Globalization, Divergence and Long-Run Growth*

Gino A. Gancia†
MIT and IIES

November 2002

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 the international income gap. 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.

*I am grateful to Pol Antràs, Francesco Caselli, Paolo Epifani, seminar participants at MIT, IIES Stockholm, the European Winter Meeting of the Econometric Society (Budapest, 2002) and especially Daron Acemoglu, Torsten Persson, Jaume Ventura and Fabrizio Zilibotti for helpful comments. The usual caveat applies. Financial support from the Wallander and Hedelius Foundation is gratefully acknowledged.

†Massachusetts Institute of Technology, Department of Economics, E52, 50 Memorial Drive, Cambridge MA 02142-1347 (USA). Phone: 617 - 253 1015 Fax: 617 - 253 6915. E-mail: ganciag@mit.edu

1 Introduction

This paper studies how North-South trade affects innovation, cross-country income distribution and long run-growth. A motivation is provided in Figure 1, showing two trends characterizing the evolution of the world economy during the last four decades: globalization and divergence.[1] There is little disagreement on the first: during the period 1960-1998, the average share of import plus export in total GDP rose from less than 0.55 up to 0.75 and the total volume of world merchandize trade rose steadily at a rate of 10.7% per year. Perhaps less known is the fact that the fastest growing component of world trade is North-South: as examples, trade between the US and non-OECD countries almost tripled during the period 1980-95 (Wood, 1998) and the number of poor countries opening their markets to international trade increased sharply in the 80s and 90s (Sachs and Warner, 1995). Further, globalization is pervasive: the trade share in GDP rose by 1.4% per annum in open economies and by 1.1% in economies protecting their markets.[2]

The second trend, instead, is more controversial: although the number of people living below the poverty line seems to have declined, the average poor country is diverging from the group of prosperous economies.[3] Figure 1 shows the evolution of a popular measure of cross-country inequality, the variance of log real per capita GDP. The dispersion of income has increased constantly, from 0.7 in 1960 to more than 1.3 in 1998. Additional historical evidence is reported by Pritchett (1997), using data from Maddison (1995), and is summarized in Table 1: over the past century, advanced economies consistently grew faster than the less developed and the average growth differential appears to reach a peak in the last two decades.[4] The increase in income dispersion is even more surprising given that rich countries have experienced weak productivity growth

[1] Data are taken from the Penn World Table Mark 6.0, Summers et al. (2001) and cover 115 countries over the period 1960-1998.

[2] This numebrs are estimated regressing trade shares on a time trend and allowing for a country fixed effect. An economy is defined as open if the Sachs and Warner index is higher than 0.5; 36 of the 115 countries in the sample are classified as open.

[3] 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 performance, the country is the relevant unit of analysis, since regulations are country-specific.

[4] See also Quah (1996) on the evolution of the world income distribution.

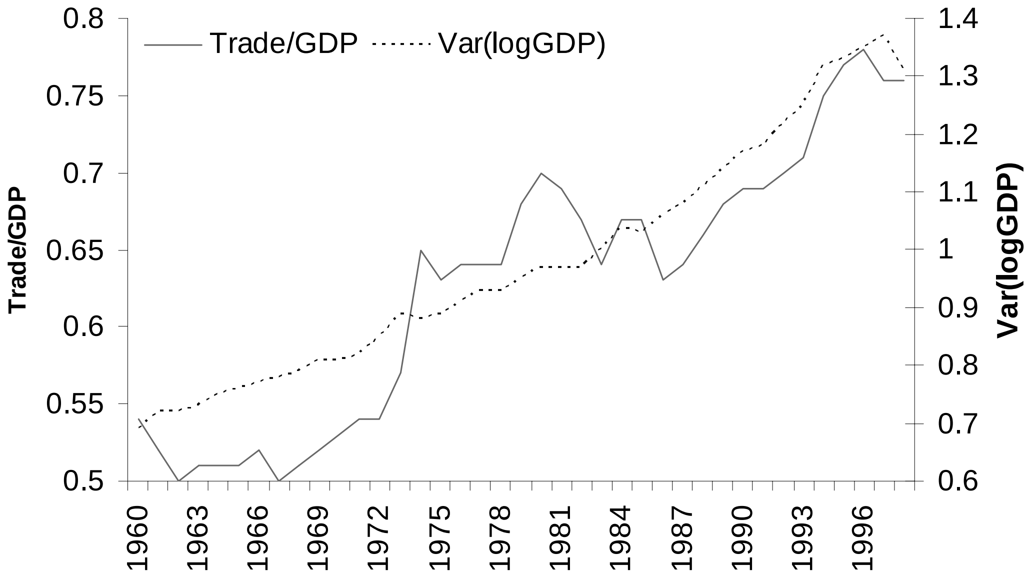

Figure 1: Globalization and Divergence

since the mid-1970s.

