North-South Trade and Directed Technical Change*

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Abstract

In a world where poor countries provide weak protection for intellectual property rights, market integration shifts technical change in favor of rich nations. Through this channel, free trade may amplify international income differences. At the same time, integration with countries where intellectual property rights are weakly protected can slow down the world growth rate. A crucial implication of these results is that protection of intellectual property is most beneficial in open countries. This prediction, which is novel in the literature, is consistent with evidence from a panel of 53 countries observed in the years 1965-1990.

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1 Introduction

The past decades have witnessed a dramatic rise in the degree of economic integration across the globe. A notable feature of this phenomenon is the emerging role played by less developed countries (LDCs) in world markets. Although trade between the US and non-OECD countries is still relatively small, its share in US GDP increased by more than fourfold between 1970 and 1995. In the same years, unprecedented episodes of economic liberalization took place in countries like China, Mexico and India. As a result, North-South trade is now the fastest growing component of world trade. This process of international integration has been accompanied by concerns regarding the economic losses due to weak protection of intellectual property rights (IPRs) in less developed countries. The issue has become one of the most debated in international negotiations and led to the inclusion of the Agreement on Trade Related Intellectual Property Rights (TRIPs) in the statute of the WTO in 1994.[1] After more than ten years, the extent to which LDCs should protect intellectual property is still controversial. Moreover, despite the close connection between IPRs and trade negotiations, the relationship between market integration and the protection of intellectual property remains largely unclear.

This paper studies how North-South trade affects the direction of technical progress, growth and relative income in a model where less developed countries provide weak protection for intellectual property. Although it does not address the question of how to design an optimal system of international IPRs regulations, it shows that the effect of trade opening on income growth and its distribution depends crucially on the degree of protection of intellectual property worldwide. In particular, whenever poor countries do not provide adequate protection for IPRs, North-South trade shifts the direction of technical change in favor of rich nations. By making the sectors in which poor countries are specialized relatively less productive, trade may thus amplify North-South wage differences. Moreover, the paper shows that market integration with countries where intellectual property rights are weakly protected may lower the incentives to innovate, leading eventually to a slowdown in the growth rate of productivity.

To obtain these results, the paper builds a Ricardian model with a continuum of goods and endogenous, sector specific, technical change. It describes a world economy composed by two sets of countries, the North and the South, distinguished by an exogenous pattern of comparative advantage. Except for these Ricardian differences and given that nowadays

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

barriers to the flow of ideas are low, all countries have access to the same stock of technical knowledge, that can be expanded by investing in innovation. As in R&D-driven models of endogenous growth, innovation is financed by the monopoly rents it generates. However, the key assumption of the paper is that innovators can only appropriate a fraction of the rents from the Southern markets because of weak protection of IPRs.

The model is solved both in autarky and free trade and the 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. Without commodity trade, each country produces all goods and the South can free ride on innovation performed for the Northern markets. Under free trade, instead, the two countries specialize in the sectors of comparative advantage and benefit from different innovations because they produce different goods. In this case, weak IPRs imply that rents from the South are smaller so that the Southern sectors attract less innovation. Thus, by making the sectors in which poor countries are specialized relatively less productive, trade can amplify North-South wage differences. At the same time, the paper shows that trade with weak IPRs countries may reduce the growth rate of the world economy. The reason is that, in the long run, trade equalizes the returns to innovation across sectors and countries. Hence, the disincentive to innovate due to imperfect IPRs enforcement in the South spills over to the North.

The results of the paper are based on four assumptions: specialization driven by trade, sector-specific (directed) technical progress, imperfect appropriability of profits in developing countries and an elasticity of substitution between goods higher than one. All of them seem plausible. That countries specialize in different sets of products, at least to some extent, appears reasonable.[2] 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 particularly suitable for analyzing income differences across countries. 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. Infringements of IPRs in developing countries appear to be significant, as proven by the many complaints of companies based in industrial countries. In this respect, the US Chamber of

[2] Ohlin went as far as to say that trade means specialization.

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.

Although the main contribution of the paper is theoretical, it is nonetheless desirable to assess the empirical plausibility of the mechanism it proposes. This is done in the final part of the paper, which is a first attempt to test a key prediction of the model: that protection of IPRs is most beneficial in open countries. To this end, measures of protection for IPRs and other macroeconomic variables have been collected for a panel of 53 countries observed in the years 1965-1990. The main finding is that, consistent with the model, the correlation between IPRs protection and GDP is higher among open countries.

This paper is related to various strands of literature. First, it is part of the literature on North-South trade and endogenous growth. A common theme of some of these works (e.g., Young, 1991 and Galor and Mountford, 2003) is that trade opening may be less beneficial to LDCs if they specialize in the "wrong" sectors (i.e., those with low growth potential or low human capital intensity). The result of this paper is more general in that it shows how trade shifts innovation in favor of rich countries irrespective of the characteristics of the sectors of specialization. Other works (Acemoglu et al., 2006, and Aghion et al. 2003) suggest instead that the effects of trade may depend on characteristics such as the level of technological backwardness of a country or a sector. In comparison, this paper shows that the effect of trade may also depend on the level of protection of IPRs. In particular, the fact that trade shifts the direction of innovation in favor of countries where IPRs are better enforced is novel.

