Regulation of Intellectual Property Rights and Trade

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Abstract

This thesis consists of three essays on the regulation of Intellectual Property Rights (IPRs) and trade in open economies.

The first chapter investigates the differences in Intellectual Property Rights between countries. The analysis of a cross-country panel reveals that the protection of IPRs is higher in countries that are (i) richer, (ii) more productive in R&D and (iii) more open to trade. It is then shown that the first two facts can be explained in a model where innovations are a global public good and where demand for innovations is non-homothetic in income.
The second chapter addresses the third observation. If trade is driven by large differences in productivities across countries and sectors then having strong IPR protection can become more beneficial for the individual country, since a part of the associated costs are passed onto the trading partners.
The third chapter aims to explain why and when countries link agreements on trade with agreements that regulate the provision of global public goods. It shows that a linkage is particularly attractive if countries are different in size.

Resum

Aquesta tesi es composa de tres assaigs sobre la regulació dels Drets de la Propietat Intel·lectual (IPRs) i el comerç en economies obertes.

El primer capítol investiga les diferències en els Drets de la Propietat Intel·lectual entre països. L'anàlisi empíric mostra que la protecció dels IPRs és més alta en països que són (i) més rics, (ii) més productius en I+D i (iii) més oberts al comerç. Es mostra que els dos primers fets es poden explicar en un model on les innovacions són un bé públic global, i on la demanda d'innovacions és no homotètica en els ingressos.
El segon capítol tracta la tercera observació. Si el comerç és conduït per grans diferències de productivitat entre països i sectors, tenir una forta protecció dels IPRs pot ésser beneficiós per al país individual, degut a què una part dels costs associats es traspassa als països amb els quals es comercia. El tercer capítol té per objectiu explicar per què i quan els països vinculen acords sobre comerç amb acords sobre la regulació dels bens públics globals. Es mostra que un vincle és particularment atractiu si els països són diferents en mida.

Prolog

During December last year, delegates from the 192 member countries of the United Nations Framework Convention on Climate Change (UNFCCC) met for a 11-day conference in the Danish capital of Copenhagen to agree upon measures to reduce CO_2 emissions. Despite almost universal acknowledgment of man-made global warming, negotiations proved utterly contentious and any prospect of a binding agreement was deferred to the next meeting in Mexico at the end of this year.
At the same time, demands to strengthen climate change policies by linking them to trade policies are gaining support. Proposals include both multilateral approaches such as the introduction of environmental objectives in the WTO as well as unilateral approaches such as border tax measures to compensate differences in national climate legislation.

The difficulty of reaching a binding compromise should not have been too surprising. Multilateral agreements are generally preceded by long and controversial negotiations, regardless of whether these concern measures designed to mitigate climate change or policies aimed at the preservation of fishing stocks or other endangered species.
What these issues have in common is that they can be characterized as public goods that are transnational or even global in scope. A stable climate and an intact fauna and flora are amenities that are enjoyed by all, even if domestic policies contribute little to their preservation. The disputes at the international negotiation rounds are consequently not about *whether* reducing CO_2 emissions or protecting endangered species are desirable aims, but rather about *how (much)* each country should contribute to the common good.

A particular example for a global public good are innovations that are financed through Intellectual Property Rights (IPRs). Insofar as innovations diffuse and thereby contribute to a global stock of knowledge, they are global public goods. Since IPRs raise production costs and are created through national legislation, they represent the national contributions to this common good, just as more environmentally-friendly production mandated by national legislation on CO_2 emissions are national contributions to the global climate. Consequently, a country has little incentives to protect Intellectual Property if it can free-ride by accessing the innovations financed by the other countries' IPRs while enjoying the lower prices that result from weak, domestic IPRs.
International agreements on IPRs that aim to mitigate the free-riding incen-

tives have existed at least since the Paris Convention on common standards and mutual recognition for patents in 1883 and the Bern Convention on copyright protection in 1886. However, the effectiveness of these treaties was often limited as enforcement mechanisms were absent. This deficiency was remedied with the TRIPS agreement that became part of the WTO framework in 1994. It prescribes minimum IPR standards that can be enforced through the organization's dispute settlement procedures. Thereby, the incorporation of the TRIPS agreement into the WTO effectively links an agreement on Intellectual Property Rights with the agreement(s) on trade liberalization.

This thesis wants to contribute to the understanding of the relationship between trade and the international regulation of common goods in general and the regulation of Intellectual Property Rights in particular.
In the first chapter, we examine the public-goods hypothesis of IPRs. For this purpose, we model each countries' decision on the strength its national IPR regulation as a non-cooperative game. The main predictions of this model - that large countries, rich countries and those that are productive in R&D have stronger IPR laws - are confirmed in a cross-country panel using the Ginarte-Park (1997) measure of Intellectual Property Rights legislation.

The empirical analysis also unveils trade openness as an additional factor associated with high Intellectual Property Rights, an observation that seems to be at odds with the public-goods hypothesis of IPR creation. If anything, trade should improve the spill-over of innovations, enabling countries to even better free-ride on the fruits of foreign IPR protection.
In the second chapter, we offer an alternative view on the relationship between trade and IPRs which is able to explain the positive association between the two. If the productivity differences across countries and sectors that shape the pattern of trade are large compared to the price mark-up caused by IPRs, then the IPRs of the producing country continue to determine the price in the importing country, independently of its own IPRs. A strong pattern of specialization thereby leads countries to internalize only partially the benefits of IPRs - the *global* stock of innovations - as well as to internalize only partially the costs of IPRs - the *globally* higher prices.

Linking two issues in one single agreement, as happened with the TRIPS agreement in the WTO, weakly improves enforceability, since it creates the possibility of retaliating a breach in one issue by withdrawing concessions in the other. However, when the issues are independent and the countries are symmetric, linkage can improve cooperation in one issue only at the expense

of a worse outcome in the other issue.
In the third chapter, we consider the case for issue linkage when countries differ in size. This introduces an asymmetry in the enforceability of cooperation with respect to issues and countries. For the larger country, cooperation in regulation is better enforceable compared to either the smaller country or to cooperation in trade. Linking the issues then provides an opportunity to exchange concessions across issues and countries, where the larger country reduces the tariff and weakens its regulation, while the smaller country increase its regulation and tariff rate.

Contents

Chapter 1

Cross-country differences in Intellectual Property Rights

1.1 Introduction

Ideas manifest as product innovations, literary works or industry designs. They are valuable, costly to come up with, but free for use by everyone else. These characteristics merit the creation of property rights that give the innovator more exclusive possibilities to commercialize his idea. Such Intellectual Property Rights (IPRs) include patents, copyrights and trademark protection. The scope of these rights, their protection and their priority in the legal system differ across countries and across time. The most extensive IPRs are granted in the United States, followed by several OECD countries. In those countries, the scope of patentable products continues to be extended to include software, plant varieties and animals. Other, mostly developing countries create much more restricted IPRs and do not grant patents on, say, pharmaceutical products, much less on plant or animal varieties.

The objective of this paper is to explain those cross-country differences in Intellectual Property Rights. This is worthwhile as differences in the national IPR systems have been permanent sources of international disputes. Over the past decades, the United States and other OECD countries have exerted pressure on developing countries to raise their levels of Intellectual Property Rights, which they perceived to be too low. This finally led to the Agreement on Trade-Related Intellectual Property Rights (TRIPS), which became in 1994 part of the World Trade Organization's founding treaty. The minimum levels of IPRs stipulated in this treaty imply a substantial increase in the level of patent protection and other IPRs granted. The often cited rationale for coordinating the IPR regulations on a high level is the idea that each country, by granting IPRs, is effectively contributing to a global public good, namely the stock of innovations. Without coordination, countries will have incentives to provide only little patent protection themselves and to free-ride on the research financed by patent-protection abroad. The larger the country, the more will it internalize the beneficial, innovations-generating effect of patents and thereby install a higher level of IPRs. Our model formalizes this public goods contribution argument, generates predictions analytically and numerically, and tests those on the data.

Two assumptions are crucial. The first is that innovations are indeed a global public good, so that the knowledge of how to produce any newly innovated good immediately 'spills over' to all other countries alike. The second concerns a characteristic of the IPR system. It is assumed that the same Intellectual Property Rights that are given to domestic innovators are also granted to foreigners. This implies that the patent protection producers enjoy only depends on the IPR protection granted in the market where the good is sold, not where it is produced. To give an example: assume that IPR protection is lower in the South than in the North. Then Southern products sold in the North enjoy the North's higher patent protection, although Northern products sold in the South are only protected by the weaker Southern standards. This so-called National Treatment is one of the main principles required by the TRIPS agreement, but it also was a feature of most national IPR legislation before.

The seminal paper on optimal patent protection, albeit in a single economy, is Nordhaus (1969). He models the trade-off between the dynamic gains of more innovations that are brought by higher patent protection and the static losses that are incurred when the patent-protected goods are priced with a monopoly mark-up. In an international economy setting, there are several more recent papers dealing with differential Intellectual Property Rights across countries. Helpman (1993) analyzes the growth and trade implications of lower IPRs in the South. However, in this model innovation is only done in the North and the innovating firms there do not receive any profits from selling their products in the South, since IPRs in the South are understood as determining the rate of imitation, not the contribution to the innovator's profit. This is different in Gancia (2006), where national treatment is not assumed. Instead, the IPRs in one region affect the profits made of the goods produced in that same region, regardless of where they are sold. This biases innovations towards sectors located in high-IPR regions.

The idea of national IPRs as contributions to the global, public-goods, knowledge stock, is due to Lai and Qiu (2002) and Grossman and Lai (2004), which is the theoretical paper most closely related to ours. In their as in our model, IPRs are determined endogenously by the regional policymakers that maximize the welfare of their regions' respective representative household. They also assume national treatment, e.g. IPRs are granted in a nondiscriminatory manner to all goods sold in one jurisdiction, regardless of the origin of the producer. Equally similar, they consider the effects of different R&D capacities by introducing a second factor, human capital, that is used, along with unsophisticated labor, in R&D, but not in manufacturing. They differ in their specification of preferences. In their model, demand for differentiated products is quasilinear and therefore unrelated to income levels. This is problematic since empirically it is the per-capita income that has a first-order effect on the level of a country's Intellectual Property Rights. The authors seem aware of this when they suggest that the population variable in their model should be re-interpreted as the scale of the demand for innovative products. However, this is not innocuous, since the price for innovative products which determines the demand is itself a function of the IPRs granted.

In the empirical literature, Maskus and Penubarti (1995) and Ginarte and Park (1997) have investigated the determinants of IPRs across countries and across time. Their results are broadly consistent with our findings and are described in more detail in the empirical section.

The paper is organized as follows. Section 1.2 develops the theory. First the model is presented and then comparative statics exercises are performed by means of numerical simulation to analyze the effect of changes in relative size, productivity and human capital endowment on the IPRs. Section 3 empirically tests the model, section 4 concludes.