These trends raise the concern of a possible causal link from globalization to divergence, a possibility animating an intense debate among policy-makers, international organizations and the general public. According to traditional trade models, however, even if gains from trade are in general not evenly distributed, there is no presumption that they should be systematically biased in favor of rich countries.

Table 1: Mean per annum growth of GDP per capita

	1870-1960	1960-1979	1979-1994
Advanced economies (17)	1.5	3.2	1.5
Less developed (28)	1.2	2.5	0.34

Source: Pritchett (1997) using data from Maddison (1995)

This paper argues that there may indeed be a causal link from globalization to divergence. It shows that North-South trade can amplify income disparities through the endogenous response of technical change. The key reason why trade can systematically bias technology towards the North is that less developed 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. At the same time, the uneven distribution of technical progress can undermine the world incentives to innovate.

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 the rich ones.

Is then North-South trade always beneficial for advanced countries? The somehow surprising answer, leading to the second and most original result of the paper, is no: under free trade, weak IPRs have a strong potential to disrupt incentives for innovation. 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 is thus 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, in a world of interdependent economies, the regulatory policies of each country are important to sustain the growth rate of the entire global system.

These results have important implications. First, they provide a strong rationale for 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 become crucial for attracting and sustaining innovation.

Second, that the desirability of patent laws depends on the trade regime can shed light on an observed change in attitudes of more and less advanced countries towards IPRs protection. The importance of defining common regulations in a global economy was recognized by the inclusion of the Agreement on Trade Related Intellectual Property Rights in the statute of the WTO.[5] 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.

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.

Fourth, the analysis suggests that trade between countries with similar IPRs-related laws may raise less redistributive concerns, since it is not accompanied by innovation diversion. This can help explain the emergence of trade blocs and commercial agreements between countries with similar institutions.

The results of the paper are based on four assumptions: specialization driven by trade, sector-specific technical progress, low IPRs protection in developing countries, and an elasticity of substitution between goods higher than one. All of them seem

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

realistic and are shared by many models. That countries specialize in different sets of products, at least to some extent, appears plausible. More specifically, the Ricardian model has proven to be useful in the 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 targeted 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.[6] 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 studying any 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. They also show that trade leads to skill-biased technical change, more favorable for the endowment of the North. Their results differ in a number of ways from those of this model. First, in Acemoglu and Zilibotti (2001) trade generates productivity convergence, whereas in this paper it generates productivity divergence. Second, in their model, the transmission mechanism between trade and technology comes through a change in world prices, whereas in this paper it is specialization driven by trade, affecting the market size for innovations, that matters. Third and more important, their model has no implications on the world growth rate.

[6] Cross-sectoral spillovers can be included in the model without affecting the qualitative results as long as spillovers from an innovation in another sector are less effective than a targeted innovation.

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. In contrast, this paper shows that trade induces innovation diversion in favor of rich countries, irrespective of the sectors of specialization.

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 aspect of the issue, including the effects of licensing or FDI. The earlier contributions highlighted the negative effects of strong IPRs as they would restrict technology diffusion.[7] More recently, the view that IPRs can foster growth and stimulate the diffusion of technology has gained consensus, but the results depend crucially on the channel of technology transfer.[8] Abstracting from product-cycles, this paper focuses more on process innovation and shows how this approach leads to strong and unambiguous results in favor of IPRs protection. Further, none of the afore mentioned papers deals with the effects of IPRs under different trade regimes. Another strand of literature focus on the welfare effects of the monopoly distortion introduced by IPRs protection in a trading environment.[9] Compared to that literature, this paper introduces a new inefficiency generated by asymmetric regulations in different countries, innovation diversion, and suggests that limits to IPRs protection (if needed to alleviate the monopoly distortion) should be imposed evenly across countries. Diwan and Rodrik (1991) recognize that IPRs can be important for attracting "appropriate" innovations, but their useful insight is confined to static partial equilibrium analysis.

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.

The rest of the paper is organized as follows. Section 2 presents the basic two-

[7] Among these models are Helpman (1993) and Glass and Saggi (1995).