The paper is also related to the line of research on "appropriate technologies". Diwan and Rodrik (1991), Acemoglu and Zilibotti (2001) and Saint-Paul (2004) argue that, whenever countries differ in terms of technological needs or preferences, the enforcement of IPRs can be instrumental to stimulate the development of the most appropriate innovations. The contribution of this paper is to show that specialization in production due to trade opening makes the technological need of countries more diverse and may thus exacerbate the problem of inappropriate technologies.

Finally, the paper is related to the literature on imitation and innovation in a trading world. Some contributions, including Helpman (1993), Glass and Saggi (1995), Dinopoulos and Segerstrom (2004), highlight the potential downsides of strong IPRs protection, as it restricts the efficient allocation of resources across countries. Others, such as Lai (1998), Yang and Maskus (2001), suggest instead that IPRs can foster growth and promote the diffusion of technology. Another group of papers, including Grossman and Lai (2004), Goh and Oliver (2002) and Chin and Grossman (1989), study the incentives that governments have to protect intellectual property in a trading economy. Although all these papers made important contributions, they generally neglect the idea that technologies can be inappropriate for developing countries and that IPRs protection can play a role in attracting better technologies. More fundamentally, they do not study the effect of trade under different IPRs regimes, which is the focus here.[3]

The rest of the paper is organized as follows. Section 2 presents the basic model, solves for the equilibrium under autarky and free trade and derives the two main results: that trade integration with countries where IPRs are weakly protected can amplify income differences and slow down the world growth rate. The model is then extended to study imperfect market integration in the presence of non-traded goods. Section 3 shows some supportive empirical evidence. Section 4 concludes.

2 The Model

This section describes first the simplest case of a single economy with full IPRs protection (the North). The analysis is then extended by adding a second economy (the South) with imperfect IPRs protection. Then, three distinct equilibria are compared: autarky, with and without IPRs protection in the South, and free trade in goods with imperfect IPRs protection. Finally, non-traded goods are introduced to study a case of imperfect trade integration.

2.1 Basic Setup: the North

Consider first a group of advanced countries, called the North, taken in isolation. The North is assumed to be a collection of perfectly integrated economies with similar characteristics and full protection of IPRs. Consumers have identical isoelastic preferences:

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

The time index, t, is omitted when this causes no confusion. There is a continuum $[0, 1]$ of sectors, indexed by i. Output of each sector, $y\,(i)$, is costlessly aggregated into a basket

[3] Dinopoulos and Segerstrom (2004) is an exception in that they study the effect of globalization in a model with innovation and imitation. However, they define globalization as an increase in the size of the open South and do not consider any autarkic regime. Thus, they perform a very different exercise from the one attempted here.

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 basket 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 a range $N\,(i)$ of machines and labor, $l\,(i)$:

$$y\,(i) = [\phi\,(i)\, l\,(i)]^{\beta} \int_0^{N(i)} x\,(i,j)^{1-\beta}\, dj, \quad \beta \in (0,1) \tag{4}$$

where $\phi\,(i)$ is an exogenous index of labor productivity and $x\,(i,j)$ is the quantity used of machine $j \in [0, N(i)]$ available in sector i. Machines are sector-specific, non tradeable and depreciate fully after use. Demand for machine $x\,(i,j)$ derived from (4) is:

$$x\,(i,j) = \left[\frac{(1-\beta)\, p\,(i)}{\chi\,(i,j)} \right]^{1/\beta} \phi\,(i)\, l\,(i)\,, \tag{5}$$

where $\chi\,(i,j)$ is the price of machine $x(i,j)$. Each machine in each sector is 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 all monopolists charge the same price, $\chi\,(i,j) = \chi = (1-\beta)$. Substituting χ and (5) into (4), yields the quantity produced in sector i as a linear function of the level of technology $A(i) \equiv \phi(i)N\,(i)$ and employed labor $l\,(i)$:

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

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 a relationship between equilibrium prices and the wage rate:

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

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 yields the 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. Solving (7) for $p(i)$, substituting this expression into equation (3) and simplifying shows that the equilibrium wage rate is a CES function of sectoral productivity:

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

where $\sigma \equiv \beta(\epsilon - 1)$, to simplify notation. Using (6) and (8) in (2) yields the optimal allocation of workers across sectors. Integrating over the interval $[0, 1]$ gives:

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

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 from the sale of single type of machine in sector i are a fraction $\beta(1-\beta)/N(i)$ of the value of sectoral output:

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

Its now time to discuss the characteristics of technology. As already stated, overall productivity in each sector, $A(i)$, is the product of two components: an exogenously given productivity parameter, $\phi(i)$, and the level of technical knowledge in sector i, represented by the number of machines $N(i)$. While $\phi(i)$ is fixed and determined by purely exogenous factors, such as geography, $N(i)$ can be increased through innovation as in models of endogenous growth with expanding variety of products (see Gancia and Zilibotti, 2005, for a survey). More specifically, innovation is costly and sector specific: i.e., a new machine in sector i cannot be used in any other sector j. To design a new variety of machines, the innovator has to pay a cost of μ units of the numeraire. Once a new machine is discovered, the innovator is granted a patent that entails a perpetual monopoly over its use. The patent is then sold to a firm that becomes the sole producer of that type of machine. Free-entry in the R&D sector implies that the present discounted value of profits from innovation cannot exceed the entry cost μ. Along a balanced growth path with positive innovation, in which $\pi(i)$ and r are constant, the free-entry condition can be written as:

