation, the exogenously more productive sectors need to have an higher than average $a(i)$.

Finally, using (12), (9) and the Euler equation for consumption growth $g=r-\rho$,

[15] This normalization, where σ is defined below as $\beta(\epsilon-1)$, is meant to simplify the algebra only.

[16] When trade is allowed, this assumption yields a stable distribution of income across countries. Evidence of stability of the world income distribution is provided by Acemoglu and Ventura (2002), showing that countries growing faster than the average experienced a deterioration of their terms of trade.

the autarky growth rate of the economy can be found as:

$$g = L \left[\int_0^1 \phi(i)^{\sigma/(1-\sigma)} di \right]^{(1-\sigma)/\sigma} - \rho \tag{14}$$

Consider now the set S of poor countries (the South). In the aggregate, the South is assumed to have a schedule of exogenously given productivity, ϕ_S, different from that of the North, ϕ_N. This Ricardian element captures the fact that geographic, cultural and economic differences (taken as exogenous) make the South relatively more advantaged in some activities compared to the North, even when technological knowledge is common. Following Dornbusch et al. (1977), sectors are conveniently ordered in such a way that the index $i \in [0,1]$ is decreasing in the comparative advantage of the North, i.e., $\phi_N(i)/\phi_S(i) > \phi_N(j)/\phi_S(j)$ if and only if $i < j$. To further simplify the analysis, assume that $\phi_N(i)$ is weakly decreasing in i and $\phi_S(i)$ is weakly increasing in i, so that the most productive sector in the North is the least productive in the South. To start with, consider the case of no protection of IPRs in the South. Still, the South is allowed to imitate at a small cost the innovations introduced in the North, so that the endogenous component of technology, $a(i)$, is identical in all the countries. This assumption reflects the quasi public good nature of technical progress, according to which only IPRs protection can exclude others from exploiting past discoveries. For simplicity, the analysis adopts a stylized description of the R&D sector in which innovators produce for the world economy and the cross-country distribution of the R&D cost is proportional to the net revenue accruing to the innovator in each country.[17] With no IPRs protection in the South and no trade, the Northern equilibrium is unaffected by other countries. In particular, the sectoral distribution of technical progress, $a(i)$, is determined by (13) according to the exogenous productivity index of the North, $\phi_N(i)$. The only difference in the South is that technical progress, embedded in $a(i)$, is taken as given from the North.[18] Using equations (9) and (13) yields the North-South wage ratio, $\omega \equiv$

[17]This assumption makes the localization of R&D irrelevant for the purpose of the analysis. Equivalently, the localization of R&D could be studied by allowing profit transfers between countries in terms of Y. In any case, given the small size of the R&D sector, about 2% of GDP in advanced countries and much less in the rest of the world, this simplification seems innocuous.

[18]In the South, each machine i will be produced by a monopolist, as in the North. In presence of a small imitation cost, no two firms have an incentive to produce the same machine because price competition would lead them to negative profits. The postulated independence between the monopoly distortion in the imitating South and its IPRs regime is dictated by simplicity and precludes the analysis of the trade-off between the dynamic loss and the static benefit of weak IPRs

w_N/w_S:

$$\omega = \left[\frac{\int_0^1 \phi_N(i)^{\sigma/(1-\sigma)} \, di}{\int_0^1 \phi_N(i)^{\sigma^2/(1-\sigma)} \phi_S(i)^{\sigma} \, di} \right]^{1/\sigma} \tag{15}$$

First, note that $\partial\omega/\partial\phi_N(i) > 0$ and $\partial\omega/\partial\phi_S(i) < 0$. Intuitively, the relative wage is proportional to the exogenous productivity of the two regions, ϕ_N and ϕ_S. More important, the Appendix shows that the sectoral profile of technology is optimal for the North, in the sense that it maximizes Y_N, and is appropriate for the South only in the limit case when the two regions have the same sectoral distribution of ϕ ($\phi_S(i) = \alpha\phi_N(i), \forall i$, with α equal to a constant of proportionality).[19] This result mirrors, in a different setup, that of Acemoglu and Zilibotti (2001). Further, the Appendix shows that $\forall\sigma \in (0,1)$ ω is bounded by $\max\{\phi_N(i)/\phi_S(i)\} = \phi_N(0)/\phi_S(0)$. Lastly, since growth is due to the expansion of the $a(i)$ that are identical across countries, equation (14) for the North gives also the growth rate of the South.

Consider now the case of imperfect protection of IPRs in the South. To keep the analysis a simple as possible, assume that the owner of a patent can extract only a fraction θ of the profits generated by its patent in the South.[20] Therefore, θ can be interpreted as an index of the strength of IPRs protection. The profitability of an innovation is now the sum of the rents generated both in the North and in the South, and the marginal condition for buying innovations becomes:

$$\left[\frac{\partial\pi_N(i)}{\partial a(i)} + \theta \frac{\partial\pi_S(i)}{\partial a(i)} \right] \frac{1}{r} = \mu$$

Substituting the expressions for profits and solving for $a(i)$ yields:

$$a(i) = \left[\frac{L_N\phi_N(i)^{\sigma}(w_N)^{1-\sigma} + \theta L_S\phi_S(i)^{\sigma}(w_S)^{1-\sigma}}{r} \right]^{1/(1-\sigma)} \tag{16}$$

in poor countries. This trade-off, studied extensively in the literature, is particularly important for welfare analysis, which is not the main concern of the paper. On the contrary, positive rents from innovation in the South are crucial to study the case of partial protection of IPRs. This latter case seems realistic, since companies do receive royalties from developing countries.

[19] Remember that it is optimal to have high quality machines in sectors where the exogenous productivity is already high. Copying the technology from the North, the South is using high quality machines in sectors that are originally not productive. This inefficiency lowers the wage in the South.

[20] This description of IPRs is both simple and general. It can also capture practices such as licensing, where rent sharing is necessary to deter default or imitation on behalf of the licensee. See Yang and Maskus (2001) on this.