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

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

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 ends with an extension of the results to a multi-country world. 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 1:

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

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:

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

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 machines i are a fraction $\beta(1-\beta)$ of the value of sectoral output:

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

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, $\phi(i)$, and the level of current technology in use in sector i, $a(i)$:

$$A(i) = a(i) \, \phi(i) .$$

While $\phi(i)$ is fixed and determined by purely exogenous factors, such as the specific environment of a country, $a(i)$ can be increased by technical progress. For simplicity, the model assumes that all the countries in the North share the same productivity schedule $\phi = (\phi(i))$. Innovation is targeted and sector specific. To simplify, without loss of generality, innovation is modelled as incremental:[10] in the R&D sector, $(1-\beta)$ units of the numeraire can increase the productivity of machine i by $\partial a(i)$. Once an innovation is made, the innovator is granted a perpetual monopoly over its use. The

[10] This modeling of innovation is isomorphic to the expanding variety framework of Romer (1990)

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 $(1-\beta)$. 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 $\partial\pi(i)/\partial a(i)$ and r are constant, this condition is:

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

Using (11), (10) and (7), the previous expression reduces to:

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

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.[11] 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,

[11] Stability can be violated because the market size for innovation is proportional to $l(i)$ which is a positive function of innovation itself.

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 $g = r - \rho$, 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 capture the fact that geographic, cultural and institutional 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 revenue generated from innovation in each country.[12] 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

[12] This assumption makes the localization of R&D irrelevant for the purpose of the analysis. Equivalently, the localization of R&D could be studied allowing for profit transfers between countries in terms of the final aggregate 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.

in the South is that technical progress, embedded in $a(i)$, is taken as given from the North.[13] Using equations (9) and (13) yields the North-South wage ratio, $\omega \equiv w_N/w_S$:

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

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, and is appropriate for the South only in the limit case when the two regions are identical $(\phi_S(i) = \phi_N(i), \forall i$, yielding $\omega = 1)$.[14] This outcome mirrors, in a different set up, the result 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 the 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.[15] 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,

[13] 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 Bertrand competition would lead them to negative profits. The presence of the monopoly distortion in the imitating South precludes the analysis of the trade-off between the dynamic loss and the static benefit of weak IPRs in poor countries. This trade-off has been studied extensively in the literature and is not the main concern of the paper. On the contrary, the presence of some rents from innovation in the South is crucial to study the case of partial protection of IPRs. This latter case seems realistic, since companies do receive royalties from developing countries.

[14] 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 very productive. This inefficiency lowers the wage in the South.

[15] This description of IPRs is both simple and general. It can also capture practises 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.

and the marginal condition for buying innovations becomes:

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

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

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

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:

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

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. 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 IPR 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 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 2 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 to 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 under free trade, as measured by ω, are larger than income differences under autarky.*

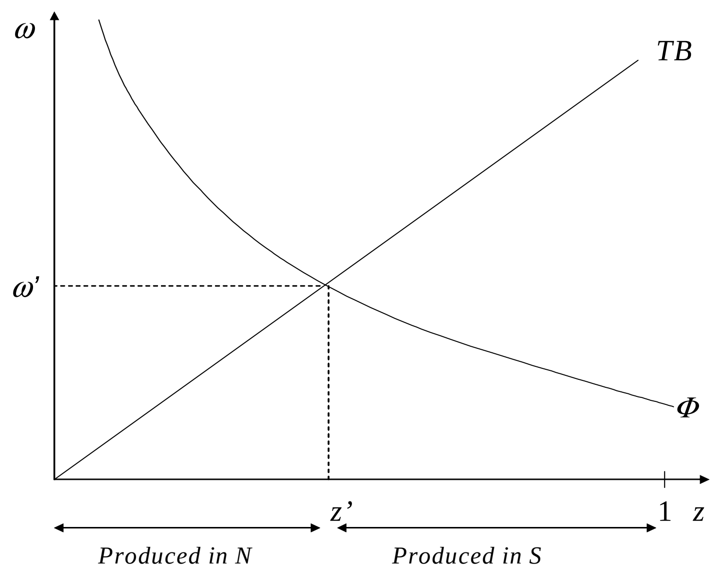

Figure 2: Free Trade Equilibrium

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 pools 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: not necessarily. 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 incentive 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.* To understand this result, remember that endogenous growth is here possible because all the sectors grow together: if some sectors would grow less than average, the others would experience falling output prices and profit margins, and if any sector did not grow at all (because specialization and $\theta = 0$ reduces to zero the market size for some innovations) then the rest of the economy would be trapped into decreasing returns. 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 would not depend on technology, because every country and sector would benefit equally from any improvement in $a(i)$. Also, sector-specific technical process is a key assumption for deriving Proposition 2. In a set-up with factor-specific innovations, as in Acemoglu and Zilibotti (2001), the market size for any innovation depends on endowments only that are unaffected by specialization and trade: for this reason, incentives to invest in R&D would never go to zero even if $\theta = 0$.[16]

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 under free trade than under autarky.*

What happens during the transitional dynamics from autarky to the free trade equilibrium? Since technology adjust slowly, initially the equilibrium is determined by

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

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. But 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. If $\theta = 0$, this process will go on until the last sector moves to the South and growth will eventually stop. Note that in a trading environment with asymmetric IPRs protection, divergence and stagnation are closely related: it is the growing cost of producing 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 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 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 behaves 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 it limited ability to benefit from others' policies. To better understand these implications, the analysis is now extended to a multi-country setting.