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

Using (11), (10), (9), (7) and normalizing $\mu = (1-\beta)\beta$, the above expression reduces to:[4]

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

For the remainder of the paper, assume $\sigma \in (0,1)$. On the one hand, the assumption $\sigma > 0$ (equivalent to $\epsilon > 1$) rules out immiserizing growth: the fact that a sector (later on a country) growing faster than the others would become poorer in relative terms. 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 profitability falls, discouraging further innovation. If this condition was violated, it would be profitable to innovate in one sector only and all the others would disappear asymptotically. This case does not seem very realistic and is thus ruled out.[5] From this discussion, it should be clear that along a balanced growth path R&D must be performed in all sectors so that they all grow at the same rate. For this to be the case, the incentive to innovate has to be equalized across sectors. Imposing condition (12) for all i, it is possible to characterize the long-run relative productivity across sectors:

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

Equation (13) shows that, as long as $\sigma > 0$ (i.e., $\epsilon > 1$), innovation amplifies the exogenously given productivity differences $\phi(i)/\phi(j)$: in order to equalize the returns to innovation, exogenously more productive sectors need to have a higher than average $N(i)$.

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

[4] This normalization is meant to simplify the algebra only. It is innocuous, since the paper does not study the effects of changes in the cost of innovation μ.

[5] When trade is allowed, this assumption yields a stable distribution of income across countries. Evidence on this is provided by Acemoglu and Ventura (2002). In particular, they estimate $\epsilon = 2.3$ which, together with a labor share $\beta = 0.66$, implies $\sigma = 0.85$. Similar values for ϵ are estimated by Epifani and Gancia (2005). Thus, the restriction $\sigma \in (0,1)$ seems empirically plausible.

growth rate of the economy can be found as:

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

2.2 Imitation and the South

Consider now a set S of less developed countries, called the South. From now on, the subscripts N and S will be used whenever necessary to distinguish the North and the South respectively. The South is assumed to have a schedule of exogenous labor productivity, $\phi_S = (\phi_S(i))$, different from that of the North, $\phi_N = (\phi_N(i))$. This Ricardian differences captures the fact that geographic, institutional and economic differences (taken as given) make the South relatively more productive in some sectors than 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 $i < j$.

The way imitation is modeled emphasizes the quasi public good nature of knowledge, according to which ideas can flow rapidly across borders. For simplicity, protection of IPRs is modeled as in Acemoglu (2003) and Acemoglu and Zilibotti (2001). They assume that firms in the South can copy any machine at a small cost ξ and sell them to firms in the South.[6] This means that the endogenous component of technology, $N(i)$, is identical in all countries and that all machines are sold by local monopolists. In fact, no two firms have an incentive to copy the same machine because price competition would lead them to negative profits. The role of IPRs protection is simply to determine how much of the revenue from the sale of machines in the South accrues to the original innovator. In particular, the original innovator receives royalties from the imitator in the South equal to a fraction $\theta \in [0, 1]$ of the profits he makes.[7] Therefore, θ can be interpreted as an index of the strength of IPRs protection.

[6] Consistent with most patent laws, firms in the South are never allowed to re-export copied machines to the Northern market, so that there is no competition between technology firms in the North and the South.

[7] The obvious limit of this approach to IPRs is that the monopoly distortion in the South does not depend on θ. This simplification is innocuous except for welfare analysis, which is not in the scope of the paper. Alternatively, one could assume that imitated products are sold at marginal cost and model IPRs protection as an additional per-unit cost that must be paid to the original innovator in the form of royalties. For example, the unit cost inclusive of royalties could be defined as $(1-\beta)(1+\beta\theta-\beta)$, so that $\chi_S = \chi_N = (1-\beta)$ if $\theta = 1$ and $\chi_S = (1-\beta)^2 < \chi_N$ if $\theta = 0$. The qualitative results of the paper would carry over because such a modification affects both the autarky and free trade equilibrium in the same way.

Innovation, in turn, is global: the R&D sector produces for the world economy and the cross-country distribution of R&D costs is assumed to be proportional to the net revenue accruing to the innovator in each country. This assumption is not essential, but it does simplify the analysis by making the localization of the R&D industry irrelevant.[8] Note that, despite the fact that the North and the South have access to the same innovations, their productivity will generally differ for two reasons: first, because of the exogenous differences in labor productivity ϕ_N and ϕ_S, and second, as it will be shown soon, because innovations may be more appropriate for a country than the other.

2.3 Case I: no International Trade and $\theta = 0$

Consider first the simplest case in which there is no IPRs protection in the South (i.e., $\theta = 0$) and no trade in goods. Under this conditions, the equilibrium in the North is the one described in section 2.1 and is unaffected by the presence of other countries. In particular, the state of technology across sectors, $N(i)$, is given by (13) according to the exogenous labor productivity of the North, $\phi_N(i)$. The equilibrium in the South is characterized by a set of equations analogous to those that apply to the North, with the difference that machines are copied and thus $N(i)$ is taken as given from the North. Then, using equations (9) and (13) it is possible to solve for the North-South relative wage, $\omega \equiv w_N/w_S$:

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

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 appropriate for the North, in the sense that it maximizes Y_N, while it is appropriate for the South only in the limit case in which ϕ_N and ϕ_S are proportional to each other so that there is no comparative advantage (i.e., $\phi_S(i) = \alpha\phi_N(i), \forall i$, with $\alpha > 0$ equal to a constant of proportionality).[9] This result extends the finding of Acemoglu and Zilibotti (2001) that technologies developed in

[8] 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.