Note that the endogenous component of sectoral productivity is now proportional to a weighted average of the two exogenous indexes $\phi_N(i)$ and $\phi_S(i)$, with weights that depend on country size, the strength of property rights and relative income. The general expression for the relative Northern wage becomes:

$$\omega = \left\{ \frac{\int_0^1 \phi_N(i)^\sigma \left[L_N \phi_N(i)^\sigma + \theta L_S \phi_S(i)^\sigma (\omega)^{\sigma-1} \right]^{\sigma/(1-\sigma)} di}{\int_0^1 \phi_S(i)^\sigma \left[L_N \phi_N(i)^\sigma + \theta L_S \phi_S(i)^\sigma (\omega)^{\sigma-1} \right]^{\sigma/(1-\sigma)} di} \right\}^{1/\sigma} \tag{17}$$

Whether technology is closer to the Northern or Southern optimum, depends on which of the two markets for innovations, L_N and θL_S, is larger (see also the Appendix). As $\theta L_S / L_N \to 0$, equations (17) reduces to (15). Therefore, the case of no IPRs protection defines an upper bound for ω in autarky.

Finally, using (16), (9) and the Euler equation $g = r - \rho$, the growth rate of the world economy for the general case when $\theta \neq 0$ can be found as:

$$g = \left\{ \int_0^1 \left[L_N \phi_N(i) + \theta L_S \phi_S(i)^\sigma \left(\phi_N(i) / \omega \right)^{1-\sigma} \right]^{\sigma/(1-\sigma)} di \right\}^{(1-\sigma)/\sigma} - \rho \tag{18}$$

Note that the world growth rate increases with θ because stronger IPRs translate into higher profits for innovation. As $\theta \to 0$, the growth rate declines to (14), defining a lower bound for the growth rate in autarky.

2.2 Trading Equilibrium

Trade takes place because of the Ricardian element of the model: even if technological progress is endogenous, productivity differences across countries are completely exogenous and so is comparative advantage. Recall that the ordering of sectors $i \in [0, 1]$ is decreasing in the comparative advantage of the North, so that $\phi_N(i) / \phi_S(i) > \phi_N(j) / \phi_S(j)$ if and only if $i < j$. Further, for analytical tractability, the comparative advantage schedule, i.e., the ratio of exogenous productivity $\phi_N(i) / \phi_S(i)$, is assumed to be continuous. The static equilibrium under free trade can be found imposing two conditions. The first is that each good is produced only in the country where it would have a lower price. Therefore, the North specializes in the sectors $[0, z]$ where its comparative advantage is stronger and the South produces the remaining range of goods $[z, 1]$. Given the continuity assumption on the comparative advantage schedule, the North and the South must be equally good at producing the cut-off commodity z: $p_N(z) = p_S(z)$. Using (7), this latter condition identifies the cut-off sector z as a function of the relative wage under free trade ω:

$$\frac{\phi_N(z)}{\phi_S(z)} = \omega. \tag{19}$$

Since comparative advantage of the North is decreasing in z, condition (19) traces a downward sloping curve, Φ, in the space (z, ω). The second equilibrium condition is trade balance, i.e., imports and exports have to be equal in value. Since total output in a country is proportional to the wage bill and the share of consumption allocated to a set $[0, z]$ of goods is $\int_0^z p(i)^{1-\epsilon} di$, trade balance can be written as:

$$w_N L_N \int_z^1 p(i)^{1-\epsilon} di = w_S L_S \int_0^z p(i)^{1-\epsilon} di$$

Note that, by homogenous tastes, the origin of demand (and R&D spending) is irrelevant. Using (7) the trade balance condition can be rewritten as:

$$w_N^{1+\sigma} L_N \int_z^1 A(i)^{\sigma} di = w_S^{1+\sigma} L_S \int_0^z A(i)^{\sigma} di \tag{20}$$

Along a balanced growth path, the profits generated by innovation in any pair of sectors must be equal. In particular, considering innovations for the Northern and the Southern markets, i and j, the following condition must hold: $\partial\pi_N(i)/\partial a(i) = \theta\partial\pi_S(j)/\partial a(j)$. Substituting (11) for profits, noting that under free trade the optimal allocation of labor (10) is $l_N(i) = L_N A_N(i)^{\sigma} / \int_0^z A_N(v)^{\sigma} dv$ and $l_S(j) = L_S A_S(j)^{\sigma} / \int_z^1 A_S(v)^{\sigma} dv$ and using (20), yields the equilibrium sectoral productivity profile:

$$\frac{A_N(i)}{A_S(j)} = \left[\frac{\phi_N(i)}{\theta\phi_S(j)}\right]^{1/(1-\sigma)} (\omega)^{\sigma/(\sigma-1)} \quad \forall i, j \in [0,1] \text{ with } i \leq z \leq j \tag{21}$$

Compared to the autarky case, the relative productivity of sectors under free trade still depends on the exogenous $\phi(i)$, but also on the IPRs regime of the country where the innovation is sold. Technology is still biased towards the exogenously more productive sectors (as $\sigma \in (0,1)$, original differences $\phi_N(i)/\phi_S(j)$ are amplified) but also against the Southern sectors where some rents from innovation are lost ($\theta < 1$). Integrating i over $[0, z]$ and j over $[z, 1]$ in (21) and using (20), the trade balance

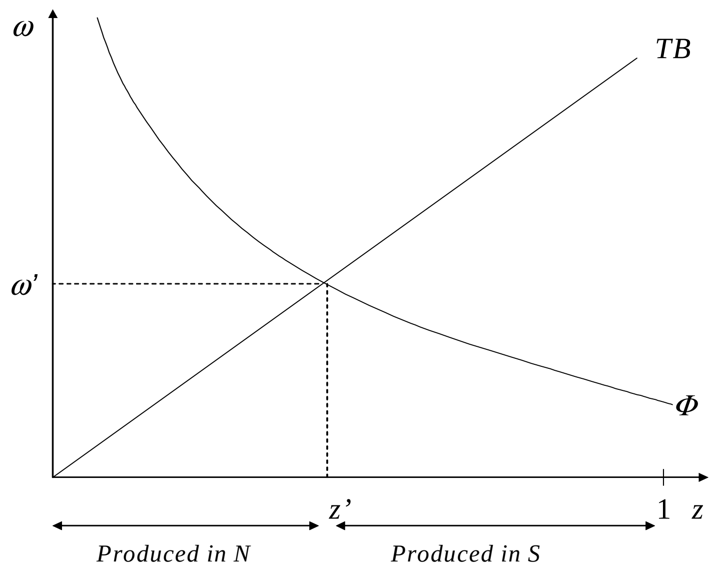

Figure 1: Free Trade Equilibrium

condition (TB), incorporating equilibrium technologies, can be rewritten as:

$$\omega = \theta^{-\sigma} \left[\frac{L_S}{L_N} \frac{\int_0^z \phi_N (i)^{\sigma/(1-\sigma)} di}{\int_z^1 \phi_S (i)^{\sigma/(1-\sigma)} di} \right]^{1-\sigma} \tag{22}$$

Note that ω is increasing in z and decreasing in θ. Further, if $\sigma = 0$ (or $\epsilon = 1$, as in the Cobb-Douglas case), the equilibrium becomes independent on the sectoral distribution of productivity and the degree of IPRs protection.