1.2 The Model

There are two countries, the North and the South, that differ in their population size (M_k), in their relative factor endowments (h_k), productivities (A_k), and level of Intellectual Property Rights (θ_k). "Complete" IPRs confer the entire monopoly rights to the producer and allow him to charge the full monopolistic mark-up. Without any IPRs competitors are free to enter the market at no cost, hence the producer has to set the price equal to marginal costs. Under "Partial" IPRs there are entry costs for imitators. The producer will set a price somewhere between the monopolistic price and the marginal cost price so as to just deter entry. "Partial" IPRs could mean a narrow patent protection that allows potential competitors to "invent around" the original innovation at some cost or compulsory licencing or other regulations that prohibit the inventor to charge the full monopolistic mark-up.

1.2.1 Preferences and Technology

Consumers in all regions share the same preferences over the differentiated and homogeneous goods, representable by a Stone-Geary utility function

$$U = (z - \kappa)^{\alpha} X^{1-\alpha} \tag{1.1}$$

where z is consumption of a homogeneous, undifferentiated good and X is an aggregate of differentiated goods. κ represents the subsistence consumption level of basic necessities, such as a minimum amount of calorie intake or shelter. These are undifferentiated goods. For consumption beyond mere subsistence, variety is appreciated as represented by X, which is an aggregate of a continuum of N differentiated goods j

$$X = \left[\int_0^N x_j^{\rho} dj \right]^{\frac{1}{\rho}} \tag{1.2}$$

with $\rho \in (0,1)$, so that the differentiated goods are substitutes, and $\alpha \in (0,1)$, so that both classes of goods are consumed. Note that these preferences are non-homothetic. The higher the subsistence level of consumption κ, the more luxury are the differentiated goods. As it will become clear when discussing the results from the simulations, this implies that income and size have different effects on IPR provision. Following demand functions are associated with these preferences

$$z = \begin{cases} \frac{\alpha I}{p_z} + (1-\alpha)\kappa & for \quad I \geq p_z \kappa \\ \frac{I}{p_z} & for \quad I < p_z \kappa \end{cases} \tag{1.3}$$

for the homogeneous good and

$$x_j = \begin{cases} p_j^{-\frac{1}{1-\rho}} \frac{(1-\alpha)(I - p_z \kappa)}{\mathbf{P}} & for \quad I \geq p_z \kappa \\ 0 & for \quad I < p_z \kappa \end{cases} \tag{1.4}$$

for the differentiated good. I is the total income spent on z and X, p_z is the price of z, p_j is the price of the differentiated good j and $\mathbf{P}$ is the CES-price aggregator for the good x

$$\mathbf{P} \equiv \left[\int_0^N p_j^{-\frac{\rho}{1-\rho}} dj \right]^{-\frac{1-\rho}{\rho}} \tag{1.5}$$

In both regions, households provide one unit either of unskilled (L) or of skilled labor (H)

$$M_k = L_k + H_k. \tag{1.6}$$

The factors are used in three sectors, the homogeneous good sector, the differentiated goods sector and the R&D sector which produces new varieties of the differentiated good. Production of both goods is linear in labor, while innovations are developed via a Cobb-Douglas function using skilled and unskilled labor

$$N = \sum_k A_k H_k^{1-\beta} L_{R\&D,k}^{\beta} \tag{1.7}$$

$$x_{j,k}^S = A_k L_{x_j,k} \tag{1.8}$$

$$z_k^S = A_k L_{z,k} \tag{1.9}$$

where $L_{R\&D}$, L_x and L_z are unskilled labor in, respectively, R&D, differentiated and homogeneous goods production. Note that since knowledge is a public good, its total stock equals the research contributions from all regions. The regions differ in their factor productivity A_k and in their factor endowments. Manufacturing and R&D are done in the North and the South, since, by assumption, technology, demand and factor endowments are such that the factor prices equalize when measured in efficiency units.

$$\overline{w} \equiv \frac{w_k}{A_k} \quad and \quad \overline{s} \equiv \frac{s_k}{A_k} \qquad \forall k \in \{N, S\}, \qquad \omega \equiv \frac{\overline{s}}{\overline{w}} \tag{1.10}$$

where w is the wage paid to generic labor and s is the wage paid to skilled labor. The relative wage of skilled to unskilled labor is defined as ω.

1.2.2 Market Structure

The homogeneous goods sector is competitively organized, equalizing prizes and wages

$$p_z = \overline{w} \tag{1.11}$$

In the differentiated goods sector the prices that producers can charge depend on the level of patent protection. A patent works as an entry barrier against potential competitors. The stronger the patent, the more costly is entry. The strength of the patent is meant to capture all differences in the various dimensions along which actual patent rights and their enforcements can differ.[1] The incumbent patent holder then sets a limit price that is just high enough to deter entry. At their maximum, patents are strong enough so that the patent holder can charge the monopoly price. At their minimum, they are so weak that they do not pose any barrier to competitors' entries. If that is the case, the patent holder prices at marginal cost. The price of good j in region k then equals

$$p_{j,k} = \overline{w}\theta_k \tag{1.12}$$

where $\theta \in \left[1, \frac{1}{\rho}\right]$ is the mark-up over marginal cost the producer can charge and as such a measure of the strength of IPRs.

The R&D sector is competitively organized and entry into the differentiated goods sector is free. This property first relates the factor shares to factor prices via the first-order conditions

$$L_{R\&D,k} = \frac{\beta}{1-\beta}\omega H_k \tag{1.13}$$

and second ensures that all profits are spent on R&D, so that expenditure on goods equals the factor income

$$I_k = w_k L_k + s_k H_k \tag{1.14}$$

To avoid trivial outcomes, we assume that the average household can afford the subsistence level of consumption. A sufficient condition for this to hold is that the share of income from unskilled labor alone suffices to pay for the necessities, so that $\kappa \leq A_k \frac{L_k}{L_k+H_k}$. To ensure that also the skilled households have enough income, we assume the existence of an intra-country social insurance, that costlessly redistributes income so that all households are at least at their subsistence level. This helps to aggregate the demand for each region

$$z_k^D = \alpha A_k(L_k + \omega H_k) + (1-\alpha)\,\kappa M_k \tag{1.15}$$

$$x_{j,k}^D = \frac{1-\alpha}{N}\left[A_k(L_k+\omega H_k)\theta_k^{-1} - \kappa M_k \theta_k^{-1}\right] \tag{1.16}$$

[1] That includes patent breadth (e.g. how different competing products have to be in order not to be considered a patent infringement), eligibility (in which fields patents can be granted), and various other requirements on patents, such as novelty and non-obviousness.

1.2.3 Market Equilibrium

Substituting the equations on factor-shares in R&D (1.13) into the production function for knowledge we can relate the total number of goods N to the relative wage and the aggregate endowment of Human Capital

$$N = \left(\omega \frac{\beta}{1-\beta}\right)^{\beta} \sum_k A_k H_k \tag{1.17}$$

World demand for goods must equal world supply

$$\sum_k \left(z_k^D + \int_0^N x_{j,k}^D dj\right) = \sum_k \left(z_k^S + \int_0^N x_{j,k}^S dj\right) \tag{1.18}$$

Substituting for the demand in (1.15) and (1.16), for the supply in (1.8) and (1.9) and rearranging, we can express the relative wage as

$$\omega = \frac{(1-\alpha)\sum_k [A_k L_k - \kappa M_k]\left(1 - \theta_k^{-1}\right)}{\sum_k A_k H_k \left(\alpha + (1-\alpha)\theta_k^{-1} + \frac{\beta}{1-\beta}\right)} \tag{1.19}$$

The relative wage for skilled labor is falling in its relative world supply, increasing in the share of skilled labor in R&D $(1-\beta)$, decreasing in the subsistence level of consumption, for which no innovation is needed, and increasing in the level of IPR protection θ.

1.3 Strategic IPR Provision

Policymakers will set the IPRs such as to maximize welfare of the representative, national individual, which is

$$u_k = (z_k/M_k - \kappa)^{\alpha} \left[\int_0^N x_{j,k}^{\rho} dj\right]^{\frac{1-\alpha}{\rho}} \tag{1.20}$$

Substituting in the equilibrium values for consumption and the number of differentiated goods to get the indirect utility function

$$U_k = \alpha^{\alpha} (1-\alpha)^{(1-\alpha)} N^{\frac{(1-\alpha)(1-\rho)}{\rho}} \theta_k^{\alpha-1} \left[A_k(l_k + \omega h_k) - \kappa\right] \tag{1.21}$$

where the small-letter values l_k and h_k represent the fraction of unskilled and skilled workers in the population: $l_k \equiv L_k/M_k$ and $h_k \equiv H_k/M_k$. As can be seen, the utility of each region's representative household not only depends on the IPR-regulation in that region, but also, by the variety of differentiated goods N and by the relative factor prices ω, on the IPR-regulation in all the other regions. To illustrate, consider the small-country case where the policy-maker takes the latter two variables, that are determined in global equilibrium, as given. The optimal strategy for him is to set $\theta = 1$, e.g. he will not grant any IPRs. In the general case, policymakers take this interdependence into account and set their regions' IPRs so as to maximize utility of their regions' households only, responding optimally to the IPRs present in the other regions

$$\theta_k' \left(\theta_{j \neq k}\right) = \arg \max_{\theta \in \left[1, \frac{1}{\rho}\right]} U_k \tag{1.22}$$

The resulting Nash-Equilibrium, with all regions mutually and optimally responding to each other in their IPR setting, then maps the different size, productivity and factor endowments of the regions into different IPR protection.

1.3.1 The one-factor case

A closed-form solution characterizing the Nash-equilibrium is obtainable for the case with only one factor ($\beta = 1$). Product innovations are now produced using unskilled labor only, so that, to solve the model, the equation relating the factor shares to factor prices in R&D (1.13) is replaced by a 'free-entry-condition'. Entry by producers of new varieties will occur as long as the profits made by the firm exceed the costs of inventing the new variety. Hence in equilibrium profits will equal the costs of R&D.

$$\sum_k \pi_{j,k} = \overline{w} \quad \forall j \in N \tag{1.23}$$

The profit made in each country is simply the quantity demanded times the mark-up

$$\pi_{j,k} = x_{j,k}^D \left(p_{j,k} - \overline{w}\right) \tag{1.24}$$

substituting in the demand - equations (1.15) and (1.16) - and the prices - equation (1.12) - into (1.23), taking into account that the expenditure on the goods now only consists of unskilled labor income $I_k = w_k L_k$ and rearranging we get

$$N = (1-\alpha)\sum_k \overline{A_k} L_k \left(1-\theta_k^{-1}\right) \tag{1.25}$$

where $\overline{A_k} \equiv (A_k - \kappa)$. Substituting the equilibrium consumption into the utility function

$$U_k = \alpha^\alpha (1-\alpha)^{(1-\alpha)} N^{\frac{(1-\alpha)(1-\rho)}{\rho}} \theta_k^{\alpha-1} \overline{A_k} L_k \tag{1.26}$$

and maximizing w.r.t. $\theta_k \in \left[1, \frac{1}{\rho}\right]$ results in the reaction function

$$\theta_k' = \max\left\{ \frac{\overline{A_k} L_k}{\rho\left[\overline{A_k} L_k + \sum_{j\neq k} \overline{A_j} L_j \left(1-\theta_j^{-1}\right)\right]}, 1 \right\} \tag{1.27}$$

The kink in the reaction function is resulting from the lower bound on θ. Countries that are small enough will find it optimal not to grant any IPRs. If the size of all countries is sufficiently similar so that all create some positive IPRs, the Nash-Equilibrium level of Intellectual Property Rights is

$$\theta_k^{NE\prime} = \frac{1+\rho(K-1)}{\rho} \frac{\overline{A_k} L_k}{\sum_k \overline{A_k} L_k} \qquad for \quad \overline{A_k} L_k \geq \frac{\rho}{1+\rho(K-1)} \sum_k \overline{A_k} L_k \quad \forall k \tag{1.28}$$

where K is the total number of countries and the condition on the relative size of each country ensures that each country is at an interior solution when maximizing equation (1.26).