[9] In fact, it is optimal to have a relatively high level of technology $N(i)$ in sectors where the exogenous labor productivity $\phi(i)$ is already high. Copying the technology from the North, the South is using too many machines in sectors that are originally not very productive. This inefficiency lowers the wage in the South.

advanced countries may be inappropriate for the economic conditions of LDCs.[10] The Appendix also 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 $N(i)$ that are identical across countries, equation (14) for the North gives also the growth rate of the South.

2.4 Case II: no International Trade and $\theta \geq 0$

Consider now the more general case of imperfect protection of IPRs in the South: $\theta \in [0,1]$. In this case, profitability of an innovation is given by the sum of the rents from both the markets in the North and in the South. Then, the free-entry condition according to which the value of innovation must be equal to its cost becomes:

$$\frac{[\pi_N(i) + \theta\pi_S(i)]}{r} = \mu.$$

Note that an innovator can extract only a fraction θ of the profits from the Southern market. Substituting the expressions for profits and solving for $N(i)$ yields:

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

The endogenous component of productivity, $N(i)$, 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 implicit formula for the relative wage is:

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

Whether technology is closer to the Northern or Southern optimum, depends on which of the two markets for innovations is larger (see the Appendix for further details). As $\theta L_S/L_N \to 0$, equations (17) approaches from below (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

[10] In their model, this happens because of a skill-technology mismatch: the Northern technology is too skill-biased for the skill-endowment of the South. Here, any source of comparative advantage captured by ϕ_N and ϕ_S implies that the North and the South have different technological needs.

economy for the general case when $\theta \in [0,1]$ 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 is increasing in θ because stronger IPRs protection translate into higher rewards to innovation. As $\theta \to 0$, the growth rate declines to (14), defining a lower bound for the growth rate in autarky.

2.5 Case III: Free Trade with $\theta \geq 0$

Consider now the possibility to trade $y(i)$ internationally. The exchange of goods between the North and the South is profitable because of Ricardian comparative advantage. Even if technological progress is endogenous, sectoral productivity differences across countries are fixed by ϕ_N and ϕ_S, and so is the pattern of comparative advantage.[11] 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 $i < j$. This means that the North is better at producing goods with a low-index i. Further, for analytical tractability, the comparative advantage schedule, $\phi_N(i)/\phi_S(i)$, is assumed to be continuous. As in Dornbusch et al. (1977), the equilibrium under free trade and for a given technology 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. This implies that 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 of $\phi_N(i)/\phi_S(i)$, the North and the South must be equally good at producing the cut-off commodity z: $p_N(z) = p_S(z)$.[12] Using (7), this condition identifies the cut-off sector z as a function of the relative wage under free trade ω:

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

For a given relative wage, (19) gives the pattern of specialization between the two countries. Since comparative advantage of the North is decreasing in z, (19) traces a downward sloping curve, Φ, in the space (z,ω). The second equilibrium condition is trade balance,

[11] This is of course a simplification. Saint-Paul (2004) makes the same assumption, while Taylor (1994) builds a model where comparative advantage is endogenous and may depend on IPRs policies.

[12] Since goods $y(i)$ are produced by competitive firms, no one can undercut the price in face of foreign competition. Further, given that each monopolist is infinitesimal, it has no incentive to undercut the price of its machine to make an industry more competitive.

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:

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

where the left hand side is the value of imports in the North and the right hand side is the value of imports in the South. Note that, by homogeneity of tastes, the location 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, profits from innovation in any pair of sectors must be equal. In particular, considering innovations for goods i and j produced in the North and in the South respectively, the following research-arbitrage condition must hold: $\pi_N(i) = \theta\pi_S(j)$. 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 relative productivity compatible with balanced growth:

$$\frac{A_N(i)}{A_S(j)} = \left[\frac{\phi_N(i)}{\theta\phi_S(j)}\right]^{1/(1-\sigma)} (\omega)^{\sigma/(\sigma-1)}, \tag{21}$$

$\forall i, j \in [0, 1]$ with $i < z < j$. Compared to the case without trade, the relative productivity of sectors still depends on the exogenous component $\phi(i)$, but also on the IPRs regime of the country where the innovation is used. Technology is still biased towards 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 rents from innovation are lost (as long as $\theta < 1$). Hence, equation (21) shows that under free trade weak protection of IPRs in the South shifts technology in favor of the goods produced by the North.

Integrating i over $[0, z]$ and j over $[z, 1]$ in (21) and using (20), the trade balance condition (TB), incorporating the research arbitrage condition that must hold along the balanced growth path, can be rewritten as:

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

Note that ω is increasing in z and decreasing in θ. Further, if $\sigma = 0$ (or $\epsilon = 1$, as in the