2.4 A Multi-Country Model

This section provides a sketch of how to extend the results of the model to a multi-country world. This extension is instrumental to the empirical analysis in the next section using cross-country data, and therefore ends with a list of empirical predictions. A key assumption here is that countries have different exogenous productivities; countries with very similar characteristics should be treated as a single economy.

The autarky solution is straightforward. To keep the analysis under free trade as simple as possible, consider a three country case (countries are indexed 1, 2 and 3) and assume that $\phi_1(i)/\phi_2(i)$ and $\phi_2(i)/\phi_3(i)$ are continuous and strictly decreasing in i. Further, assume that $\phi_1(i) > \phi_2(i) > \phi_3(i)$, $\forall i \in [0,1]$, implying that $w_1 > w_2 > w_3$ and that country 1 specializes in the lower range of goods $[0, z_1)$, country 2 in an intermediate range $[z_1, z_2)$ and country 3 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 country to another as a function of wages, becomes:

$$\frac{w_1}{w_2} = \frac{\phi_1(z_1)}{\phi_2(z_1)} \quad \text{and} \quad \frac{w_2}{w_3} = \frac{\phi_2(z_2)}{\phi_3(z_2)}.$$

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

$$w_1 L_1 \int_{z_1}^{1} p(i)^{1-\epsilon} \, di = w_2 L_2 \int_0^{z_1} p(i)^{1-\epsilon} \, di + w_3 L_3 \int_0^{z_1} p(i)^{1-\epsilon} \, di,$$

requiring the value of total imports in country 1 to be equal to the value of total export from country 1; and similarly for country 3:

$$w_3 L_3 \int_0^{z_2} p(i)^{1-\epsilon} \, di = w_1 L_1 \int_{z_2}^1 p(i)^{1-\epsilon} \, di + w_2 L_2 \int_{z_2}^1 p(i)^{1-\epsilon} \, di.$$

Trade balance in country 2 is redundant. For a given technology, this system of four equations in four unknown (the relative wage in two countries, 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 countries, the following condition must hold:

$$\theta_1 \frac{\partial \pi_1(i)}{\partial a(i)} = \theta_2 \frac{\partial \pi_2(j)}{\partial a(j)} = \theta_3 \frac{\partial \pi_3(v)}{\partial a(v)},$$

for any i, j, v such that $i \leq z_1 \leq j \leq z_2 \leq v$. These conditions provide a complete characterization of the 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 country attracts more innovation towards the goods the country is producing. This translate into a higher wage and a reduction of the range of activities performed in the county (moving production abroad becomes more convenient as the domestic labor cost increases). On the contrary, the positive effects of tighter IPRs in autarky are spread across all sectors and benefit all countries. Further, if a country is small (or if there is a high number of countries) a policy change in autarky is unlikely to have a significant impact on world incentives to innovate. Suppose now that country 1 and 2 form a free-trade area, whereas country 3 stays in autarky. In this case, the incentive for country 1 and 2 to provide better protection for IPRs is smaller because part of the benefits are shared with country 3 and the policy change is less effective as it cannot affect the profitability of innovation in country 3. Therefore, the more integrated the world economy, the higher is the effect of a country's policy.

To summarize, the model has the following predictions. First, in autarky, a tightening of IPRs in a single country is likely to have no effect on productivity, but the effect is positive and large under free trade. Second, trade has an unambiguously positive effect on economic performance for countries with strong IPRs protection, as it induces specialization in highly productive sectors. However, for countries with weak IPRs protection, the effect is expected to become smaller over time because of innovation diversion. Third, since the benefits from regulations are higher under free trade than in autarky, globalization is likely to be followed by higher pressure to tighten IPRs. Fourth, under free trade, the R&D effort of advanced countries should become more specialized towards the sectors in which those countries have a comparative advantage. The next section is a first attempt to see whether these predictions are supported by the data.

3 Empirical analysis

Confronting the predictions of the model with the data requires measures of productivity, openness to trade and the strength of IPRs. For the first measure, Hall and Jones (1999) provide estimates of labor productivity (YL) and total factor productivity (TFP) relative to the US in 1988. Although the second may better capture the effects of innovation on productivity, the first is probably less noisy, so both are included in the following analysis. Sachs and Warner (1995) built an index of trade openness (on the $[0, 1]$ scale) that measures the fraction of years during the period 1950-1994 that the economy has been classified as open.[17] This index is particularly attractive because it considers the time since a country adopted a free-trade regime and therefore it alleviates problems related to slow adjustments. Finally, Rapp and Rozek (1991) have compiled an index of the strength of patent laws that measures conformity of nation's patent regulations and enforcement to the minimum standards put forward by the US Chamber of Commerce Intellectual Property Task Force. This index (IPRs) varies from 0 to 5 and was computed for 1984.[18] The collection of all these data covers a sample of 75 countries.[19]

[17] An economy is classified as open if satisfies all ofthe 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.