The long-run free trade equilibrium can now be found in Figure 1 as the intersection of the two schedules Φ (19) and TB (22). The graph can be used to study the effects of a strengthening of IPRs in the South. From (22), this implies a downward shift of the TB schedules which raises the relative wage in the South and reduces the set of goods produced there (z increases). Vice versa, a reduction of θ leads to a deterioration of the Southern relative wage and a relocation of some industries from the North to the South. Comparing (22) with (15), and noting that $\lim_{\theta \to 0} \omega = \max \phi_N(i)/\phi_S(i)$, proves the following:

Proposition 1 *For any $\sigma \in (0,1)$, there exists a level $\overline{\theta}$ such that if $\theta < \overline{\theta}$ income differences in free trade, as measured by ω, are larger than income differences in autarky.*

This is the first result of the paper, that trade can lead to divergence in income and productivity levels. Proposition 1 is based on the interplay between specialization and weak IPRs in developing countries: first, trade and specialization imply that the North and South benefit directly from different sets of innovations. Second, weak IPRs make innovations directed to the South less profitable. As $\theta \to 0$, R&D is directed towards Northern sectors only and the income gap grows up to its maximum $(\phi_N(0)/\phi_S(0))$, irrespective of any other country characteristics. In autarky, instead, even with $\theta = 0$, the South benefits from the innovation activities performed in all the sectors for the Northern market.

If North-South trade (with a low θ) shifts technology systematically in favor of the North, is it always beneficial for advanced countries? The striking answer is negative, as divergence opens the door to stagnation. To see this, calculate the equilibrium growth rate in free trade (see the Appendix for the derivation):

$$g^{FT} = L_N \left[\int_0^z \phi_N(i)^{\frac{\sigma}{(1-\sigma)}} \, di \right]^{\frac{1-\sigma}{\sigma}} \left(1 + \frac{L_S}{L_N} \frac{1}{\omega} \right)^{1/\sigma} - \rho. \tag{23}$$

Note that the growth rate of the world economy is increasing in θ: a higher θ expands the range z of goods produced in the North and decreases ω, all effects that contribute to raising the growth rate in (23). The intuition is simple and is the common argument in favor of IPRs protection: better enforcement of IPRs strengthens the incentives to innovate and therefore fosters growth. *But the surprising implication of (23) is that the growth rate of the world economy approaches zero if θ is low enough.* Endogenous growth is here possible because both the North and the South are growing. If innovations were not directed to Southern sectors, the Northern economy would be trapped into decreasing returns, not only because its sectors would experience falling output prices and profit margins, but also because more and more sectors would move to the South, where production is increasingly cheaper. In fact, long-run growth can stop even if $\theta > 0$. To see this, note that along the balanced growth path innovation has to be equally profitable in all the sectors; if θ is low enough, profitability of R&D in the South becomes so low that returns from investment fall short of the discount factor ρ and growth is destined to cease. Note that this result, like Proposition 1, requires $\sigma > 0$ (i.e., an elasticity of substitution between goods larger than one): with $\sigma = 0$ the cut-off commodity z and the wage ratio ω would not depend on technology, because every country and sector would benefit equally from any improvement in $a(i)$, and (23) would not depend on θ. Also, sector-specific technical process is a key assumption for deriving Proposition 2. In a setup with factor-specific innovations, as in Acemoglu and Zilibotti (2001), the market size for any innovation depends on exogenous endowments that are unaffected by specialization and trade: for this reason, incentives to invest in R&D would never go to zero even if $\theta = 0$.[21]

Comparing the growth rate in free trade, (23), and autarky, (14), and noting that (23) is a continuous function of θ with $\lim_{\theta \to \theta^* > 0} g^{FT} = 0$, proves the following:

Proposition 2 *For any $\sigma \in (0, 1)$, there exists a level $\widehat{\theta}$ such that, if $\theta < \widehat{\theta}$, the world growth rate is lower in free trade than in autarky.*

What happens during the transitional dynamics from autarky to the free trade equilibrium? Since technology adjusts slowly, initially the equilibrium is determined by equations (19) and (20) using the pre-trade values of $a(i)$. In general, the wage in both countries will jump up, as specialization increases the overall efficiency of the whole economy. Then, if the instantaneous wage ratio falls short of its long run free-trade value, there will be a period in which innovation is biased towards Northern sectors. During the transition, the Northern relative wage will rise and at the same time firms will move to the South where production costs are lower. Note that in a trading environment with asymmetric IPRs protection, divergence and stagnation are closely related: it is the growing cost of production in the wealthier North that induces the relocation of production towards the South (an important phenomenon in recent years) which in turn makes more sectors subject to weak IPRs and lowers the global incentives for innovation.

2.3 Why Are IPRs Not Protected in the South?

The previous analysis suggests that Southern countries may benefit from the enforcement of IPRs: it would attract more appropriate innovations and foster world growth. It is then interesting to ask why these policies are often not adopted. A first

[21] As a consequence, in Acemolgu and Zilibotti (2001) trade opening has no effect on the world growth rate.

reason is that imitating countries would lose some profits: a marginal increase in θ induces a profit loss of $\beta(1-\beta) Y_S d\theta$, thereby reducing a country consumption level. Therefore, it can be optimal from the point of view of the South not to have full protection of IPRs. This is more likely the higher the profit share in the economy. Even if strong protection of IPRs is in the interest of the South, in the sense that the productivity gain due to higher or more appropriate innovation outweights the profit loss, the government might fail to implement the optimal policy for political reasons: if the group of monopolists that enjoy the rents from imitation has more political power that the workers, it may prefer to defend its share of profits at the expenses of the rest of the economy. Further, if the Southern policy makers behave myopically and fail to consider the effect of their policies on world innovation, then they would set an inefficiently low level of IPRs protection. Finally, in implementing IPRs protection, there might be a coordination problem among Southern governments of similar countries: each of them prefers the others to enforce IPRs, in order to attract innovation, but has an incentive to free ride not enforcing these property rights itself. However, this depends on the pattern of specialization and on the size of each country. If each Southern country specialized in a different set of commodities, then the coordination problem would disappear, as stronger IPRs would be beneficial for the enforcing country only. Similarly, a large country would have a higher incentive to protect IPRs because of its larger impact on world innovation and its limited ability to benefit from others' policies. To better understand these implications, the analysis is now extended to a multi-country setting.