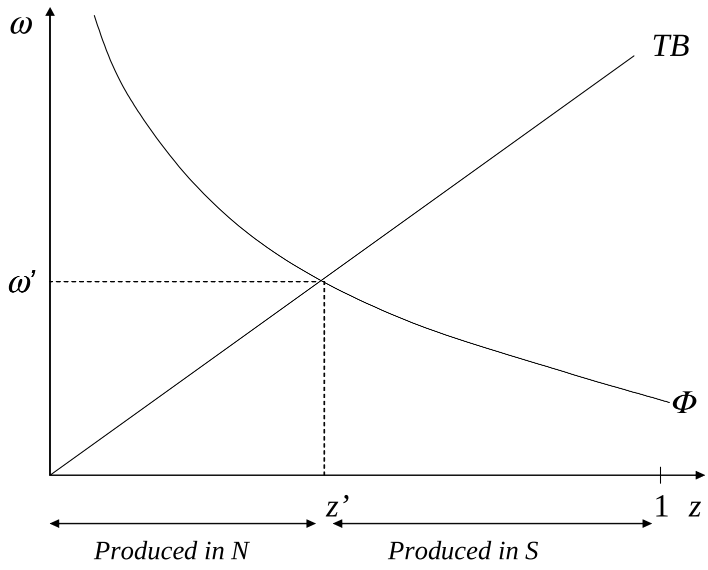

Figure 1: Free Trade Equilibrium

Cobb-Douglas case), the equilibrium becomes independent of the sectoral distribution of productivity and the degree of IPRs protection. Conversely, if $\sigma = 1$ the relative wage is determined exclusively by IPRs protection: $\omega = 1/\theta$.

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 weak IPRs in the South when international trade is allowed. From (22), a fall in θ implies an upward shift of the TB schedules which lower the relative wage in the South and increases the set of goods produced there (z falls). Comparing (22) with (15), and noting that $\lim_{\theta \to 0} \omega = \max \phi_N(i)/\phi_S(i)$, proves the following:

Proposition 1 *Suppose that parameters (L_N, L_S, ϕ_N, ϕ_S, σ and ρ) are such to guarantee positive long-run growth and $\sigma \in (0,1)$. Then, there exists a level θ^* such that if $\theta < \theta^*$ income differences in free trade, as measured by ω, are larger than income differences without international trade.*

This is one of the main results of the paper: that trade can amplify income and productivity differences if protection of IPRs in less developed countries is too low. 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. Hence, trade may shift technology in favor of rich nations. As $\theta \to 0$, R&D would be directed towards Northern sectors only and the income gap would grow up to its maximum $(\phi_N(0)/\phi_S(0))$, irrespective of any other country characteristics.[13] In autarky, instead, even with $\theta = 0$, the South still benefits from the innovations performed in all sectors for the Northern market.

Another interesting result can be found by calculating the long-run growth rate of the world economy 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. What is more surprising is that the growth rate of the world economy approaches zero if θ is low enough. This is in contrast to the case without international trade, where the growth rate is bounded from below by the growth rate of the North economy taken in isolation (14).

The reason behind this result is that weak IPRs in the South spills over to Northern sectors because trade equalizes the long-run returns to innovation across sectors and countries (i.e., $\pi_N(i) = \theta \pi_S(j)$). In turn, this is possible because returns to innovation in a given sector fall asymptotically to zero as the sector grows faster then the rest of the economy (a consequence of $\sigma \in (0,1)$). Thus, balanced growth is achieved by expanding the Northern sectors up to the point where further investment in innovation for the North is no more profitable than it is for the South.[14]

[13] Acemoglu and Zilibotti (2001) show instead that trade leads to skill-biased technical change. However, in their model trade generates productivity convergence and has ambiguous effects on relative income, even when $\theta = 0$ (the only case they study). The main reason for these different results is that they use a Heckscher-Ohlin trade model with factor price equalization.

[14] Note that sector-specific technical process is needed for Proposition 2 to hold. 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 $\theta = 0$. As a consequence, in Acemolgu and Zilibotti (2001) trade opening has no effect on the world growth rate.

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

Proposition 2 *For any $\sigma \in (0, 1)$, there exists a level θ^{**} such that, if $\theta < \theta^{**}$, the long run world growth rate is lower when international trade is allowed.*

In summary, Propositions 1 and 2 imply that if protection of intellectual property is too low in less developed countries, trade integration can either amplify income differences, slow down the world growth rate, or both.

2.6 Non-Traded Goods

The introduction of non-traded goods gives rise to a regime the combines 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 $(1 - t)$ on non-traded goods.[15] In particular, define consumption over two baskets of goods:

$$C = (Y)^t \, (Y^*)^{1-t} \,,$$

where Y, representing the traded component of consumption, is still given by (1), while Y^* is a basket of non-traded good. In this section, all variables related to the non-traded sectors are denoted by an asterisk. To preserve symmetry, output of the non-traded good, Y^*, is defined by a CES function over a new $[0, 1]$ interval of (non-traded) commodities as in (1). In fact, it is convenient to model the two sectors, traded and non-traded, as similar in all respects and independent from each other, in that each sector uses its own output as the only input to produce its machines and innovation. As before, the price index of the traded good Y is set equal to one, while the price of Y^* is P^*. Under these assumptions and for given wages and technology, the equilibrium conditions in the traded sector are almost unchanged. The only difference is that, due to Cobb-Douglas preferences and symmetry in market structure, only a fraction t of the total labor force is allocated in each country to the traded sector. Likewise, equilibrium conditions in the non-traded

[15] Non-traded goods can also arise endogenously in the presence of a trade cost. See Dornbusch et al. (1977) for more details.