[18] Maskus and Penubarti (1995) corrected this index for endogeneity and measurement errors. However, the instruments they use are not appropriate in this context. Still, using their measure does not change the results.

[19] Data for all the measures are avaliable for the following countries: Argentina, Australia, Austria, Bangladesh, Belgium, Benin, Bolivia, Brazil, Burkina Faso, Cameroon, Canada, Chile, Colombia, Costa

To get a first sense for the patterns in the data, Table 2 presents a set of conditional correlations. As predicted by the model, trade is indeed associated with higher productivity only for countries that do provide strong protection for IPRs; likewise, tight regulations are associated with high productivity for open economies only.

Table 2: conditional correlations

Variable	Conditional on	CORR with TFP	CORR with YL	N. obs.
Open	IPRs<=2	-0.067	0.125	26
Open	IPRs<=3	0.174	0.340	39
Open	IPRs>3	0.849	0.812	36
IPRs	Open<0.5	-0.199	-0.057	44
IPRs	Open>=0.5	0.744	0.804	31

A better way to analyze these correlations is through simple least-square regressions. In Table 3, the two measures of productivity (in logs) are regressed on (log of) openness, strength of IPRs, an interaction term between the two, plus a number of controls. Columns (1) and (4) report on the results when the right-hand side incudes only the three variable of interest. The coefficient on the interaction term is positive and precisely estimated, whereas the coefficients on Open and IPRs alone are negative and generally not significantly different from zero. This suggests that the positive effect of trade on productivity is mediated by the strength of IPRs protection. Since countries with "good" institutions tend to have simultaneously high productivity, open markets and strong IPRs protection, the interaction term could appear positive and significant even when in fact productivity is determined by other omitted institutional variables. To control for this problem, Columns (2) and (5) add two measures of institutional quality: an index of government anti-diversion policies (GADP) and a dummy for capitalism

Rica, Denmark, Dominican Rep., Ecuador, Egypt, El Salvador, Finland, France, Germany West, Ghana, Greece, Guatemala, Hong Kong, Hungary, India, Indonesia, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kenya, Korea Rep., Malawi, Malaysia, Mali, Mauritius, Mexico, Morocco, Netherlands, New Zealand, Nigeria, Norway, Oman, Pakistan, Panama, Paraguay, Peru, Philippines, Portugal, Sierra Leone, Singapore, South Africa, Spain, Sri Lanka, Sweden, Switzerland, Syria, Thailand, Togo, Tunisia, Turkey, U.K., U.S.A., Uganda, Uruguay, Venezuela, Yugoslavia, Zaire, Zambia, Zimbabwe.

(EcOrg), both taken from Hall and Jones (1999).[20] Albeit reduced in magnitude, the interaction term remains positive and significantly different from zero. Finally, columns (3) and (6) controls for other two potentially important determinants of productivity: (log of) human and physical capital per worker (HL and KL, respectively, again from Hall and Jones, 1999). Again, the coefficient on the interaction term is slightly smaller, but remains positive and significantly different form zero at the 5% level.

Table 3: Productivity, Trade and IPRs

	YL	YL	YL	TFP	TFP	TFP	g(TFP)	g(TFP)
Open	-0.411	-0.304	-0.339	-0.517	-0.588	-0.508	-0.274	-1.189
	(0.649)	(0.542)	(0.294)	(0.483)	(0.483)	(0.440)	(1.231)	(1.056)
IPRs	-0.242	-0.234	-0.065	-0.187	-0.204	-0.097	-0.323	-0.436
	(0.107)	(0.090)	(0.051)	(0.079)	(0.080)	(0.077)	(0.202)	(0.172)
IPRs*Open	0.694	0.324	0.199	0.487	0.393	0.299	0.860	0.701
	(0.185)	(0.163)	(0.089)	(0.137)	(0.146)	(0.134)	(0.384)	(0.324)
GADP	-	3.108	-0.127	-	0.853	-0.190	-	6.174
	-	(0.519)	(0.387)	-	(0.463)	(0.581)	-	(1.210)
EcOrg	-	-0.012	0.036	-	0.057	0.055	-	0.009
	-	(0.063)	(0.034)	-	(0.056)	(0.051)	-	(0.129)
HL	-	-	0.232	-	-	-0.651	-	-
	-	-	(0.252)	-	-	(0.379)	-	-
KL	-	-	0.549	-	-	0.324	-	-
	-	-	(0.053)	-	-	(0.079)	-	-
Gdp1960	-	-	-	-	-	-	-3.397	-5.986
	-	-	-	-	-	-	(0.874)	(0.875)
R^2	0.56	0.72	0.92	0.45	0.49	0.59	0.31	0.53
No. Obs.	75	75	75	75	75	75	68	68