2.4 Extensions

This section provides a sketch of how to extend the results to a multi-country world and how to incorporate non-traded goods. These extensions add more realistic features to the basic model and help to clarify some of its empirical predictions. Consider first a case where the world economy can be divided into three homogenous regions: high (H), middle (M) and low (L) income countries. A key assumption here is that countries belonging to different regions have different exogenous productivities. The autarky solution is straightforward. To keep the analysis under free trade as simple as possible, assume that $\phi_H(i)/\phi_M(i)$ and $\phi_M(i)/\phi_L(i)$ are continuous and strictly decreasing in i. Further, assume that $\phi_H(i) > \phi_M(i) > \phi_L(i)$, $\forall i \in [0,1]$, implying that $w_H > w_M > w_L$ and that region H specializes in the lower range of goods $[0, z_1]$, region M in an intermediate range $[z_1, z_2]$ and region L produces the high-index goods $[z_2, 0]$. In this case, the first condition for a trading equilibrium, defining the cut-off sectors where it becomes profitable to move production form one region to another as a function of wages, becomes:

$$\frac{w_H}{w_M} = \frac{\phi_H(z_1)}{\phi_M(z_1)} \quad \text{and} \quad \frac{w_M}{w_L} = \frac{\phi_M(z_2)}{\phi_L(z_2)}.$$

The second equilibrium condition, trade balance, can be written in two equations:

$$\begin{aligned} w_H L_H \int_{z_1}^{1} p(i)^{1-\epsilon}\, di &= w_M L_M \int_{0}^{z_1} p(i)^{1-\epsilon}\, di + w_L L_L \int_{0}^{z_1} p(i)^{1-\epsilon}\, di, \\ w_L L_L \int_{0}^{z_2} p(i)^{1-\epsilon}\, di &= w_H L_H \int_{z_2}^{1} p(i)^{1-\epsilon}\, di + w_M L_M \int_{z_2}^{1} p(i)^{1-\epsilon}\, di. \end{aligned}$$

The first requires the value of total imports in region H to be equal to the value of total export from region H; the second is the equivalent condition for region L. Trade balance in region M is then redundant. For a given technology and using (7) to substitute prices away, this system of four equations in four unknown (w_H/w_M, w_M/w_L, z_1 and z_2) can be solved to find the static equilibrium. Along the balanced growth path, innovation has to be equally profitable in all the sectors. In particular, considering sectors localized in different regions, and allowing θ to vary, the following condition must hold:

$$\theta_H \frac{\partial \pi_H(i)}{\partial a(i)} = \theta_M \frac{\partial \pi_M(j)}{\partial a(j)} = \theta_L \frac{\partial \pi_L(v)}{\partial a(v)},$$

for any i, j, v such that $i \leq z_1 \leq j \leq z_2 \leq v$. These conditions can be used to characterize the new trading equilibrium. Leaving the details of the analysis aside, it is easy to see how the logic of previous results extends to the multi-country setting: because of specialization, under free trade a tightening of IPRs in a region (or in a large country of the region) attracts more innovation towards the goods the region is producing. This translates into a higher wage and a reduction of the range of activities performed in the region (moving production abroad becomes more convenient as the domestic labor cost increases). On the contrary, the positive effects of tighter IPRs in a region in autarky are spread across all sectors and affects only a small fraction of the market for innovations (the fraction of profits coming from that specific region) and therefore are less likely to have a significant impact on world incentives to innovate. The main result of the basic model is therefore reinforced:

because of specialization, regulations of even small countries become more effective in an integrated economy.

The introduction of non-traded goods gives rise to a regime that combines elements of both the free-trade and autarky equilibrium. Following Dornbusch et al. (1977), assume that a fraction t of income is everywhere spent on internationally traded goods and a fraction $(1-t)$ is spent in each country on non-traded goods.[22] Assume also that the range of traded goods is represented by the familiar $[0,1]$ interval, maintaining all the characteristics already discussed. More explicitly, consumption and investment are now made out of a new output aggregate, $(Y)^t (Y^*)^{1-t}$, defined over the bundle Y of traded goods and a non-traded good Y^*, denoted by an asterisk. The non-traded good Y^* can be thought of as another range $[0,1]$ of commodities similar to that in the traded sector, although it is simpler to treat it here as a single good, with a production function similar to that of any single $y(i)$.[23] Given the Cobb-Douglas specification, a fraction $(1-t)$ of total labor force is allocated to the non-traded sector: $L^* = (1-t)\,L$. As before, the price index of the traded good Y is set equal to one.[24] The rest of the analysis follows the steps of the basic model, with the difference that now the costs of machines and innovation are not defined in terms of the numeraire, but in terms of final output, with a price index proportional to $(P^*)^{1-t}$. In turn, from the equivalent of equation (7), the price of non-traded goods is found to be proportional to the wage rate: $w = \xi\,(P^*)^{t(1-\beta)/\beta} A^*$, where ξ is a constant and A^* is productivity of labor in the non-traded sector. After redoing all the intermediate caluclations, the condition for efficient specialization in the traded sector, $p_N(z) = p_S(z)$, becomes:

$$\omega = \left[\frac{\phi_N(z)}{\phi_S(z)}\right]^t \left[\frac{A_N^*}{A_S^*}\right]^{1-t}. \tag{24}$$

[22]Non-traded goods can also arise endogenously in the presence of a trade cost. However, modelling a trade cost explicitly would complicate the analysis. More simply, in this setup a reduction of trade cost can be thought of as an expansion of the traded sector. See Dornbusch et al. (1977) for more details.

[23]By treating Y^* as a single good, the analysis abstract from the issue of "appropriateness" of technology in the non-traded sector (i.e., the fact that different countries may desire different technologies for non-traded goods). In order to study the impact of θ_i on income differences, this simplification is innocuous as long as Southern countries are small compared to the world economy. In this case, a change of θ_i would attract better technologies only for the traded goods produced by country i, where specialization neutralizes the small country assumption.

[24]Final output cannot be taken as the numeraire because, in the presence of non-trade goods, its price index will not be equalized across countries.