In the general case with no size restrictions, the NE set of IPRs can be characterized in the following way. First, order the countries decreasing in $A_k L_k$, so that $\forall \widehat{k}, \widetilde{k} \in K \quad \widehat{k} > \widetilde{k} \rightarrow A_{\widehat{k}} L_{\widehat{k}} \leq A_{\widetilde{k}} L_{\widetilde{k}}$. Then, define as $j \in [1, K]$ the smallest country that is still big enough to optimally provide IPRs, so that

$$\overline{A_j} L_j \geq \frac{\rho}{1+\rho(j-1)} \sum_{k=1}^{j} \overline{A_k} L_k$$

$$\overline{A_{j+1}} L_{j+1} < \frac{\rho}{1+\rho(j-1)} \sum_{k=1}^{j} \overline{A_k} L_k$$

The Nash Equilibrium can then be characterized as

$$\theta_k^{NE\prime} = \begin{cases} \frac{1+\rho(j-1)}{\rho} \frac{\overline{A_k} L_k}{\sum_{k=1}^{j} \overline{A_k} L_k} & for \quad k \leq j \\ 1 & for \quad k > j \end{cases} \tag{1.29}$$

$\alpha = \frac{1}{3}$	$\kappa_{low} = 0$
$\beta = \frac{1}{3}$	$\kappa_{high} = 0.5$
$\rho = \frac{2}{3}$	

Table 1.1: Parameter values for the simulation

If the country is large enough to provide some IPRs, then the protection is linear in the size of the country, relative to the total size of all the countries that provide patent protection.

1.3.2 The two-factor case

The equilibrium IPRs in the general model discussed previously and characterized in (1.22) are solved numerically, for the case of two countries, representing the North and the South. This is done by searching over a discrete grid of $\theta's$, to find the pair $(\theta_N, \theta_S)^{NE}$ that maximizes the best-response functions. Comparative static exercises are then performed to see how the equilibrium IPRs change with the countries' differences in population size, productivity and relative factor endowment.

Table 1.1 informs about the parameters chosen for this purpose. The choice of $\alpha = 1/3$ corresponds to an expenditure share for the homogeneous goods - without the necessities κ - of one-third, and the choice of $\beta = 1/3$ indicates the same share of unskilled labor in R&D. Setting $\rho = 2/3$ leads to a monopolistic mark-up over marginal costs of 50%. First, we simulate the IPR setting without a subsistence consumption level ($\kappa = 0$). To analyze its impact we then set $\kappa = 0.5$, which indicates an expenditure on necessities as a share of the unskilled households income of $0.5/A$. By default, the North and the South are identical with a productivity normalized to one ($A = 1$), world population totals 10, equally divided between the two regions ($M_N = M_S = 5$), and skilled labor has a 10% share in population ($h = 0.1$). To analyze the effect of productivity differences, only A_N is changed so that it is a measure of the relative productivity. The share of world population living in the North is varied to understand the effect of population size on IPRs. To investigate the impact of human capital, the share of skilled labor in population is varied in the North, while the share in the South is held constant at the default level.

IPRs diverge in productivity, population and human capital differences.

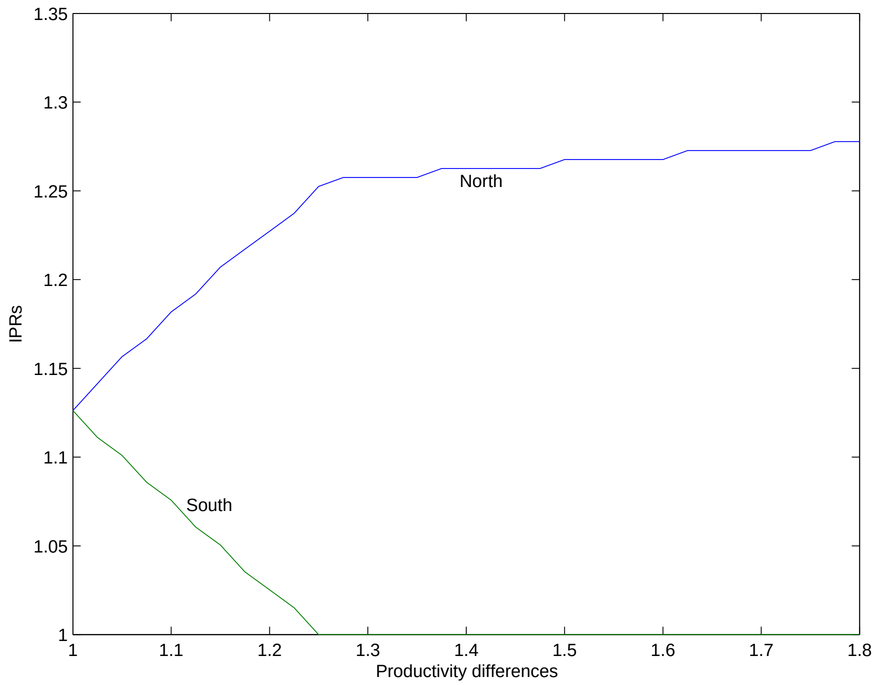

Figure 1.1: The effect of productivity differences on IPRs.
Productivity differences are expressed as the productivity in the North relative to the productivity in the South.

Figure 1.1 plots the equilibrium IPRs for the North and for the South as the relative productivity of the North increases. $A_N = 1$ marks a situation where the countries are exactly identical. They then both grant the same level of IPRs. However, as the relative productivity of the North increases, the North provides more and the South less IPRs.[2] For the range of productivity differences where both regions grant some IPRs, the simulations suggest a linear relationship, a result that is welcome when specifying the regression

[2]It can be observed that even when θ_S hits the lower bound of one and the South stops to provide any IPR protection at all, the Northern IPRs continue to increase in relative productivity, although at a smaller rate. The reason for this is that even if there are no IPRs in the South, research continues to be done there, as long as there is some skilled labor in the South and some positive IPR-levels - and hence incentives for research - abroad. The more important the South's contribution to supply R&D is - and it will become negligible only if the relative productivity of the North goes to infinity - the smaller the levels of IPRs the North will find optimal to provide.

equations in the next section.

Figure 1.2 demonstrates how the equilibrium level of IPRs react to changes in population, productivity and the share of human capital. Since North and South share the same reaction function, for dispositional clarity only the Northern IPRs are plotted. All three variables have a positive impact on IPR provision. Graphs 1 and 2 point to a linear relationship for relative productivity and population share. Moreover, varying population size (Graph 1), or human capital (Graph 2) seems only to shift the graph, with no effect on it's shape. By contrast, Graph 4 suggests that the marginal effect of skilled labor is decreasing. This is the result of two effects. A larger share of skilled labor initially raises the incentives to provide IPR protection, since having a higher share of the world supply of skilled labor means that more of the contributions to the R&D costs are spent domestically. However, with an increasing global endowment, the relative wage of skilled labor decreases. By this the income in the economy with the high endowment of skilled labor is decreasing and hence the demand for differentiated products and therefore the incentives to provide IPR protection fall. However, since the latter effect relates to the total world endowment of skilled labor, it should not show up in a cross-sectional analysis of the countries' levels of Intellectual Property Rights.

A higher subsistence level for consumption of the homogeneous good makes the impact of productivity on the IPRs more pronounced, but does not change the effect of population size. Graph 3 plots the effects of an increase in relative productivity for the default of no subsistence consumption ($\kappa = 0$) and for the case of $\kappa = 0.5$, which implies that about half of the Southern household spending goes to bare necessities. For this case the slope of the plot is considerably steeper. In contrast to this, varying κ does not change the effect that population size has on IPR provision, since the plots in Graph 2 are invariant to changes in κ. The intuition is that since richer individuals consume a smaller share of their income on necessities, the effect of an increase in per-capita income on the relative demand for differentiated goods is the greater the higher is the level of necessities consumption. The impact of shifts in the population on the IPRs is independent of the level of κ, since - with equal productivities - Northern and Southern households have the same income.

We are now in a position to test the model on the data. The linearity of the plots and the fact that variations in the other variables seem just to shift those plots suggest a linear and additive specification for the regression equation.

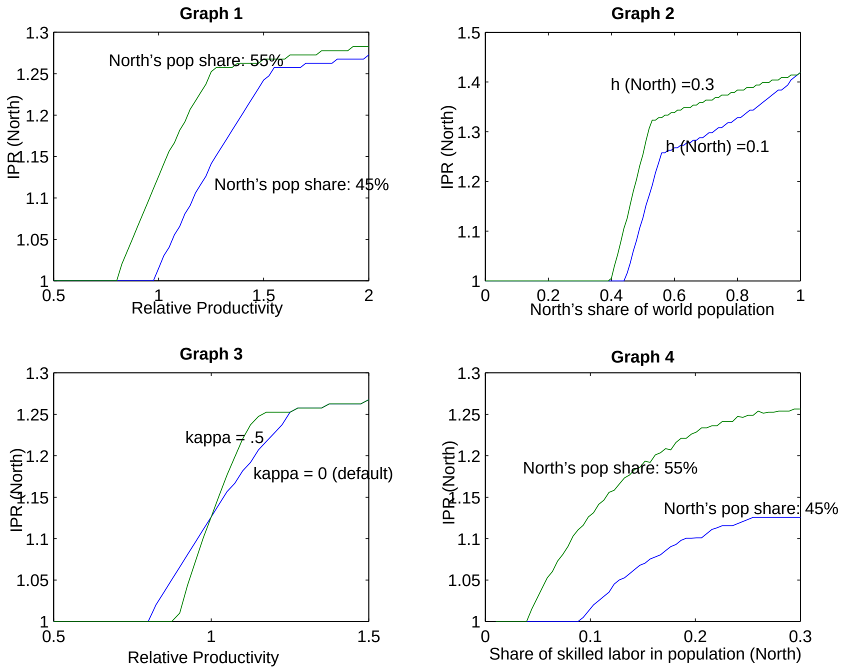

Figure 1.2: The effect of differences in productivity, human capital and population on the IPRs in the North.
Graph 1 shows the IPR effect of productivity difference for different population distributions, graph 3 shows the same effect for difference in the necesity of the basic good, graph 2 show the IPR effect of differences in relative population and graph 4 shows the IPR effect of difference in human capital.