Note: standard errors in parenthesis

The magnitude of these coefficients suggests that the effect of the interaction be-

[20] GADP is measured on a scale from zero to one and it is the average of five variables created by a specialized firm, Political Risk Service, to assess risk for international investors: (1) law and order (2) bureaucratic quality (3) corruption (4) risk of expropriation and (5) government repudiation of contracts.

tween openness and IPRs on economic performance can be large. According to the last estimates, being open is uncorrelated with higher productivity in the absence of IPRs protection (IPRs=0). But for every point above zero of the IPR index (up to its maximum of 5), being open for the entire period 1950-1994 (i.e., having Open=1) is associated with a 20% higher labor productivity and 30% higher TFP. Similarly, a tightening of IPRs is uncorrelated with better economic performance in closed economies. But for countries that have been open for the entire period, a one-point increase in the IPR index is associated with a 20% increase of labor productivity and a 30% increase of TFP.

Columns (7) and (8) show the results of a different exercise: the growth rate of TFP over the period 1960-1985 is regressed on the variables of interest and per capita GDP in 1960.[21] According to the model, even if along the balanced growth path all countries grow at the same rate, innovation diversion implies a transition with North-biased innovation and therefore differences in growth rates. Again, the estimation suggests that countries whose productivity has grown fast are those with both open markets and strong IPRs protection.[22] These results are interesting for interpreting the evidence on trade and divergence reported at the beginning of the paper, because they imply that open countries with similar starting points but different IPRs policies have diverged in terms of productivity more than similar closed economies. Similarly, they suggest that a common increase in the degree of openness is associated to divergence for countries with different regulations. The negative and (statistically) significant coefficient for initial per capita GDP constitutes evidence of conditional convergence in TFP and suggests that the interaction term between openness and IPRs might indeed be a determinant of country-specific steady-state productivity levels. The general results do not change if other institutional variables (GADP and EcOrg) are included (in the last column). This evidence is consistent with the work of Gould and Gruben (1996), showing that intellectual property protection is a determinant of economic growth and that the effect is stronger in open economies. Finally, a word of caution is in order: since many of the

[21]TFP growth over the period 1960-85 is taken from Klenow and Rodriguez (1997).

[22]Note that the measure of openness already incorporates the time dimension; even if IPRs protection is computed for the end of the 1980s and is not available for other years, the major changes in regulations took place during the 1990s.

variables used in these regressions are simultaneously determined, the results can only be interpreted as correlations consistent with the theory. More detailed empirical work is required for causal inference, but this is left for future research.

Another piece of evidence consistent with the model is the growing pressure for protection of IPRs in developing countries. The theory shows that the cost of weak IPRs protection is higher under free trade than in autarky, as it can lead to innovation diversion and decrease the world growth rate. Globalization is therefore expected to be followed by a move towards tighter worldwide regulations. Accordingly, Table 4 documents that the number of countries signing international agreements on IPRs increased sharply during the last decade.

Table 4: membership in IPRs treaties

	1960	1970	1980	1990	2000
Paris Convention	47	75	87	97	160
WIPO Membership	-	20	92	123	175
Patent Cooperation Treaty	-	-	29	44	107

Source: World Intellectual Property Organization (WIPO)

The information contained in Table 4 can also be used to build a time-varying index of country-specific regulations. Signing the Paris Convention, a major international treaty for the protection of industrial property, and joining the WIPO, whose mission is to promote the use and protection of intellectual property, are important steps in adopting tight regulations.[23] A proxy for a strengthening of IPRs can then be constructed averaging the two dichotomous variables that take value one if a country has signed the Paris Convention and joined the WIPO, and zero otherwise. This measure, admittedly crude, can be used to add a time-dimension to the cross-section evidence summarized in Table 3. Unfortunately, however, limited time-series data are available for many of the other variables previously considered. Therefore, the following analysis relies on new regressors with fewer controls and should be interpreted with caution. Collecting data on (log of) real GDP per capita as a measure of economic performance, the (log of) GDP share of import plus export as an index of openness and the newly

[23]The Patent Cooperation Treaty was first signed in 1978 and therefore provides information on a shorter time period.

constructed proxy for IPRs, yields a panel of 112 countries with observations form 1968 (the year after WIPO came into existence) to 1998.[24] The dataset is then used to run a fixed-effects regression, including on the right hand side openness, the proxy for IPRs, an interaction term between the two and a time trend. Results are reported in Table 5. Again, the coefficient on the interaction term is positive and significantly different from zero at the 1% level. The individual coefficient on openness is now positive and very precisely estimated, whereas the individual coefficient on the IPRs proxy is negative and statistically different from zero. These results confirm the broad pattern found in cross-sectional data, that openness is more correlated with economic performance for countries protecting IPRs and that tight regulations are correlated with high productivity for open economies only.