A higher productivity in the non-traded sector makes a country more competitive because machines are produced with final output, which incorporates also non-traded goods. Trade balance and the arbitrage condition in R&D, $[\partial\pi_N(i)/\partial a(i)]\,(P_N^*)^{t-1} = \theta\,[\partial\pi_S(j)/\partial a(j)]\,(P_S^*)^{t-1}\ \forall i,j \in [0,1]$ with $i \le z \le j$, now yield:

$$\omega = \theta^{\frac{-t\sigma}{(1-\sigma)t+\sigma}} \left[\frac{L_S}{L_N}\frac{\int_0^z \phi_N(i)^{\frac{\sigma}{1-\sigma}}\,di}{\int_z^1 \phi_S(i)^{\frac{\sigma}{1-\sigma}}\,di}\right]^{\frac{t(1-\sigma)}{(1-\sigma)t+\sigma}} \left[\frac{A_N^*}{A_S^*}\right]^{\frac{\sigma(1-t)}{(1-\sigma)t+\sigma}} \tag{25}$$

Note that, as $t \to 1$ the economy approaches the free trade equilibrium; conversely, as $t \to 1$ the wage ratio converges to the relative productivity of labor in the non-traded sector of the two countries, A_N^*/A_S^* (as in the autarky case, where A^* was a more complicated function of technology). Further, it is easy to see that the presence of non-traded goods makes the two schedules (24) and (25) flatter; given that the absolute value of the exponent of θ in (25) is increasing in t, it follows that the relative wage, ω, is more elastic to a change of the IPRs regime, θ, the higher the share of traded goods, t, in the economy. Considering the wage ratio in real terms, $\omega\,(P_S^*/P_N^*)^{1-t}$, reinforces this result: since the price of non-traded goods is proportional to the wage level, for a given change of ω real income difference reacts more the higher is t.

2.5 Empirical Predictions

The key mechanism of the model is the interaction between trade-driven specialization and the ability of a country to attract better technologies by changing the level of protection of IPRs. Given an elasticity of substitution across sectors larger than one ($\epsilon > 1$ or $\sigma > 0$), more innovation targeted to a sector translates into higher sectoral income, both in absolute terms and relative to the rest of the economy. Because of this, a country unambiguously gains from innovations on the goods it is producing. Innovation, in turn, can be stimulated by protecting more the rewards of inventors. In this setup, specialization has two effects. First, by increasing a country's share of world production (and profits) in the sectors of specialization, it increases the impact of country policies on global profitability of innovations directed to those sectors, thereby increasing the ability of a country to attract technologies tailored to its needs. Second, by reducing the number of countries producing a specific good, it limits the benefits of innovations directed to that good on the rest of the world. For these reasons, the model suggests the positive effect of raising θ_i on income of country i to be higher under free trade than in autarky or, more generally, the larger the share t of traded goods in the economy. Further, since the ability of country i to attract innovation in sector j depends on its share in world production of that sector, which in turn depends on country size, the model suggests that the impact of θ_i on productivity should be higher in larger countries. More precisely, assuming that a single country is "small" compared to the world economy, but "large" compared to the subset of countries specialized in the same range of goods, these implications can be derived formally and summarized as:

$$\frac{\partial\left(y_i/\overline{y}\right)}{\partial\theta_i\partial t} > 0 \quad \text{and} \quad \frac{\partial\left(y_i/\overline{y}\right)}{\partial\theta_i\partial L_i} > 0 \tag{26}$$

where y is real GDP per worker and $\overline{y}$ is the world average. The first inequality follows directly form (24) and (25). To derive the second, note that what matters to attract better technologies is the population-weighted average of the index of IPRs protection in a given region R of similar countries, $\theta_R = \left(\sum_{i\in R}\theta_i L_i\right)/\sum_{i\in R} L_i$. Since the main results of the paper hinge critically on these interactions, testing the sign of the cross-partial derivatives in (26) provides a way to assess the empirical plausibility of the model. Predictions on the overall effect of IPRs seem instead less useful to evaluate the theory. Although the model implies that raising θ should always have a positive effect on productivity, this result relies heavily on the simplifying assumption that θ does not affect the monopoly distortion in the South.

3 Empirical Analysis

To test the inequalities in (26), measures of labor productivity, IPRs protection, openness to trade and size have been collected for a panel of countries from 1965 to 1995. Labor productivity is proxied by real GDP per worker (GPDW) from the Penn World Table 6.0 (PWT6.0). Two important determinants of productivity are also included in the analysis: the stock of physical capital per worker (KL), again from PWT6.0, and the fraction of working age population with at least secondary schooling as a proxy for human capital (HL), from Barro-Lee. As for trade openness, two different measures are considered: the Sachs and Warner (1995) index, which is a dummy taking value one if a country is classified as open, and the trade share in total GDP form PWT6.0.[25] Although the first is useful to distinguish countries under different trade regimes, it exhibits almost no time variation in the sample and is therefore appropriate for the cross-section only. The second measure, instead, captures well the increase in market integration over time. Country size is measured by total population (POP), as reported in PWT6.0. The last challenge is to find reliable data on the degree of protection of intellectual property. In this respect, this study uses the index of patent rights built by Ginarte and Park (1995). Although patents are only a component of IPRs, they are likely to be highly correlated with the overall level of protection; further, this index has the advantages of being available for a large number of countries with quinquennial observation since 1965 and of being based on both the strength and enforceability of national laws.[26] The index (IPR) ranges from 0 to 5. In summary, the overall dataset comprises a cross-section of 53 countries and 6 time observations, from 1965 to 1990 at 5 year intervals.[27] Descriptive statistics are reported in Table 1.

To get a first sense for the patterns in the data, Table 2 presents a set of conditional correlations. The results are encouraging for the present theory. As predicted by the model, IPRs protection is associated with higher productivity only for countries classified as open by Sachs and Warner. The correlation is zero for closed economies. Likewise, being open has a much higher correlation with productivity in countries with strong patent rights. Also the second prediction in (26) seems broadly consistent with the data, as IPRs protection is found to have a higher correlation with productivity in larger countries.

[25]According to Sachs and Warner, an economy is classified as open if satisfies all of the following criteria: (1) nontariff barriers cover less than 40 percent of trade (2) average tariff rates are less than 40 percent (3) any black market premium was less than 20 percent during the 1970s and 1980s (4) the country is not classified as socialist and (5) the government does not monopolize major exports.