sector in any country can be derived as:

$$x^*(i) = [p^*(i)/P^*]^{1/\beta} \phi^*(i) l^*(i) \tag{24}$$

$$y^*(i) = [p^*(i)/P^*]^{(1-\beta)/\beta} A^*(i) l^*(i) \tag{25}$$

$$w = \beta p^*(i)^{1/\beta} P^{*(\beta-1)/\beta} A^*(i) \tag{26}$$

$$w = P^* \beta \left[\int_0^1 A^*(i)^\sigma di\right]^{1/\sigma} \tag{27}$$

$$\pi^*(i) = \beta(1-\beta) p^*(i)^{1/\beta} P^{*(\beta-1)/\beta} \phi^*(i) l^*(i), \tag{28}$$

where $P^* = \left[\int_0^1 p^*(i)^{1-\epsilon} di\right]^{\frac{1}{1-\epsilon}}$. These conditions are analogous to equations (5) (6) (7), (9) and (11), with the difference that the price of the non-traded basket is not normalized to one. Hence, machines in the non-traded sector are sold at the monopoly price $(1-\beta)P^*$ (instead of $1-\beta$). Finally, assuming that the cost of developing new machines for the non-traded sector is μ units of Y^*, the relative productivity among non-traded goods can be found imposing the arbitrage condition: $\pi(i) = \pi(j), \forall\, i, j \in [0,1]$.

For a given wage, the price of traded goods does not depend on the non-traded sector. Thus, the condition for efficient specialization is still given by (19). Trade balance is also unaffected, because every country spends the same share t of total income on the traded goods. Thus, equation (22) still applies. However, the price of non-traded goods will generally differ across countries. To take this into account, it is possible to rewrite the equilibrium conditions (19) and (22) in terms of the real wages: $\omega^R = \omega(P_S^*/P_N^*)^{1-t}$. Using (27) to substitute for the price of non traded goods yields:

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

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

where $A_j^* \equiv \left[\int_0^1 A_j^*(i)^\sigma di\right]^{1/\sigma}$, $j = N, S$, is an aggregate measure of productivity in the non-traded sector, that will depend, among other things, on $\phi_N^*(i)$, $\phi_S^*(i)$ and θ. 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^*, which reduces to (17), just as in the autarky case. Similarly, it is possible to show that the growth rate is given by a combination of the formulas valid in autarky and in free trade.

At this point, it is instructive to isolate the mechanism emphasized in the paper by considering a simple case in which the two countries are perfectly symmetric except for the degree of protection of IPRs, θ. In particular, assume that the two countries have the same size, $L_N = L_S$, the same productivity in the non-traded sectors, $\phi_N^* (i) = \phi_S^* (i)$ implying $A_N^* = A_S^*$, and the same *average* productivity in the traded sectors. However, the North and the South still differ in how the exogenous component of labor productivity is distributed across the traded sectors. For example, assume that $\phi_N (i) = \phi_S (1 - i)$. In such a situation, no country is inherently better than the other.[16] Then, it easy to show that the relative wage in autarky is one and that the following inequalities hold:

$$\frac{\partial \omega^R}{\partial t} \geq 0, \quad \frac{\partial \omega^R}{\partial \theta} \leq 0, \quad \frac{\partial^2 \omega^R}{\partial \theta \partial t} < 0,$$

i.e., the North-South wage ratio increases with the extent of trade (t) whenever IPRs are not fully protected in the South. Further, the North-South wage ratio falls with IPRs protection in the South (θ), the more so the higher the extent of trade (t). Moving back to the general case, it is straightforward to use Proposition 1 to show that, if θ is low enough, real wage differences will increase with the extent of trade (t).

2.7 Why Are IPRs Not Protected in the South?

The previous analysis suggests that Southern countries may benefit from the enforcement of IPRs. It is then interesting to ask why these policies are often not adopted. Although this question goes beyond the scope of the paper, a number of possible answer come to mind. First of all, enforcing IPRs can be costly, particularly in countries with weak legal institutions. A second reason might be that a tightening of IPRs implies a profit loss. Therefore, it may be optimal from the point of view of the South not to have full protection of IPRs. Even when strong protection of IPRs is in the interest of the South, 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 than the workers, it may prefer to defend profits at the expenses of the rest of the economy. Finally, in implementing IPRs protection, there might be a coordination problem among

[16] The assumption that there is a pattern of comparative advantage in traded sectors (i.e., $\phi_N (i) \neq \phi_S (i)$) while there is none in non-traded sectors (i.e., $\phi_N^* (i) = \phi_S^* (i)$) is a simplification that captures, albeit in an extreme fashion, what would be a general result if non-traded goods arose endogenously due to the presence of a trade cost: that comparative advantage would be stronger among traded goods. The reason is that non traded goods would be precisely those for which comparative advantage (i.e., the price difference between the two countries) is not strong enough to justify spending the trade cost.

Southern governments: 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. 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.

3 Empirical Evidence

The key mechanism of the model is that trade-driven specialization affects the ability of a country to attract better technologies by changing the level of protection of IPRs. While a country in autarky can free ride on innovation, trade-induced specialization implies that the North and the South benefit from different innovations so that the scope for free-riding is limited.[17] More precisely, specialization has two effects. First, by increasing a country's share of world production (and profits) in the sectors of comparative advantage, it increases the impact of country-specific policies on 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 increasing IPRs protection of a country, θ_i, on its income to be higher under free trade than in autarky or, more generally, the larger the extent of trade. Further, since the ability of a country to attract innovation for its own sectors depends on its share in world production of those sectors, which in turn depends on country size, the model suggests that the impact of θ_i on productivity should be higher in larger countries. This is the case in autarky, but also under free trade whenever there are countries specialized in the same products. These implications can be summarized as:

$$\frac{\partial^2 \left(Y_i/\overline{Y}\right)}{\partial\theta_i \partial t_i} > 0 \quad \text{and} \quad \frac{\partial^2 \left(Y_i/\overline{Y}\right)}{\partial\theta_i \partial L_i} > 0, \tag{29}$$

where Y_i is the real GDP per worker in country i, $\overline{Y}$ is the world average, L_i is the size of country i and t_i the size of its traded sector. Since the results of the paper hinge on (29), testing them provides a first way to assess its empirical plausibility.