1.4 Empirical Evidence

One of the major challenges facing the empirical literature is the measurement of Intellectual Property Rights. Two main approaches to assign a number to the level of IPRs can be distinguished. One is based on surveys. In these, the respondents, usually managers of multinational firms, are asked for their personal assessment on the level of effective IPR protection that is granted in different countries. The most popular survey is entertained by the World Economic Forum and published annually in its World Competitiveness Report. The other approach is based on assessments of the national IPR legislation. The relevant IPR laws and regulations are checked for whether and how strongly they incorporate certain features, such as length and scope of patents and membership in international IPR cooperation treaties. The main reservation against the use of surveys is that their responses are subjective and possibly biased by exogenous factors such as competitiveness of the local market or the growth perspectives of the particular firm. While indices based on the legal regulations do not face this distortion, they are often met with skepticism concerning their ability to represent differences in the *effective* IPRs. After all, the *statutory* IPRs that are codified in the legal texts still have to be interpreted by judges and be enforced by the bureaucracy. However, Ginarte and Park (1997), who created the most extensive legal index system on IPRs, provide evidence that the differences between effective and statutory rights on intellectual property are not too significant. They show, for instance, that most complaints filed by US firms are statutory, e.g. about the lack of laws and not about bad enforcement.

Rapp and Rozek (1990) are the first ones to develop such a cross-country index based on statutory IPR laws. Their approach has been extended by Ginarte and Park (1997) to include more countries, more time periods and a wider range of features of IPR laws. Hence, in this paper we use the index by Ginarte and Park (GP-index), containing observations in 5-year intervals from 1960 to 1995 and over a sample of 110 countries. The index is reproduced in the appendix.

The question of what determines Intellectual Property Rights has been investigated most notably by Maskus and Penubarti (1995), Ginarte and Park (1997) and Maskus (2000). [3] The first paper by Maskus and Penubarti uses the index by Rapp and Rozek (RR-index), while in his later work Maskus revisits the analysis using the GP-index. Both groups of authors control for the influence of per-capita income, R&D capacity and political institutions on Intellectual Property Rights. Both find that the last two factors matter. Concerning per-capita income Ginarte and Park could not discover a significant impact on IPR creation, unlike Maskus and Penubarti, who find a significant, albeit u-shaped, relationship between the two.

Richer countries have higher levels of Intellectual Property Rights. This is suggested by visual inspection of the scatter plot in Figure 1.3 and confirmed in a simple regression of the log of GDP per capita on the GP-index, as seen in column 1 of Table 1.2). It mirrors the findings of Ginarte and Park and of Maskus and Penubarti.

[3] Rapp and Rozek use their index only as an explanatory variable in a cross-county income regression.

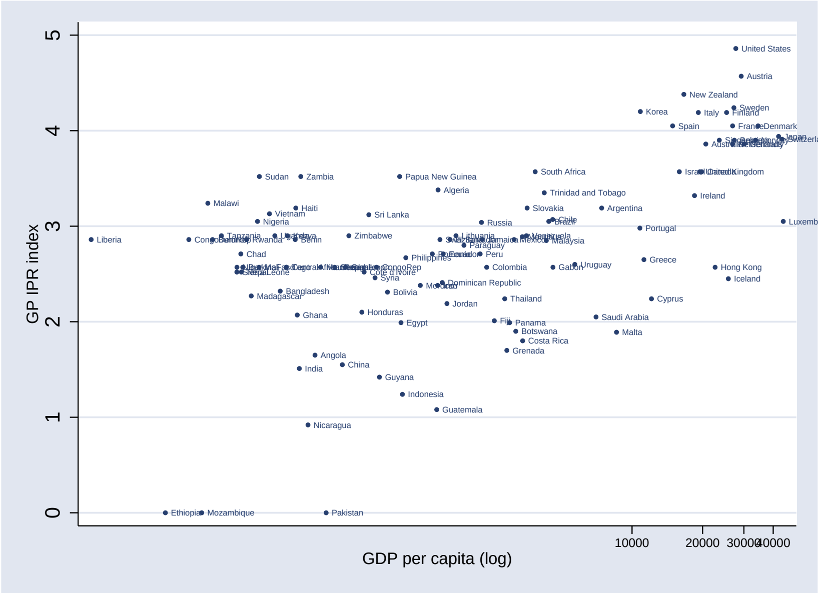

Figure 1.3: Strength of Intellectual Property Rights legislation across countries GP-Index vs Income for 1995.
The graphs plots the index devised by Ginarte and Park (1997) measuring the statutory strength of national IPR legislation versus the per-capita income, both for 1995.

Following this first, simple specification, both pair of authors then continue testing for the IPR determinants by controlling for R&D capacity and political institutions. Both groups of authors find that countries with higher R&D capacity create more IPRs. To measure this variable, Ginarte and Park use the share of R&D expenditure in GDP, while Maskus and Penubarti take the number of Scientists and Technicians employed in R&D. A third measure for the R&D capacity is the share of population that attended higher schooling. This is preferable for two reasons. First, R&D expenditure becomes insignificant when regressed together with schooling on IPR. Second, data on the share of R&D expenditure and on the scientists and technicians in R&D are only available for some countries and the most recent time periods.

To assess the impact of trade on the provision of Intellectual Property Rights, Ginarte and Park as well as Maskus and Penubarti use the Sachs-Warner Openness-to-Trade dummy.[4] Both find that so-defined more open

[4]See Sachs and Warner (1995).

IPR-Index	(1)	(2)	(3)	(4)	(5) [IV]	(6)
Intercept	0.155	0.595	0.665	-0.448	-0.871	-0.087
	(0.567)	(0.653)	(0.636)	(1.23)	(1.11)	(0.551)
GDP per capita (log)	0.162**	0.246**	0.169**	0.295**	0.344**†	0.170**
	(0.030)	(0.037)	(0.033)	(0.115)	(0.130)	(0.031)
Population (log)	0.057*	-0.010	0.036	0.038	0.033	0.066**
	(0.034)	(0.038)	(0.034)	(0.048)	(0.035)	(0.031)
Human Capital	0.033**	0.016**	0.031**	0.029**	0.024**	0.030**
(share of population with higher schooling)	(0.003)	(0.004)	(0.003)	(0.011)	(0.007)	(0.003)
French Legal Origin		-0.364**	-0.397**	-0.370**	-0.345**	-0.350**
		(0.137)	(0.127)	(0.166)	(0.136)	(0.125)
EU member		0.227**	0.433**	0.700**	0.377**	0.461**
		(0.089)	(0.081)	(0.258)	(0.101)	(0.079)
African country		0.669**	0.779**	0.740**	0.881**	0.646**
		(0.157)	(0.160)	(0.201)	(0.239)	(0.143)
Openness		0.090**				
		(0.041)				
Remoteness			-0.061**			
(distance in 1000km from either Rotterdam, Tokyo or New York)			(0.029)			
Rule of Law				-0.162		
				(0.189)		
Observations	686	526	643	91	643	686
R^2	0.24	0.42	0.46	0.46	0.44	0.43

Table 1.2: Regression Results

† In (5) GDP per capita is instrumented by French and British legal origin, remoteness and the African country dummy. A Random Effects specification was chosen on the basis of a Hausman test. Standard errors are reported in parenthesis, ** denotes significance at the 5% level, * at 10%

economies have higher levels of IPRs, a result our analysis confirms, as seen in column 2 in the regression results reported in table 1.2. The index essentially measures the presence or strength of certain policies deemed important for free trade, such as the existence of state monopolies for exports or the extent of tariff and non-tariff barriers. One could argue against using this policy index as an explanatory variable for another policy index, namely the IPR-index.[5] For

[5] In particular, the same policy can be understood as a weak protection for Intellectual Property Rights *and* as a barrier to trade. This is the case for so-called 'working requirements' that are present in some national IPR legislation. These regulations require that, to be eligible for patent protection, the good has to be produced domestically, either entirely or in parts. Materially, this is the same as a local-content requirement, which is a non-tariff barrier to trade.

this reason, we also use a geographic variable in order to capture the influence of trade. This is done in the third regression, where a measure of 'remoteness' is included among the explanatory variables. This variable, taken from Gallup and Sachs (1999), is the population-weighted, average distance to the next 'core economic zone'. Core economic zones are defined as the cities New York, Rotterdam and Tokyo. Trade costs can plausibly assumed to be high for those economies that are far away from any of these cities. As the regression confirms, economies with high trade costs and hence lower trade volumes have indeed lower levels of IPRs, about one-half of an index point for each 10,000 kilometers.

A fundamental institutional determinant of IPRs is the legal system. Countries have often adopted their legal institutions from others. For instance, after reaching independence new countries have usually modeled their legal system after the one prevailing in their former colonizing country. It is reasonable to assume that at least the statutory level of IPRs is affected by the legal history. To control for this, we use a set of data compiled by La Porta, Lopez de Silanes, Shleifer and Vishny (1998). They classify 152 countries as having either English, French, German, Scandinavian or Socialist legal origins. Testing down, we find significance only for French legal origin. Countries whose legal system is in this tradition - those include not only the former French colonies in Africa and Asia, but also most Latin American countries, since the Spanish legal system is of French origin as well - will have about one–third of an index point less Intellectual Property Rights than countries with other legal traditions.

An index aimed to directly capture the difference between formal, legal provisions and their enforcements is constructed by Kaufman, Kraay and Mastruzzi (2004). Their 'rule of law' measure is based on a collection of surveys asking the respondents to assess the quality of law enforcement. While this variable is indeed positively correlated with the IPR index, it becomes insignificant once the other explanatory variables are included, as can be seen in the fourth regression. However, the variable can still be informative about the measurement error. Only the *effective* protection is important and that is what theory aims to explain. Since the index is based on an evaluation of the formal IPR laws, its measurement error is larger, the lower the quality of law enforcement. To check for this, we run a fixed-effects regression.[6] The 'rule of law' index is then regressed on the absolute values of the resulting

[6]In all other cases we use the random-effects specification, as the Hausman test does not point to systematic country-specific differences.