[26]This index is based on an assessment of five aspects of patent laws: (1) extent of coverage, (2) membership in international patent agreements, (3) provision for loss of protection, (4) enforcement mechanisms and (5) duration of protection. An alternative, but time-invariant, measure of IPRs is provided by Rapp and Rozek (1990). On the cross-section, the two proxies yield very similar results.

[27]Data are available for the following countries: Argentina, Australia, Austria, Belgium, Bolivia, Botswana, Canada, Chile, Colombia, Denmark, Dominican Rep., Ecuador, Finland, France, Greece, Guatemala, Honduras, Hong Kong, Iceland*, India, Iran, Ireland, Israel, Italy, Jamaica, Japan, Kenya, Korea Rep., Malawi, Mauritius, Mexico, Nepal, Netherlands, New Zealand, Norway, Panama*, Paraguay, Peru, Philippines, Portugal, Sierra Leone, Spain, Sri Lanka, Sweden, Switzerland, Syria, Thailand, Turkey, U.K., U.S.A., Venezuela, Zambia, Zimbabwe. An asterisk (*) indicates no Sachs and Warner index available.

Table 1: Descriptive Statistics

	IPR	OPEN*	OPEN	KL	HL	POP	GDPW
1965	2.47 (0.59)	0.52 (0.50)	46.69 (25.69)	7848 (7703)	19.82 (18.39)	26420 (70771)	16953 (11608)
1970	2.52 (0.67)	0.51 (0.50)	50.37 (29.52)	10232 (9265)	23.51 (19.61)	29003 (78764)	18915 (12248)
1975	2.53 (0.67)	0.49 (0.50)	57.83 (29.51)	12997 (11394)	26.11 (19.95)	31833 (87549)	20917 (13244)
1980	2.69 (0.85)	0.52 (0.50)	61.42 (31.38)	15190 (12781)	32.72 (22.09)	34782 (97354)	21347 (14101)
1985	2.71 (0.89)	0.49 (0.50)	60.69 (35.42)	16507 (14154)	35.59 (21.63)	37821 (107662)	23412 (15666)
1990	2.75 (0.90)	0.70 (0.46)	63.54 (38.14)	18754 (16336)	40.26 (21.99)	41039 (118867)	25433 (16960)
Correlation Matrix							
IPR	1.00						
OPEN*	0.40	1.00					
OPEN	0.20	0.26	1.00				
KL	0.55	0.50	0.11	1.00			
HL	0.61	0.50	0.16	0.78	1.00		
POP	-0.05	-0.07	-0.31	-0.07	-0.01	1.00	
GDPW	0.59	0.60	0.16	0.86	0.80	-0.05	1.00

Note: OPEN* is the Sachs and Warner index of openness. Standard error in parentheses.

Table 2: Conditional Correlations

Variable	Conditional on	CORR with GDPW	N. obs.
IPR	OPEN=0	0.003	146
IPR	OPEN=1	0.748	166
OPEN	IPR<2.5	0.238	135
OPEN	IPR>=2.5	0.726	177
IPR	POP<mean	0.48	254
IPR	POP>=mean	0.85	70

Note: OPEN= Sachs and Warner index of openness

A better way to display these correlations is through simple least-square regressions on the pooled data. Throughout, all the variables are in logs, except for dummies; further, to alleviate simultaneity concerns, all the right-hand side variables are lagged five years. Column (1) of Table 3 reports the results of regressing real output per worker (GDPW) on patent rights (IPR) the Sachs and Warner openness index (OPEN), an interaction term between IPR and OPEN, an interaction term between IPR and country size (POP) and country size itself (POP). The regression also controls for the two important determinants of productivity, physical (KL) and human (HL) capital per worker. According to (26) the two interaction terms should have a positive sign. Consistently, column (1) shows that the coefficient on both interactions is positive and precisely estimated.

Table 3: Panel Analysis

	OLS(1)	OLS(2)	LSDV(3)	LSDV(4)	LSDV(5)
IPR	-1.941 (0.697)***	-5.723 (1.568)***	-0.407 (0.875)	-0.464 (0.411)	-0.904 (0.488)*
OPEN	-0.437 (0.200)**	-0.719 (0.231)***	0.041 (0.098)	0.038 (0.096)	0.153 (0.114)
IPR*OPEN	0.801 (0.265)***	0.556 (0.212)***	0.216 (0.105)**	0.219 (0.103)**	0.385 (0.122)***
IPR*POP	0.163 (0.065)**	0.393 (0.089)***	-0.005 (0.074)	-	-
POP	0.207 (0.70)***	-0.452 (0.092)***	-0.013 (0.113)	-	-
KL	0.400 (0.075)***	0.453 (0.073)***	0.323 (0.034)***	0.321 (0.031)***	-
HL	0.164 (0.084)*	0.214 (0.080)***	-0.037 (0.036)	-0.042 (0.024)*	-
R^2	0.83	0.82	0.58	0.58	0.39
No. of Obs.	306	318	318	318	318
F-test[country effects] (P-value)	-	-	31.02 (0.000)	39.06 (0.000)	122.44 (0.000)
Hausman χ^2 (P-value)	-	-	176.16 (0.000)	48.56 (0.000)	8.63 (0.034)

LHS: real GDPW. All variables, except dummies, in logs. RHS variables are lagged (5 yeras). Column 1 uses the Sachs and Warner Openness index. Columns 2-5, use the trade share in GDP. Standard errors in parenthesis (robust, in OLS regressions). Constant not reported. *, ** and *** indicate significance at 10%, 5% and 1% level.

Although the pooled OLS regression is a useful way to summarize partial correlations in the data, it may place too much weight on cross-sectional variation and suffer from omitted variables, particularly given the small number of covariates. In this respect, a LSDV regression with country fixed-effects has more advantages, as it controls for omitted variables that change very little over time and that may be correlated with other regressors, such as institutional and geographical characteristics of countries. However, since this estimator uses only within-country variation, the Sachs and Warner index of openness, with its almost nil time variation, is here inadequate. The analysis therefore continues using the trade share in GDP as a measure of openness. Before moving to the fixed-effects regression, Column (2) shows again the pooled OLS estimates with the new trade measure and it confirms the previous findings: the two interaction terms are positive and significant at the 1% level.