Table 5: Fixed-Effects

	Coefficient	Standard Error	Observations:	3454
Open	0.133	(0.018)	Countries:	112
IPRs	-0.208	(0.078)	F-test on fixed-effects:	619.81
Open*IPRs	0.050	(0.018)	Within R-squared:	0.25
Time	0.011	(0.001)		

Note: the dependent variable is log real per capita GDP.

Finally, 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).

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

[24]Data are taken from the Penn World Table 6.0.

growth and convergence. In particular, a first strand of literature documents a positive correlation between trade and growth.[25] 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 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 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 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.

4 Concluding Remarks

Traditional trade models do not explain the simultaneous trends of growing market integration and diverging income levels characterizing the world economy during the last four decades, yet many observers fear that globalization may take place at the expense of already disadvantaged nations. This paper presents a simple model where trade can lead to income divergence, if protection of IPRs is too weak in poor countries. More surprisingly, the model shows that, in a trading environment, weak IPRs may strongly reduce the world growth rate. Even though these results suggest large potential gains from global regulations, imposing common standards for IPRs can be costly for some less developed countries and may not be sufficient. As long as the economic weight of

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

the South is low, profits generated from those markets would not be enough to provide the right incentives for developing technologies for the Southern sectors. Although the model has focused on property rights asymmetries, the sale of innovations in poor countries can generate small profits for a number of other reasons, such as low price levels and high transaction costs. Given these distortions, promoting research aimed at the needs of the less developed countries appears to be a key element for reducing cross-country income differences and fostering world growth.

The analysis in this paper is limited in several respects. First, it contains no welfare comparison of 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.[26] Second, the paper does not allow for some technology transfer taking place through trade. Such technology transfer contrasts with the quasi public good view of technology emerging from the endogenous growth literature and adopted in this paper. Third, the paper presents empirical evidence mainly in the form of suggestive correlations. While consistent with the model, this evidence is far from conclusive. Compared to existing studies, the paper has shown that the consequences of globalization can be very different, depending on institutional variables such as property right laws. Whether the effects highlighted in the paper can be important in shaping the world income distribution and affecting innovating incentives is ultimately an empirical question that deserves further study.

References

[1] Acemoglu, Daron and Jaume Ventura (2002) "The World Income Distribution" *Quarterly Journal of Economics* 117, 659-694.

[2] Acemoglu, Daron and Fabrizio Zilibotti (2001). "Productivity Differences," *Quarterly Journal of Economics* 116, 563-606.

[26] More detailed welfare analysis is also complicated by non trivial transitional dynamics and is left for future work.

[3] Barro, Robert J. and Xavier Sala-i-Martin (1995). *Economic Growth* McGraw-Hill.

[4] Ben-David, Ben (1993). "Equalizing Exchange: Trade Liberalization and Income Convergence," *Quarterly Journal of Economics* 108, 653-679.

[5] Bhagwati, Jagdish (1958). "Immiserizing Growth: a Geometrical Note," *Review of Economic Studies* 25, 201-205.

[6] Chin, Judith C. and Gene M. Grossman (1990) "Intellectual Property Rights and North-South Trade" in *The Political Economy of International Trade: Essays in Honor of Robert E. Baldwin*, ed. by R.W. Jones and A.O. Krueger. Cambridge, MA, Basil Blackwell.

[7] Deardorff, Alan V. (1992). "Welfare Effects of Global Patent Protection" (1992). *Economica* 59, 35-52.

[8] Diwan, Ishac and Dani Rodrik (1991). "Patents, Appropriate Technology, and North-South Trade," *Journal of International Economics* 30, 27-48.

[9] Dornbusch, Rudi, Stanley Fischer and Paul A. Samuelson, (1977) "A Continuum Ricardian Model of Comparative Advantage, Trade and Payments" *American Economic Review* 67, 823-839.

[10] Easterly, William and Ross Levine (2002). "Tropics, Germs and Crops: How Endowment Influence Economic Development," mimeo, Center for Global Development and Institute for International Economics, 2002.

[11] Frankel, Jeffrey and David Romer (1999). "Does Trade Cause Growth?" *American Economic Review* 89, 379-399

[12] Gould, M. David and William C. Gruben (1996). "The Role of Intellectual Property Rights in Economic Growth," *Journal of Development Economics* 48, 323-350.