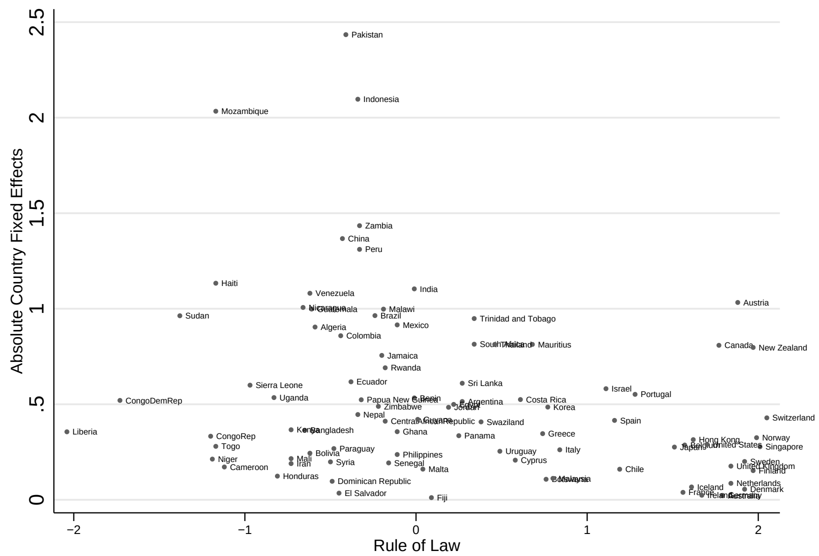

Figure 1.4: Fixed Country effect versus Rule of Law.

country-specific error terms (the 'fixed effects' in the panel regression). There is indeed a negative correlation, confirming that the prediction error is higher in countries with a weak 'rule of law', supporting the idea that the IPR index is more 'noisy' when the quality of law enforcement is bad. Figure 1.4 plots the absolute values of the country fixed-effects on the rule of law index.

The European Union is the most far-reaching union between countries, with an increasing number of economic policies set jointly. Certainly in the area of Intellectual Property Rights most decisions are coordinated, with patent granting and administration centralized at the European Patent Agency (EPA) and patent legislation increasingly made by the European Commission and the European Parliament. One does not need to assume the EU member states to act as one - and indeed the Index shows some, albeit minor, variation among the EU countries even for the later time periods. But certainly one should expect that the IPRs among the member countries reflect the higher degree of cooperation. This is confirmed in the data. EU member states have about an one-half index point higher IPRs than non-members.

To control for possible endogeneity, we instrument income per capita by the geographic and 'deep institutions' variables at hand (those are distance, legal origin and the Africa dummy), resulting in an R^2 of 50% in the first stage regression. In the second stage regression, neither size nor relative magnitudes of the coefficients are changed, although population is now insignificant, as documented in column 5 in Table 1.2.

We conclude that the empirical results supporting the theory are stable to measurement errors and endogeneity problems. The results of a more parsimonious specification are presented in column 6. GDP per capita and Population size have both a significant and positive impact on the level of IPRs, confirming the main predictions of the model. Moreover, the coefficient on income is significantly greater than the coefficient on population. A 1% increase in GDP per capita raises the IPR-index by 0.17 points, while a 1% higher population is associated with only a 0.07 index point increase, although both variations raise the market size - total GDP - by the same amount. These unequal magnitudes are captured by introducing the subsistence consumption level of unsophisticated goods in the model. As the simulations confirmed, a higher subsistence level κ raises the effect of productivity (A) on IPRs, but not that of population size (M). Human capital - the share of skilled labor - also has the expected positive sign and is significant.

1.5 Conclusion

This paper provides a link between the theoretical and the empirical parts of the literature that aim to understand the determinants of Intellectual Property Rights across countries. The central elements of the model are the global public-goods nature of innovation and the non-discrimination of foreign and domestic innovators by national IPR legislation and enforcement. Both elements turn the creation of Intellectual Property Rights by the countries into a public-goods contribution game, where larger players give more. The contribution of the paper here is that it disentangles the effects of 'being large' along different dimensions: productivity, population size and human capital endowment. For the first two dimensions, the presence of a size effect is shown analytically. For the general case with all three variables, this is done numerically, simulating the responses of IPRs to variations along these dimensions. The results from this exercise guide the specification for the empirical testing, which confirms the directions and relative magnitudes of all effects.

The empirical analysis points to another factor that seems important in determining the strength of a country´s Intellectual Property Rights - the degree to which a country is open to trade. The effect of this factor, which can not so readily be explained in the present model, will be analyzed in the next chapter.

Chapter 2

Trade Openness and Intellectual Property Rights

2.1 Introduction

Within the last two decades trade agreements have been broadened to include issues related to Intellectual Property Rights (IPRs). The most prominent case is the agreement on Trade Related Intellectual Property Rights (TRIPS) that in 1994 became part of the World Trade Organization's founding treaty; though many other recent multi- and bilateral agreements also include provisions on IPRs, such as the North American Free Trade Agreement. These treaties prescribe minimum standards of IPRs, such as the scope and duration of patents or copyright and trademark protection, which in particular require less developed countries to strengthen their national IPR laws. This continues to generate a substantial amount of policy debate, not only on the right level of Intellectual Property protection in these countries, but also on the appropriateness of including IPR issues in trade agreements.

Previous research motivated by these debates has established a link between trade and IPRs, showing that countries with higher levels of trade also have stronger IPR protection. However, this stylized fact has not yet been explained. This is particularly unfortunate since an understanding of the relationship between trade and Intellectual Property Rights could be informative on how to properly bundle these two issues in policy negotiations such as the WTO. This is the gap the paper aims to close.

We analyze the effect of trade openness on a country's choice of IPRs. Trade-induced specialization changes the way countries internalize the benefits and costs of providing IPRs. This offers an explanation for why countries that trade more also create more IPRs.

IPRs are necessary because innovations are a public good. Once a new good or process is invented, it can be imitated at a fraction of the original research costs. In a competitive market where imitations are allowed, few innovations would happen as the inventor would not be able to recoup his research and development costs. Intellectual Property Rights restrict the entry of imitators by conferring market power to the inventor in form of a patent that gives its holder control over production and sale. This causes a static loss of efficiency due to the monopolistic distortion, but leads to a dynamic efficiency gain since the incentives to innovate are restored. A policymaker balances these two effects when optimally choosing the level of patent protection.

The optimal balance between stimulating research and maintaining competition changes if the world is divided into different countries. As long as that division does not affect the set of technology and knowledge that the individuals can access, then they continue to benefit from the same flow of innovations, regardless of the country they reside in. Whereas innovations are global and depend on a weighted average of all countries' IPRs, the monopolistic price mark-ups will be determined - so the standard argument goes - only by the domestic IPRs. If countries do not cooperate and hence do not internalize the beneficial effect that their own IPRs exert on the welfare of the foreign consumer through a higher rate of innovations, then they provide an inefficiently low amount of IPRs. Effectively, countries are playing a private-provision-to-a-public-good's game with the predictable outcome that large players contribute more. This is confirmed by empirical studies that show that countries that are rich and/or good at research provide more IPRs.[1]

The intuition is straightforward; suppose a country stops granting patents on pharmaceuticals, allowing free entry for generic drugs. Their prices would reflect only the marginal production costs, supposedly a fraction of the previous monopoly prices. The incentives for the firms to innovate would fall, but if the country is small, then the loss of this market has only little impact on the total profit the pharmaceutical firm receives from selling the drug in all markets. However, if all countries act similarly and try to freeride on the IPRs granted abroad, then the global innovation activity will be low reducing everyone's

[1] See Maskus and Penubarti (1995), Ginarte and Park (1997) and Maskus (2000).

Trade Openness	(exports + imports)/GDP	0.160** (0.053)
Size	GDP per capita (log)	0.153** (0.035)
	Human Capital (share of population with higher schooling)	0.030** (0.003)
Controls	Intercept	1.01 (0.265)
	EU member	0.425** (0.081)
	Observations R^2	593 0.36

Table 2.1: Regression results
The explained variable is the IPR Index by Ginarte and Park (1997) for a panel of 110 countries from 1960 to 1995. A fixed effects specification was chosen on the basis of a Hausman test. Standard errors are reported in parenthesis, ** denotes significance at the 5% level, * at 10%.

welfare. This provides a strong motivation for countries to jointly coordinate on a higher and more efficient level of IP protection. While this is precisely the aim of the TRIPS and other IPR agreements, note that the argument itself does not provide a rationale to include IPRs into trade agreements, since what causes the interdependence of countries's IPRs is not trade, but the public goods nature of innovations.

The empirical literature has used differences in legal regulations to measure the strength of Intellectual Property Rights across countries and time. The most extensive index has been devised by Ginarte and Park (1997), extending the measure constructed by Rapp and Rozeck (1990). They collect information on issues such as the scope and duration of patents, legal enforcement provisions and compulsory licensing and other patent revocation procedures from a sample of 110 countries in five-year intervals from 1960 to 1995. The index has been widely used in the analysis of country differences in IPRs. Two facts have emerged: countries that are large and countries that are open to trade have higher IPRs. Table 2.1 shows our own regressions results.

The relationship between a country's openness to trade and its Intellectual Property Rights is significant and relevant. A switch from autarky to free trade implies an estimated increase in IPR protection that corresponds to extending patent protection to pharmaceuticals and transgenetic plant varieties, two of the most controversially debated issues in the TRIPS agreement.

To analyze the link between trade and IPRs we introduce innovation in a two-country Ricardian, Dornbusch-Fischer-Samuelson trade model. The Ricardian productivity differences across sectors and countries lead to specialization in production that is only restricted by the degree of trade openness, which we model by the standard division of sectors into tradeables and non-tradeables. With a specialized production, one country's IPRs also affect - via its exports - the prices in the other country. This reduces the country's private costs of higher IPRs and gives it incentives to enforce Intellectual Property Rights. In effect, while the public goods nature of innovations leads countries to only partly internalize the benefits of IPRs, the specialization in production causes them to only partly internalize the costs of IPRs as well.

To illustrate the argument, consider a simple and hypothetical example. Suppose that Switzerland grants strong and extensive patents whereas Italy does not provide any protection for inventions. Then any firm that wants either to produce, to use or to sell the invented product or process in Switzerland needs to buy a license - a permission - from the inventor that holds the patent. In Italy, no firm would need to buy such a license, since imitation is technologically possible and freely permitted. The standard argument concludes that Italian consumers would enjoy the low marginal-cost prices and free-ride on the Swiss, that, through the monopoly prices they pay, finance all innovations.

Now assume that Intellectual Property Rights are not the only cost factor that might be different across countries. Imagine that the chemical industry is more productive in Switzerland than in Italy because there are more engineers in Switzerland, or because of agglomeration effects or because of other institutional differences unrelated to IPRs. Moreover suppose that this comparative advantage is so strong, that even after including the license payments the Swiss production costs are below the Italian. If this is the case, and if countries are open to trade, then all chemicals sold in Italy would be imports from the northern neighbor and the rewards to the inventors of these products would depend solely on the Swiss - and not the Italian - IPRs. The Swiss government values the increased effectiveness of their IPRs on innovations in chemicals, but does not internalize the static efficiency losses that their strong patent laws inflict on the Italian consumers. Likewise, the Italian government realizes that their low IPRs do not affect the prices of their imports, but do hinder innovation in the - say - fashion industry, where domestic firms are so productive that only their cost conditions determine apparel prices in Switzerland, shifting the balance towards high IP protection also in Italy.