Columns (3)-(5) report the results from the LSDV fixed-effects estimator. Column (3) includes all the right-hand side variables. The interaction term between patent rights and openness is still positive and significant. On the contrary, the coefficient on country size is now very small and not statistically different from zero. This is not very surprising, given that population varies mostly across countries (Table 1 shows that the cross-sectional standard error of POP is almost three times its mean). It suggests that only the large cross-sectional variation of country size may have a significant impact on the effectiveness of IPRs, which is not inconsistent with the theory. Column (4) reports the estimates after dropping the size variables, whose contribution to explain changes in productivity over time has been found statistically small. Finally, Column (5) isolates the effects of patent rights and trade, the main variables of interest, by dropping all the other covariates. In all cases, the coefficient on the interaction term between openness and patent rights is consistently found to be positive and statistically different form zero.[28] To conclude, given that in all the specifications the coefficient on the interaction term is found to be positive with significance levels always below 4%, there seems to be fairly robust evidence that patent laws are more correlated with high productivity in open countries.

A few calculations on the coefficients in Table 3 can help to understand the magnitude of the effects and if the estimates across specifications are comparable. Consider first the impact of intellectual property protection. For the average country, Columns 1-3 imply that a 10% increase of the index of patent rights is associated

[28] Adding a time trend affects the results only marginally and turns out not significant.

with an output change of -0,3%, +0,7% and +3,8% respectively. These numbers suggest that, for the average country, gains form stronger IPRs may be uncertain. The situation is different for trading economies: with openness one standard error above the sample mean, the reaction of output becomes +3,7%, +4% and +5,1% respectively. Conversely, for countries closed to trade (one standard deviation below the sample mean) the effect may be negative: -4,3%, -2,5% and +2,5%. Similarly, according to Columns 1-3, a 10% increase of the openness index in the average country is associated with an output change of +2,9%, -2,1% and +1,5%, respectively. In countries with patent rights one standard error above the sample mean, the positive effect of trade is instead more pronounced: +5,5%, -0,3% and +2,2%. Finally, for countries with patent rights one standard error below the sample mean, the effect of trade becomes small or even negative: +0,3%, -3,9% and +0,8%. Although the variability of estimates across specifications is not too high, given that coefficients come form regressions using very different trade measures and estimation techniques, it makes it difficult to draw sharp empirical conclusions. However, these numbers indicate that open and perhaps large economies may benefit substantially from stronger patent laws. It may thus suggest that the process of trade liberalizations in India and China could be more beneficial if accompanied by a tightening of IPRs. Moreover, given the 34% increase of average openness over the sample period and the high correlation between patent rights and income, these estimates suggest that globalization may have contributed to the widening of income disparities.

How do these results relate to the empirical literature on trade, growth and convergence? A general finding of several influential papers is that openness promotes growth and convergence. In particular, a first strand of literature documents a positive correlation between trade and growth.[29] Likewise, this paper shows that integration may enhance productivity in all countries because of static (and potentially dynamic) gains from trade, but in addition it argues that countries with better IPRs policies may reap more benefits than others. Further, recent works by Easterly and Levine (2002) and Rodrik et al. (2002) have questioned the robustness of the correlation between trade and growth. In particular, these authors argue that the correlation disappears after controlling for institutional quality and addressing endogeneity issues. The importance of institutions is again in line with the central message of this paper: that the effect of trade on productivity and growth depends

[29] Frankel and Romer (1999) and Sachs and Warner (1995) are two notable examples.

crucially on property rights, which are an important institutional factor. A second strand of literature is focused on market integration and convergence. Here, Barro and Sala-i-Martin (1995) find strong evidence of convergence among highly integrated countries and regions (OECD countries, the US states, European regions and Japanese prefectures) and Ben-David (1993) shows that the removal of trade barriers fostered convergence across countries who joined the European Economic Community. These results are not inconsistent with the model and the evidence presented in this paper, because they show the pro-convergence effect of integration between countries with similar property rights related regulations.

Before concluding, it is worthwhile to mention briefly some interesting empirical observations. The model predicts that in a period of growing world trade the R&D effort of advanced countries should become more specialized towards the sectors in which those countries have a comparative advantage. In this respect, it is perhaps suggestive to look at the evolution of the number of patents by technological category issued in the US over the last four decades, reported by Hall et al. (2001): the three traditional fields (Chemical, Mechanical and Others) have experienced a steady decline, dropping from a share of 76% of total patents in 1965 to 51% only in 1990. Conversely, Computers and Communications rose from 5% to over 20%, Drugs and Medical form 2% to 10%, whereas Electrical and Electronics is the only stable field (16-18% of total). Albeit consistent with the theory, this evidence is more difficult to interpret, as it may reflect technology cycles or changes in demand. More in general, the model generates something resembling a product cycles, where sectors become less technology intensive *after* they move to the South. Distinguishing empirically between this prediction and the traditional view, according to which goods become less technology intensive *before* moving to LDCs, seem an interesting challenge for future work.

4 Concluding Remarks

This paper has presented a simple model where market integration can amplify income differences between rich and poor countries and lower the world growth rate, even in the presence of standard mutual gains from trade. Rather than raising warnings against globalization, the analysis has identified a specific market failure, weak protection of intellectual property in developing countries, under which trade can have undesirable effects.[30] In a world of integrated economies, profits from innovations play a crucial role in directing technical progress towards the needs of all countries and in sustaining long-run growth incentives. This suggests that trade liberalization in developing countries should be accompanied by reforms aimed at a tightening of intellectual property rights. With the inclusion of the TRIPS agreement in the WTO, international negotiations have recently taken important steps in that direction. A major contribution of this paper was thus to provide new theoretical foundations for these efforts. However, even though the analysis hints at large potential gains from global regulations, imposing common standards can be costly for some less developed countries and may not be sufficient. As long as the economic weight of the South is low, profits generated from its markets would not be enough to provide the right incentives for developing appropriate technologies. Although the model has focused on intellectual property rights asymmetries, the sale of innovations in poor countries can generate small profits for a number of other reasons, including high transaction costs and risks of expropriation. Given these distortions, promoting research aimed at the needs of the less developed countries appears to be a the key element for reducing cross-country income differences and fostering world growth.