[13] Grossman, Gene M. and E. Helpman, (1991). *Innovation and Growth in the Global Economy* Cambridge, MIT Press.

[14] Grossman, Gene M. and Edwin L. C. Lai (2002). "International Protection of Intellectual Property," NBER W.P. 8704.

[15] Hall, Bronwyn H., Adam B. Jaffe and Manuel Trajtenberg (2001). "The NBER Patent Citations Data File: Lessons, insights and Methodological Tools," NBER WP8498.

[16] Hall, Robert and Charles I. Jones (1999). "Why Do Some Countries Produce So Much More Output Per Workers Than Others?" *Quarterly Journal of Economics* 114, 83-116.

[17] Helpman, Elhanan (1993). "Innovation, Imitation and Intellectual Property Rights," *Econometrica* 61, 1247-1280

[18] Heston, Alan, Robert Summers and Bettina Aten (2001). Penn World Table Version 6.0, Center for International Comparisons at the University of Pennsylvania.

[19] Jaffe, Adam B., Manuel Trajtenberg and Rebecca Henderson (1993). "Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations," *Quarterly Journal of Economics* 108 577-598.

[20] Klenow, Peter J. and Anders Rodriguez-Clare (1997). "The Neoclassical Revival in Growth Economics: Has It Gone Too far?" *NBER Macroeconomics Annual* 73-102

[21] Krugman, Paul R. (1979) "A Model of Innovation, Technology Transfer and the World Distribution of Income" *Journal of Political Economy* 87, 253-266.

[22] Lai, Edwin L. C. (1998). "International Intellectual Property Rights Protection and the Rate of Product Innovation," *Journal of Development Economics* 55, 115-130.

[23] Maddison, Angus (1995). *Monitoring the World Economy, 1820-1992*. Paris: Development Center of the Organization for Co-operation Development.

[24] Maskus, Keith E. and Mohan Penubarti (1995). "How trade-related are intellectual property rights?" *Journal of International Economics* 39, 227-248.

[25] Matsuyama, Kiminori (2000). "A Ricardian Model with a Continuum of Goods under Nonhomothetic Prefernces: Demand Complementarities, Income Distribution, and North-South Trade," *Journal of Political Economy* 108, 1093-1120.

[26] Pritchett, Lant (1997). "Divergence Big Time" *Journal of Economic Perspective* 11, 3-17.

[27] Quah, Danny (1996). "Twin peaks: Growth and convergence in models of distribution dynamics," *Economic Journal*, 106, 1045-1055.

[28] Rapp, Richard T. and Richard P. Rozek (1990)."Benefits and Costs of Intellectual Property Protection in Developing Countries" *Journal of World Trade* 24, 74-102.

[29] Rodrik, Dani, Arvind Subramanian and Francesco Trebbi (2002). "Institutions Rule: The Primacy of Institutions over Geography and Integration in Economic Development" mimeo, Harvard University.

[30] Romer, Paul M. (1990). "Endogenous Technological Change," *Journal of Political Economy* 98, 71-102.

[31] Sachs, Jeffrey D. and Andrew Warner (1995). "Economic Reform and the Process of Global Integration," *Brookings Papers on Economic Activity* 1995, 1-95.

[32] Sala-i-Martin, Xavier (2002). "The Disturbing "Rise" of Global Income Inequality," mimeo Columbia University.

[33] Taylor Scott M. (1994) "TRIPs Trade and Growth," *International Economic Review* 35, 361-381.

[34] Wood, Adrian (1998). "Globalisation and the Rise in Labour Market Inequalities," *The Economic Journal* 108, 1463-1482.

[35] Yang, Guifang and Keith E. Maskus (2001). "Intellectual property rights, licensing and innovation in an endogenous product-cycle model" *Journal of International Economics* 53, 169-187.

[36] Young, Alwyn (1991) "Learning by Doing and the Dynamic Effects of International Trade," *Quarterly Journal of Economics* 101, 396-405.

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):

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

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

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

where λ is the lagrange multiplier associated to the constraint. Taking the ratio of any two FOCs and using $A_N(i) = a\left(i\right) \phi_N(i)$ 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, $(\theta \neq 0)$.

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

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 $a(i)$:

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

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 $L_N/(\theta L_S) \to 0$, technologies maximize w_S, whereas as $L_N/(\theta L_S) \to \infty$ 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 $\max \phi_N (i) / \phi_S (i) = \phi_N (0) \phi_S (0)$, first note that $\partial \omega / \partial \phi_N (i) > 0$ and $\partial \omega / \partial \phi_S (i) < 0$. Therefore, by construction:

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

5.3 The growth rate under free-trade

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

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

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.