The importance of Intellectual Property Rights for innovation has long been recognized; Nordhaus (1969) is the classic paper. While most of the research on IPRs has had a microeconomic, industrial organizations perspective, Judd (1985) extended the insight that the public goods nature of innovation is crucial to a dynamic setting. This subsequently led to the inclusion of IPRs in the then-emerging growth models by Romer (1990), Grossman and Helpman (1991) and Aghion and Howitt (1992). This has further been extended to an international context by Helpman (1993), Dinopoulos and Segerstrom (1999) and Thoenig and Verdier (2003) who study the effects of IPRs on production, trade, innovation and relative income; Saint-Paul (2005) and Gancia (2006) share with us the analysis of IPRs in a world of Ricardian productivity differences.

Most of this literature is more concerned with the consequences than with the causes of IPR differences across countries; notable exceptions that are closely related to our paper are the articles by Lai and Qui (2003) and Grossman and Lai (2005); they are the seminal contributions that describe the free-riding effect in a country's provision of IPRs. However, they can not account for the effect of trade on IPRs. Our contribution is to extend their analysis to a world in which countries have different productivities in different sectors and benefit from trade.

The paper is organized as follows. Section 2.2 presents the model, describes the technology and solves for the equilibrium. Section 2.3 first presents comparative statics of the IP differences on welfare before, in a second step, the policy game is solved and the equilibrium IPR levels explained. Section 2.4 concludes.

2.2 The Model

The two countries, Home and Foreign, indexed by $k \in \{H, F\}$, are each endowed with an equal amount of labor which we normalize to one. The different sectors are located on a unit-interval $i \in [0, 1]$. Only the output of some sectors is tradeable; output is produced by combining sector-specific intermediate inputs. A greater variety of intermediates raises the productivity of the final goods production. Innovation increases the variety: each intermediate input is one invention. Intellectual Property Rights are patents on these inventions that grant exclusive rights to control the production and the sales of the input.

Each country chooses the level of its IPRs that maximizes the welfare of their own citizens.

2.2.1 Preferences and Technology

Consumers' preferences are symmetric and representable by a Cobb-Douglas Utility function

$$U_k = \int_0^1 \ln C_{i,k} di \tag{2.1}$$

This implies that expenditure is the same across sectors and equal to the total consumption expenditure. Since labor is the only factor, expenditure on consumption equals labor earnings w_k, so that the demand in each sector equals

$$C_{i,k} = \frac{w_k}{P_{i,k}} \tag{2.2}$$

Output in each sector is produced by combining a variety n_i of different and specialized production inputs $x_{i,j}$. These intermediate goods are specific to a sector and enter production with an elasticity of substitution σ that is the same for all sectors. To guarantee a solution for the market equilibrium, we assume the elasticity to be greater than two, $\sigma > 2$.

$$X_i = \left(\int^{n_i} x_{i,j}^{\frac{\sigma-1}{\sigma}} dj \right)^{\frac{\sigma}{\sigma-1}} \tag{2.3}$$

Intermediate inputs are produced with labor, with a unit-requirement $a_{i,k}$ that differs across countries and sectors. We conventionally order the sectors such that the relative productivity advantage for Home, $A_i \equiv \frac{a_{i,f}}{a_{i,h}}$, is decreasing in the sector index, $\frac{\partial A_i}{\partial i} \leq 0$.

Inventing a new intermediate requires a prototype that is build using one unit of the sector output and that is eventually destroyed in the research process. Hence, the production and the invention of an input are subject to the same sector- and country-specific productivities.

Innovations are global and public goods. Imitation of an existing intermediate is costless, so that its production can take place in any firm and country.

Intermediates are local and specific goods in the sense that they must be produced within the same plant where they enter into the assembly of the final good. This reflects a complex production process, where many different parts and processes need to be combined to produce a single, tradeable good. Technical or contractual difficulties prohibit outsourcing and trading of the specialized parts.

The final goods are tradeable only in some sectors $i \in T$. Let t denote the size of this set of tradeables. By exclusion, $1 - t$ is the size of the set of non-tradeables N. Note that the tradeability of a sector's final good and the relative productivity of it's intermediates are unrelated. This ensures that changes in the tradeability, which we will interpret as changes in trade costs or regulations, do not bias the pattern of comparative advantage and do not affect by themselves the terms-of-trade.

This concludes the description of technology. Labor produces the intermediates that are then combined into the final good, which in turn is used for consumption and innovation. Note that the division of the production process into an intermediate and a final step allows us to decompose the aggregate labor productivity in the production of the final consumption good into two parts, a level of technology n_i that depends on the amount of innovative activities and a Ricardian productivity $a_{i,k}$ that is exogenously given. This reflects the assumption of a unique, global set of technologies that is accessible from anywhere, whereas the geographic location only matters in how efficient the technologies are used. The differences in the application of technology are captured by the country- and sector-specific Ricardian parameter and could be due to sectoral factor intensities and national factor endowments, or due to sectoral contract-imperfections and national legal institutions. Besides technology, IPRs are the other important determinant for prices and production location.

2.2.2 Intellectual Property Rights and the Pattern of Production

Innovation raises the productivity, but requires resources, while imitation is costless and lowers prices, but also reduces the incentives for innovation. The role of Intellectual Property Rights is to regulate this trade-off. In our model they achieve this by affecting the cost of producing imitated goods, which in turn determines the production costs and the price of the final good and the rewards to the inventor.

Since the intermediates are specific goods, their production and the subsequent assembly of the final good must take place at the same plant and within the same firm. However, the intermediates are invented by separate firms, such as specialized research labs. Each inventor receives a patent on the intermediate he created; this confers to him the right to control the production and the sale of the input. The producer thus needs to buy a license from the inventor in order to be able to produce and use the input. The price of the license is bounded by the alternative option of the producer, which is the production of an input that is sufficiently modified so that it would be considered a different product that does not infringe the patent on the original. Differentiating the input in such a way as to circumvent the patent is costly. More extensive and more costly modifications are necessary for stronger patent regulations.

This is the margin through which the IPR policy of a country operates. If the patent protection is very weak, than small changes in the product, e.g. the color, would be sufficient in order to fend off patent infringement charges; in this case the price of a license would be very low and in the limit of no patent protection equal to zero. Strong patent laws would make their circumvention prohibitively expensive; in this case, the inventor would set the unrestricted, profit-maximizing license fee.[2]

We assume that the imitation costs - the cost of modifying the product as to disguise its intellectual origins, are proportional to the units produced. This implies that license payments are also per-unit and that the IPRs lead to limit pricing, taking the form of a simple mark-up on the labor costs of producing the intermediate. This mark-up is bounded between one - if patent protection is nil - and the full monopolistic markup $\mu \equiv \frac{\sigma}{\sigma-1}$ if the patent protection is very strong. The IPR policy of a country is thus summarized by λ, this restriction on the mark-up is binding for $\lambda \in [1, \mu]$ and determines the producers' total cost of an input - the labor cost plus the license cost - as

$$p_{i,j,k} = a_{i,k} w_k \lambda_k \tag{2.4}$$

The prices are the same for intermediates of the same sector and country; to simplify notation we henceforth drop the variety-index j.

The market for the final good is competitive and producers are maximizing

[2]IPRs could also be understood as limiting the quality of imitations. The breath of the patent would then determine the maximum quality level that an imitation can have without infringing the patent. This alternative interpretation is isomorphic to ours.

profits given their production function in equation (2.3). The price of the final good thus equals the production cost of the most efficient producer, which is a local firm in the non-tradeable, but a global one in the tradeable sectors.

$$P_{i,k} = \begin{cases} n_i^{1/(1-\sigma)} p_{i,k} & if \quad i \in N \\ n_i^{1/(1-\sigma)} \min_k p_{i,k} & if \quad i \in T \end{cases} \tag{2.5}$$

Note that relative productivities, wages and IPR protection are country characteristics that, via the prices for the production inputs in equation (2.4), translate into differences in the production costs for the final goods, as seen in equation (2.5). In contrast, the level of technology n_i is the same for both countries and thus does not affect *relative* costs. Costs are equal in the sector z which is given by

$$A(z) = \omega \frac{\lambda_h}{\lambda_f} \tag{2.6}$$

where we define ω as the relative wage $\omega \equiv \frac{w_h}{w_f}$. As shown in Figure 2.1, this cost condition separates the sectors into those where Home has a comparatives advantage, $i \in [0, z)$, and those that are cheaper produced abroad, $i \in (z, 1]$.

Production in the tradeable sectors will locate accordingly and take place in either Home or Foreign, while non-tradeables will be produced in both places. Note that tradeability only restricts the production for the final goods used in consumption. The prototypes used in innovation will always be produced in the lowest cost location, given their public goods nature. The pattern of production is thus summarized as follows

$$X_{i,h} = \begin{cases} C_{i,h} + C_{i,f} + n_i & for \ i \in T^H \\ C_{i,h} + n_i & for \ i \in N^H \\ C_{i,h} & for \ i \in N^F \end{cases} \tag{2.7}$$

$$X_{i,f} = \begin{cases} C_{i,h} + C_{i,f} + n_i & for \ i \in T^F \\ C_{i,f} + n_i & for \ i \in N^F \\ C_{i,f} & for \ i \in N^H \end{cases} \tag{2.8}$$

where we denote by T^H the set of tradeables in which Home as a comparative advantage, $T^H \equiv \{i : i \in [0, z] \cap T\}$. By extension, T^F are the tradeables where the comparative advantage is in Foreign, $T^F \equiv \{i : i \in [z, 1] \cap T\}$; whereas N^H and N^F are the complementary sets for the non-tradeables, formally defined as $N^H \equiv \{i : i \in [0, z] \cap N\}$ and $N^F \equiv \{i : i \in [z, 1] \cap N\}$.