While the paper has emphasized the quasi public good nature of technology emerging from the endogenous growth literature, where knowledge flows with no frictions across borders, trade itself could contribute to technology transfer between countries. Similarly, the paper has abstracted from new products and product cycle trade. Further, infringements of intellectual property rights and firm structure have been modeled in a very stylized way that does not explicitly include micro details. As a consequence, the model is silent on the potential role played by multinationals. Incorporating these elements into the analysis would certainly help to understand the complex interactions between innovation and income in the global economy and seems a fruitful direction for future research. Finally, the paper has shown that the consequences of globalization may depend on institutional variables such as

[30]Note that the paper does not compare welfare across equilibria. Although free trade can lead to income divergence and even reduce the world growth rate, it also generates gains that can make all countries better off. However, welfare analysis is not the main concern of the paper, which is to show a new link between North-South trade, the world income distribution and growth. Further welfare analysis would yield arbitrary results, as it is unclear how to quantify gains from trade in the present model, and would be complicated by non-trivial transitional dynamics.

property right laws. Whether the effects described can be important in shaping the world income distribution and affecting innovating incentives, remains an empirical question that deserves further study.

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5 Appendix

5.1 Optimality of technologies

Consider first the case of no IPRs protection in S, ($\theta = 0$). Total production in the North is equal to $Y_N = w_N L_N / \beta$. Using (9):

$$Max_{\{a(i)\}} Y_N = L_N \left\{ \int_0^1 \left[a(i)\, \phi_N(i) \right]^\sigma di \right\}^{1/\sigma} \qquad s.t. \quad \int_0^1 a(i)\, di = a$$

The solution to this program has to satisfy the following first order conditions (FOCs), $\forall i \in [0,1]$:

$$L_N \left\{ \int_0^1 \left[a(i)\, \phi_N(i) \right]^\sigma di \right\}^{\frac{1-\sigma}{\sigma}} \left[a(i)\, \phi_N(i) \right]^{\sigma-1} \phi_N(i) = \lambda$$

where λ is the lagrange multiplier associated to the constraint. Taking the ratio of any two FOCs and using $A_N(i) = a(i)\, \phi_N(i)$ yields equation (13). This proves that the sectoral profile of the endogenous technology maximizes Northern output and wage and hence it is optimal for the North.

Consider now the case of imperfect protection of IPRs in S, $(\theta \neq 0)$.

$$\begin{aligned} Max_{\{a(i)\}} Y_N + \theta Y_S &= L_N \left\{ \int_0^1 \left[a\left(i\right) \phi_N(i)\right]^\sigma di \right\}^{1/\sigma} + \theta L_S \left\{ \int_0^1 \left[a\left(i\right) \phi_S(i)\right]^\sigma di \right\}^{1/\sigma} \\ s.t. \int_0^1 a_N\left(i\right) di &= a \end{aligned}$$

the FOCs for a maximum are, $\forall i \in [0,1]$:

$$\begin{gathered} L_N \left\{ \int_0^1 \left[a\left(i\right) \phi_N(i)\right]^\sigma di \right\}^{\frac{1-\sigma}{\sigma}} \left[a\left(i\right) \phi_N(i)\right]^{\sigma-1} \phi_N(i) + \\ \theta L_S \left\{ \int_0^1 \left[a\left(i\right) \phi_S(i)\right]^\sigma di \right\}^{\frac{1-\sigma}{\sigma}} \left[a\left(i\right) \phi_S(i)\right]^{\sigma-1} \phi_S(i) = \lambda \end{gathered}$$

where λ is the lagrange multiplier associated to the constraint. Using (9) and solving for $a\left(i\right)$:

$$a\left(i\right) = \left[\frac{L_N \phi_N\left(i\right)^\sigma \left(w_N\right)^{1-\sigma} + \theta L_S \phi_S\left(i\right)^\sigma \left(w_S\right)^{1-\sigma}}{\beta \lambda} \right]^{1/(1-\sigma)}$$

Comparing this condition with equation (16) in the text shows that the sectoral distribution of the endogenous technology maximizes a weighted sum of Northern and Southern aggregate output, with a weight of θ on the South. As $L_N / \left(\theta L_S\right) \to 0$, technologies maximize w_S, whereas as $L_N / \left(\theta L_S\right) \to \infty$ they maximize w_N.

5.2 Properties of the wage ratio in autarky

To show that the North-South wage ratio in autarky is bounded by $\max \phi_N\left(i\right) / \phi_S\left(i\right) = \phi_N\left(0\right) \phi_S\left(0\right)$, first note that $\partial \omega / \partial \phi_N\left(i\right) > 0$ and $\partial \omega / \partial \phi_S\left(i\right) < 0$. Therefore, by construction:

$$\omega = \left[\frac{\int_0^1 \phi_N\left(i\right)^{\sigma/(1-\sigma)} di}{\int_0^1 \phi_N\left(i\right)^{\sigma^2/(1-\sigma)} \phi_S\left(i\right)^\sigma di} \right]^{1/\sigma} \leq \left[\frac{\int_0^1 \phi_N(0)^{\sigma/(1-\sigma)} di}{\int_0^1 \phi_N\left(0\right)^{\sigma^2/(1-\sigma)} \phi_S\left(0\right)^\sigma di} \right]^{1/\sigma} = \frac{\phi_N\left(0\right)}{\phi_S\left(0\right)}$$

5.3 The growth rate under free-trade

Rewrite the marginal condition for buying innovation in a Northern sector as:

$$\frac{w_N \phi_N\left(i\right) L_N A_N\left(i\right)^{\sigma-1}}{\beta \int_0^z A_N\left(j\right)^\sigma dj} = r$$

use (7) to substitute for w_N. Rearrange it to get:

$$p(i)^{1-\epsilon} = \left[\frac{\phi_N(i)\, L_N A_N(i)^\sigma}{r \int_0^z A_N(j)^\sigma\, dj} \right]^\sigma$$

use $A_N(j) = A_N(i) \left[\frac{\phi_N(j)}{\phi_N(i)} \right]^{1/(1-\sigma)}$ to elimnate $A_N(i)$. Integrate i over the interval $[0,1]$, use (3) and rearrange:

$$r = \left\{ (L_N)^\sigma \left[\int_0^z \phi_N(i)^{\frac{\sigma}{1-\sigma}}\, di \right]^{1-\sigma} + (\theta L_S)^\sigma \left[\int_z^1 \phi_S(i)^{\frac{\sigma}{1-\sigma}}\, di \right]^{1-\sigma} \right\}^{1/\sigma}$$

Finally, use (22) to substitute for $\int_z^1 \phi_S(i)^{\sigma/(1-\sigma)}\, di$. The Euler equation $g = r - \rho$ then yields equation (23) in the text.

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