[17] Yet, free riding may still arise between the governments of similar LDCs specialized in the same type of products.

To this end, measures of GDP per worker, IPRs protection, openness to trade and size have been collected for a panel of countries from 1965 to 1995. GDP per worker (GPDW) is taken from the Penn World Table 6.0 (PWT6.0). Two important determinants of productivity are also included in the analysis to capture some of the cross-country differences in the ϕ: the stock of physical capital per worker (KL), 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 from PWT6.0.[18] Although the first measure is useful to distinguish countries under different trade regimes, it exhibits almost no time variation in the given sample and is therefore appropriate for the cross-sectional analysis. 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 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 correlated with the overall level of protection for intellectual property. This index has also the advantage of being available for a large number of countries with quinquennial observation since 1965. The index (IPR) ranges from 0 to 5.[19] In summary, the overall dataset comprises a cross-section of 53 countries and 6 time observations, from 1965 to 1990 at 5 year intervals.[20] Descriptive statistics of the main variables are reported in Table 1.

[18] 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.

[19] 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.

[20] 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	0.52	46.69	7848	19.82	26420	16953
	(0.59)	(0.50)	(25.69)	(7703)	(18.39)	(70771)	(11608)
1970	2.52	0.51	50.37	10232	23.51	29003	18915
	(0.67)	(0.50)	(29.52)	(9265)	(19.61)	(78764)	(12248)
1975	2.53	0.49	57.83	12997	26.11	31833	20917
	(0.67)	(0.50)	(29.51)	(11394)	(19.95)	(87549)	(13244)
1980	2.69	0.52	61.42	15190	32.72	34782	21347
	(0.85)	(0.50)	(31.38)	(12781)	(22.09)	(97354)	(14101)
1985	2.71	0.49	60.69	16507	35.59	37821	23412
	(0.89)	(0.50)	(35.42)	(14154)	(21.63)	(107662)	(15666)
1990	2.75	0.70	63.54	18754	40.26	41039	25433
	(0.90)	(0.46)	(38.14)	(16336)	(21.99)	(118867)	(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

To get a first sense for the patterns in the data, Table 2 presents a set of conditional correlations. The results are encouraging. 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 (29) seems broadly consistent with the data, as IPRs protection is found to have a higher correlation with productivity in larger countries.

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 endogeneity concerns, all the right-hand side variables are lagged five years.[21] 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 (29) the two interaction terms should have a positive sign. Consistently, column (1) shows that the coefficient on both interactions is positive and precisely estimated. Column (2) provides a crude attempt to check whether the IPR protection variable simply acts as a proxy for the quality of institutions. To this end, an index of government anti-diversion policies (GADP) and its interaction with openness are added to the estimated equation. This index, taken from Hall and Jones (1999), has been used to measure institutional quality and, like most other proxies of this kind, does not vary over time. Column (2) shows that, as expected, the coefficient for GADP turns out positive and significant, while the previous results are almost unaffected.

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 the advantage of controlling 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 inadequate (likewise, the institutional variable GADP

[21] To avoid losing observations by using lagged values, the dependent variable, available for 1995, is forwarded 5 years in the remainder of the empirical analysis.

cannot be included as it is already captured by the country-effect). The analysis therefore continues using the trade share in GDP as a measure of openness. Before moving to the fixed-effects regression, Column (3) replicates the pooled OLS estimates of Column (1) with the new trade measure and it confirms the previous findings: the two interaction terms are positive and significant at the 1% level.

Table 3: Panel Analysis

	OLS(1)	OLS(2)	OLS(3)	LSDV(4)	LSDV(5)	LSDV(6)	LSDV(7)
IPR	-1.941 (0.697)***	-2.622 (0.749)***	-5.723 (1.568)***	-0.407 (0.875)	-0.641 (0.885)	-0.680 (0.419)*	-0.436 (0.475)
OPEN	-0.437 (0.200)**	-0.368 (0.501)	-0.719 (0.231)***	0.041 (0.098)	0.014 (0.102)	0.013 (0.097)	0.131 (0.110)
IPR*OPEN	0.801 (0.265)***	0.609 (0.209)***	0.556 (0.212)***	0.216 (0.105)**	0.278 (0.115)**	0.279 (0.106)***	0.241 (0.121)**
IPR*POP	0.163 (0.065)**	0.224 (0.071)***	0.393 (0.089)***	-0.005 (0.074)	-0.003 (0.073)	-	-
POP	-0.207 (0.70)***	-0.258 (0.077)***	-0.452 (0.092)***	-0.013 (0.113)	-0.002 (0.134)	-	-
KL	0.400 (0.075)***	0.343 (0.078)***	0.453 (0.073)***	0.323 (0.034)***	0.354 (0.038)***	0.354 (0.038)***	-
HL	0.164 (0.084)*	0.160 (0.079)**	0.214 (0.080)***	-0.037 (0.036)	-0.016 (0.036)	-0.016 (0.032)	-
GADP	-	0.772 (0.282)***	-	-	-	-	-
GADP*OPEN	-	-0.053 (0.296)	-	-	-	-	-
R^2	0.83	0.85	0.82	0.58	0.61	0.61	0.47
No. of Obs.	306	300	318	318	318	318	318
Time effects	no	no	no	no	yes	yes	yes
F-test (FE) (P-value)	-	-	-	31.02 (0.000)	31.07 (0.000)	38.52 (0.000)	136.88 (0.000)