This concludes the description of Intellectual Property Rights. They determine the costs at which an invention can be imitated. Imitation is the producer's outside option; it does not happen in equilibrium, but its possibility

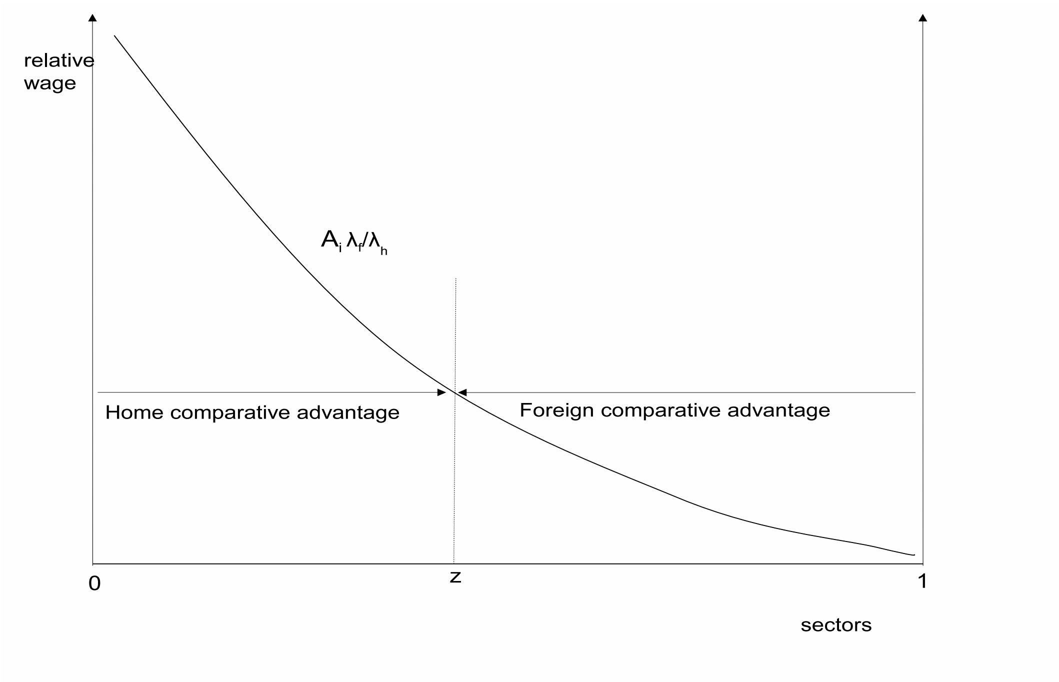

Figure 2.1: Pattern of Comparative Advantage
At the marginal sector z, relative labor productivity times relative IPR protection just equals relative wages.

fixes the price of the license that the producer obtains from the inventor. The license payments are a mark-up on the labor production costs. Differences in both the labor costs, the relative wage, and the license payments, the relative IPRs, determines the relative production costs of the final goods and thereby comparative advantage and the location of production. This effect is summarized by the relative supply equation (2.6), which is the standard Ricardian, Dornbusch-Fischer-Samuelson condition for comparative advantage augmented by relative IPR differences. Having shown how the IPRs shape the market structure, we can now turn to the description of the market equilibrium.

2.2.3 Innovation and Income

To solve for the equilibrium of this economy, we yet need to determine the relative wages ω and the level of technology in each sector n_i. For this purpose, we use two more equilibrium conditions, one reflecting that entry into research is free and the other that trade needs to be balanced.

If there are no restrictions that prevent a researcher from inventing a new input, than the value of an invention will equal its cost. The value of an innovation is simply the value of the patents in both countries, which in turn generate license payments. The cost is given by the minimum price of the prototype needed in the innovation process

$$\sum_k \pi_{i,k} = \min_k P_{i,k} \tag{2.9}$$

The value of a patent is derived from the license payments it causes

$$\pi_{i,k} = (p_{i,k} - w_k a_{i,k})\, x_{i,k} \tag{2.10}$$

where the per-unit license fee is the difference between the price and the production cost of an input and the amount of licenses sold is given by the producer's input demand as derived from the production function (2.7)

$$x_{i,k} = \left(\frac{p_{i,k}}{P_{i,k}}\right)^{-\sigma} X_{i,k} \tag{2.11}$$

Using this equation on the input demand (2.11) together with the equations for the pattern of production (2.7), consumption demand (2.2) and prices (2.5), we can sum the patent values in (2.10) and express the value of an innovation as a function of the IPR regulations

$$\sum_k \pi_{i,k} = \begin{cases} \left(1-\lambda_h^{-1}\right)\left(\frac{w_h+w_f}{n_i} + P_{i,h}\right) & for \quad i \in T^H \\ \left(1-\lambda_f^{-1}\right)\left(\frac{w_h+w_f}{n_i} + P_{i,f}\right) & for \quad i \in T^F \\ \left(1-\lambda_h^{-1}\right)\left(\frac{w_h}{n_i} + P_{i,h}\right) + \left(1-\lambda_f^{-1}\right)\frac{w_f}{n_i} & for \quad i \in N^H \\ \left(1-\lambda_h^{-1}\right)\frac{w_h}{n_i} + \left(1-\lambda_f^{-1}\right)\left(\frac{w_f}{n_i} + P_{i,f}\right) & for \quad i \in N^F \end{cases} \tag{2.12}$$

This reveals that the value of an innovation in a tradeables sector depends only on the IPRs of a single country, whereas an innovation in a non-tradeable sector is a function of the patent protection granted by both countries. The value of an innovation in equation (2.12) and the research arbitrage condition in (2.9) determine the equilibrium innovation as a function of IPRs and relative wages

$$n_i = \begin{cases} \left(\frac{\left(1-\lambda_h^{-1}\right)(\omega+1)}{a_{i,h}\omega}\right)^{\frac{\sigma-1}{\sigma-2}} & for \quad i \in T^H \\ \left(\frac{\left(1-\lambda_f^{-1}\right)(\omega+1)}{a_{i,f}}\right)^{\frac{\sigma-1}{\sigma-2}} & for \quad i \in T^F \\ \left(\frac{(1-\lambda_h^{-1})\omega+(1-\lambda_f^{-1})}{\min(\omega a_{i,h},a_{i,f})}\right)^{\frac{\sigma-1}{\sigma-2}} & for \quad i \in N \end{cases} \tag{2.13}$$

To solve for relative wages we use the requirement that trade between Home and Foreign must be balanced in equilibrium.

Trade takes place in goods and licenses. In the tradeable sectors the final good used for consumption is shipped. In the non-tradeable sectors the inventors sell a license to producers in the other country. Trade in goods and trade in services - the licenses - are both determined by the pattern of production in equation (2.7). A country imports in sectors where it has a comparative disadvantage. If trade in goods is possible, the consumption goods are imported. If trade in goods is not possible, licenses for domestic production are imported from the foreign innovators. Trade in goods and services is balanced for

$$t\underbrace{(zw_f-(1-z)w_h)}_{\text{trade in goods}} = (1-t)\underbrace{\left(z\left(1-\lambda_f^{-1}\right)w_f-(1-z)\left(1-\lambda_h^{-1}\right)w_h\right)}_{\text{trade in licenses}} \tag{2.14}$$

Rearranging the terms allows us to express relative wages as a function of the industry allocation and IPR levels

$$\omega = \frac{z}{1-z}\frac{1-\lambda_f^{-1}(1-t)}{1-\lambda_h^{-1}(1-t)} \tag{2.15}$$

This shows that an increase in domestic IPRs lowers relative wages by increasing the license transfers of domestic producers to foreign innovators. This effect is limited to the non-tradeable sectors, since for the tradeables production and innovation always takes place in the same country, so that production licenses are not traded between countries. Note that when all sectors are traded (t=1), the demand condition is the same as in the standard Dornbusch-Fischer-Samuelson model and does not depend on differences in the Intellectual Property Rights.

This concludes the description of the model. It integrates innovation into an otherwise standard Ricardian, Dornbusch-Fischer-Samuelson model, maintaining the structure of the equilibrium: relative supply (2.6) and relative demand

(2.15) determine the relative wage ω and the sector allocation z, which in turn pin down the remaining endogenous variables - the level of technology, which in difference to DFS is endogenous by equation (2.13), and the relative prices in (2.4) and (2.5) - all of which enter consumption and ultimately welfare via (2.2) and (2.1).

Intellectual Property Rights confer market power to the inventors. This raises innovation, but also the production costs. In the traded sectors where all production is located in the country with the relative cost advantage, higher IPRs in the producer country raise prices in both countries; while in the non-traded sectors only domestic IPRs matter. However, any change in the relative IPR protection can affect relative income and the sector location. The next section presents some comparative statics to build intuition on these effects. In a second step we endogenize the Intellectual Property Rights; each country now chooses the IPRs that maximize the welfare of their *own* citizens, disregarding effects on foreigners. Finally we analyze the ensuing policy game and discuss the effects of trade on its equilibrium.

2.3 Intellectual Property Rights Provision

Intellectual Property Rights have two opposing effects on welfare; they raise the level of technology by stimulating innovation, but they achieve this through higher prices for the production inputs. A policymaker that maximizes the welfare of its citizens will choose the IPRs that optimally balance these two effects. We analyze how this balance is affected by the presence of two countries that share a common set of technologies, but that do not coordinate their IP protection. For this purpose we first look at how a given set of IPRs affect equilibrium consumption and welfare. In a second step we analyze how the policymakers choose their IPRs and compare the outcome of this policy game to the IPRs that a unified government, that sets the same IPRs for both countries, would choose. At last we show how the choice of IPRs depends on the possibility to trade goods.

2.3.1 The effect of IPR differences on welfare

The effects of IPRs on the equilibrium consumption levels can be summarized using the equations on demand (2.2) and prices (2.4) and (2.5) to express the logarithms of consumption in each sector as

$$\ln C_{i,h} = \frac{1}{\sigma - 1} \ln n_i - \begin{cases} \ln a_{i,h} - \ln \lambda_h & for \quad i \in T^H \cup N \\ \ln a_{i,f} - \ln \lambda_f + \ln \omega & for \quad i \in T^F \end{cases} \tag{2.16}$$

revealing the positive technology and the negative price effect on the consumption levels. Remember that local prices depend on local cost conditions in those tradeable sectors where Home as a comparative advantage (T^H) *and* in all non-tradeable sectors (N), whereas the foreign conditions only affect prices in the tradeables with a foreign comparative advantage (T^F). Note that this double sectioning of the sectors by their tradeability and by their relative productivity is also important for the level of technology as determined by equation (2.13). The same sector partitioning applies for the IPR effects on welfare, which we derive by valuing the consumption in (2.16) via equation (2.1)

$$U_h = \underbrace{\frac{1}{\sigma - 1} \int_0^1 \ln n_i di}_{\text{innovation}} \underbrace{- \int_{i \in T^H \cup N} \ln(a_{i,h}\lambda_h) di - \int_{i \in T^F} \ln \frac{a_{i,f}\lambda_f}{\omega} di}_{\text{prices}} \tag{2.17}$$

However, in a multi-country world IPRs not only effect welfare via technology and prices, but also by influencing relative wages and the location of production, which are the missing elements to completely describe welfare through (2.17) and (2.13). Wages and sector location are determined jointly by the relative supply and demand, equations (2.6) and (2.15), which we here reproduce

$$\begin{array}{ll} \textbf{A} \ \text{relative supply} & \textbf{B} \ \text{relative demand} \\ A(z) = \omega \frac{\lambda_h}{\lambda_f} & \omega = \frac{z}{1-z} \frac{1-\lambda_f^{-1}(1-t)}{1-\lambda_h^{-1}(1-t)} \end{array} \tag{2.18}$$

Relative IPR protection has an unambiguously negative effect on the relative wage. Higher IPRs increase the license payments from producers to inventors and hence raise the relative production costs. For given relative wages, fewer of the tradeable sectors will produce at Home, as demonstrated by a downward shift in the relative supply curve **A** in Figure 2.2. In the non-tradeable sectors, the increased license payments raise the direct transfer from domestic producers to foreign innovators leading to a downward shift in the relative demand curve **B**. We express this effect of IPRs using the elasticity of relative wages with respect to domestic IPR protection, $\epsilon_{\omega|\lambda_h}$. Since the effect of IPRs on relative costs and on transfers to abroad both point in the same direction, the elasticity is negative; for convenience we define ϵ in absolute terms as $\epsilon_{\omega|\lambda_h} \equiv \left| \frac{\partial \omega}{\partial \lambda_h} \frac{\lambda_h}{\omega} \right|$.