LHS: real GDPW. All variables, except dummies, in logs. RHS variables are lagged (5 yeras). Columns 1-2 uses the Sachs and Warner Openness index. Columns 3-7, 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.

Columns (4)-(7) report the results from the LSDV estimator. Column (4) 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 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. Column (5) shows that the inclusion of time dummies does not affect the results. Column (6) reports the estimates after dropping the size variables, whose contribution to explain changes in GDPW over time has been found statistically small. Finally, Column (7) 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 from zero. To conclude, this evidence suggests that a key prediction of the model seems to be, at a first pass, consistent with the data.[22]

A few calculations on the coefficients in Table 3 can help 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 1-3-4 imply that a 10% increase of the index of patent rights is associated with an output change of -0,3%, +0,7% and +3,8% respectively. These numbers suggest that, for the average country, gains from 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 1-3-4, 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 IPR 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 IPR 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 unacceptably high, given that coefficients come from 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.

[22] Statements about causality cannot be made on the basis of this analysis because, despite the use of lagged variables, endogeneity concerns may remain. Unfortunately, IV strategies relying on historical and geographical instruments have little hope to solve the problem because the typical instruments have been shown to be weak to identify separately the effects of trade and institutions. The presence of interaction terms and the need to distinguish IPR protection from other institutional variables make the problem much worse. Developing an empirical strategy to address these issues goes beyond the scope of this paper, but it would certainly be an interesting direction for future research.

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.

Before concluding, it is worth 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. It is then instructive to look at the evolution of the number of patents by technological category issued in the US over the last four decades. As 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 from 2% to 10%, whereas Electrical and Electronics is the only stable field (16-18% of total). Albeit consistent with the theory, this evidence may also reflect technology cycles or changes in demand. On this respect, note that the model generates something resembling a product cycle, whereby 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. Next, the model suggests that trade opening may trigger a transition in which innovation is mostly directed towards Northern sectors (to satisfy equation 21) and, at the same time, economic activity is relocated from the North to the South (z falls as ω rise). On this respect, evidence of skill-biased technical change and outsourcing seems broadly consistent with these predictions. Finally, the model suggests that market integration may have increased the income gap between poor and rich nations. While the impact of trade on different countries is a controversial issue, there are empirical works showing that trade may have contributed to a widening in the world income distribution.[23]

4 Concluding Remarks

This paper has presented a simple model where market integration may amplify income differences between rich and poor countries and may lower the world growth rate. 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. Its main lesson is that, in a world of integrated economies, profits from innovations play a crucial role in directing technical progress towards the

[23] See, for example, Beaudry et al. (2002) and DeJong and Ripoll (2004).

needs of all countries and in sustaining long-run growth. Even though the analysis hints at potential gains from global IPRs regulations, it abstracts from the fact that enforcing worldwide standards may be costly for LDCs and that the profits from their markets may fail to provide the proper incentives for such reasons as high transaction costs or expropriation risk. Given these imperfections, promoting research aimed at the needs of the less developed countries appears to be a key element for reducing income differences and fostering world economic growth.

Before concluding, it is worth to mention some limitations and possible extensions of this paper. The first is the lack of welfare analysis. Although the main goal was to illustrate a novel mechanism through which North-South trade may affect the world income distribution and economic growth, it would be desirable to study its effect on welfare as well. Unfortunately, such an exercise poses serious difficulties.[24] Second, the paper is built on the hypothesis that ideas can flow rapidly across borders and technological knowledge (but not productivity) is the same across countries. While this view is not uncommon and has empirical merits (see, for instance, Acemoglu and Zilibotti, 2001), it is nonetheless possible that trade itself contributes to technology transfer between countries.[25] Third, infringements of intellectual property rights and firms' structure have been modeled in a stylized way. As a consequence, the model is silent on the role played by multinationals or other organizational forms of production. Incorporating these elements into the analysis would certainly help understand the complex interactions between innovation, imitation and growth in a global economy and seems a fruitful direction for future research.

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[24] In this model, welfare comparison across trade regimes would tend to be arbitrary because it is hard to measure comparative advantage and thus the gains from trade. Moreover, a more realistic description of IPRs would be required. Finally, the analysis would be complicated by the need to compute welfare along non-trivial transitional dynamics. A way to circumvent these problems could be to use a simpler two-good model along the lines of Saint-Paul (2004).

[25] Evidence on the role of trade in promoting technology transfer is mixed. See Keller (2004) for a survey.

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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):

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

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

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

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

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

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

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

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

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

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:

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

5.3 The growth rate under free-trade

Rewrite the free entry condition in R&D for a Northern sector ($\pi_N(i)/r = \mu$) 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 eliminate $A_N(i)$. 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.