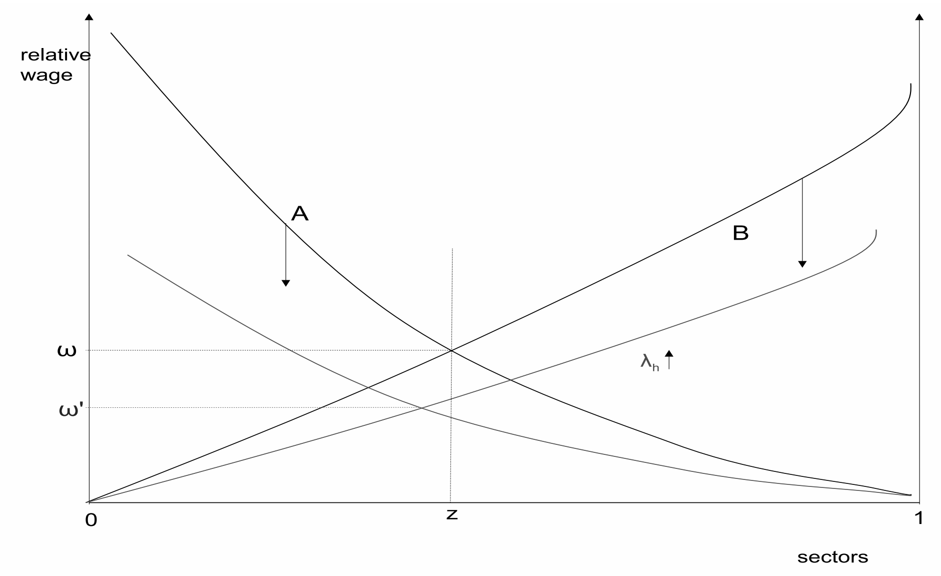

Figure 2.2: Effect of domestic IPRs on relative wages
An increase in domestic IPRs causes a downward shift of both, the relative supply (**A**) and the relative demand (**B**) curve. This leads to a fall in relative wages, while the effect on sector location is ambiguous.

To what extent an increase in domestic IPRs leads to a decrease in the relative wages depends of course on the strength of comparative advantage and on the trade openness. Next we discuss the two limiting cases.

Separation Assume that countries have separate governments, but are otherwise identical in their production structure; in particular, assume that there are no differences in productivities between countries and across sectors, represented by a flat A_i curve as shown in left graph of Figure 2.3, $A(i) = A \, \forall i$. There are no benefits from trade and even if trade is possible, it is indeterminate and would in any case cease if arbitrarily small costs of trading were to be introduced. In this case any change in the relative IP protection would lead to an equally proportional decrease in the relative wages; the elasticity of relative income with respect to IPRs is unitary, $\epsilon^{separation}_{\omega|\lambda_h} = 1$.[3]

[3]Note that existing research on the endogenous provision of IPRs has so far taken place in this case, with trade at best being indeterminate, as in the seminal paper by Grossman and Lai (2005).

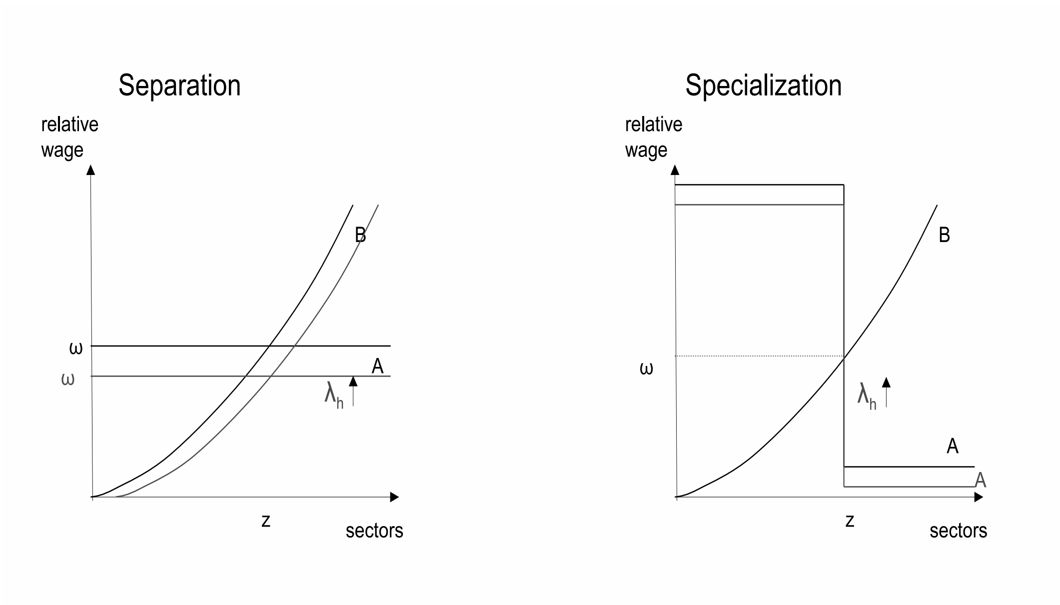

Figure 2.3: Wage effects of IPRs under different trade regimes
The left graph shows the wage effect of IPRs if countries are separated, but not specialized. The right graph shows the IPR-wage effect under full specialization.

Specialization Now assume that countries have separate governments, but also specialized economies. If the pattern of productivity differences is very strong, then the location of a tradeable sector will only very weakly depend on local cost conditions such as wages and IP regulation. In the extreme, the locational assignment will based on technology only; some sectors *can* only be produced at Home while others *must* be based abroad. For such a technological separation into Home and Foreign industries the function of relative productivity differences $A(i)$ becomes a step function as shown in the right-hand graph of Figure 2.3. In this case trade does not offset the increase in one local cost component (e.g. the license costs) by a decrease in another (e.g. labor costs). This will lead to a stronger effect of a single country's IPRs, since industries can not escape a stricter patent regulation by relocating abroad. With the sector location given by the pattern of labor-productivities $a_{i,k}$, IPR differences only affect wages through license payments, and this only in the non-tradeable sectors. With full trade integration of all sectors (t=1) *and* with an extreme pattern of comparative advantage, differences in Intellectual Property Rights have no effect on relative wages. This *specialization* case combines a strong technological motive - the extreme productivity distribution - with an unconstrained possibility for trade - all sectors are tradeable.

These two cases bound the effects of comparative advantage and thus limit the range of possible values for the elasticity of relative wages with respect to relative patent protection between zero and minus one. In the next section we analyze the choice of IPR levels by the governments of each country, first under the general case and then under the two limit distributions of the relative productivities.

2.3.2 IPR Policies

In this section we endogenise the level of Intellectual Property Rights. IPRs are no longer an exogenous parameter, but instead are determined by each country. The policymakers are aware of the welfare effects described in the previous section and choose the level of IPRs that maximizes the welfare of their countries' citizens without taking into account the well-being of foreigners. Domestic welfare does, however, depend on domestic *and* on foreign IP levels as a glance on the indirect utility in equation (2.17) confirms. This gives rise to an interdependency where the optimal domestic IPR level depends on foreign IP protection and the optimal foreign IPs depend on the domestic patent protection.

An explicit closed-form solution for these mutual best-response functions is hard to obtain given the very general pattern of relative productivities in A_i. For this reason we impose an additional condition on the productivities; for each sector in which Home has a productivity advantage, there exists another sector in which Foreign has an equally large cost advantage, using the ordering of the sectors, this can be formalized as $a_{i,h} = a_{1-i,f} \quad \forall i$. Note that by this assumption countries are completely symmetric, not only in their labor endowments, for which we assumed equality throughout the model, but also for their productivities. This symmetry is a necessary condition for the existence of a symmetric policy equilibrium. Given that indirect utility in equation (2.17) is convex and continuous in the IPR policies λ_h and λ_f, symmetry in the countries' parameters is also a sufficient condition for a policy equilibrium in which both countries set equal IPRs.

Integration Before solving for the policy game, we analyze which IPRs would be chosen by a unified government - or by two governments that co-operate in the provision of Intellectual Property Rights; this *Integration* case serves as a reference for the outcome of the strategic policy game. Let $\overline{\lambda}$ be the IPR level chosen that is same for both countries, $\lambda_h = \lambda_f = \overline{\lambda}$; by the symmetric productivities, this implies that wages are the same in both countries, $\omega = 1$. Maximizing welfare in equation (2.17) under these conditions, we can express the welfare-effects of IPRs as

$$\frac{\partial U}{\partial \lambda}\Big|_{integration} = \underbrace{\frac{1}{\sigma - 2}\frac{1}{\overline{\lambda}(\overline{\lambda} - 1)}}_{\text{innovation effect}} - \underbrace{\frac{1}{\overline{\lambda}}}_{\text{price effect}} \tag{2.19}$$

As expected, both effects have the correct signs - stronger patent protection raises innovation which is beneficial for welfare, but also raises production costs. The level of IPRs that optimally balances these two effects is given by

$$\overline{\lambda} = 1 + \frac{1}{\sigma - 2} \tag{2.20}$$

Note that this exceeds the mark-up that an unconstraint monopolist would choose, $\mu < \overline{\lambda}$ since $\frac{\sigma}{\sigma-1} < \frac{\sigma-1}{\sigma-2}$. This implies that the optimal IPR protection is always full protection and is a result that is generic to the use of the Dixit-Stiglitz CES aggregator.

We now investigate the policy game between non-cooperating governments; we solve for the symmetric Nash-equilibrium by first maximizing domestic welfare in (2.17) with respect to domestic IPRs λ_h and then imposing the symmetry condition of policies $\lambda_h = \lambda_f \equiv \hat{\lambda}$, wages $\omega = 1$ and allocations $z = 1/2$ on the first-order condition; finally we can decompose the influence of the equilibrium IPRs on the welfare effects of innovation and prices

$$\frac{\partial U_k}{\partial \lambda_k}\Big|_{sym} = \underbrace{\frac{1}{\sigma - 2}\frac{1}{2\hat{\lambda}(\hat{\lambda} - 1)}}_{\text{innovation effect}} - \underbrace{\frac{1 - \frac{t}{2}(1 - \epsilon)}{\hat{\lambda}}}_{\text{price effect}} \tag{2.21}$$

Note the innovation-effect of IPRs is only half as strong if countries are separated; innovations are a global public good and depend on the IPRs set in both country, although the national policymakers do not internalize this effect. Note moreover that the innovation effect of IPRs is independent of trade openness t. In equilibrium, domestic IPRs have the same effect on innovation in tradeables than on innovation in the non-tradeable sector. This can be confirmed by evaluating innovation in (2.13) under the symmetric allocation and is the consequence of two opposing forces. Domestic IPRs only have an effect on innovation in half of the tradeable sectors, namely the ones where Home has a comparative advantage; in those, however, the innovation effect is leveraged by the demand from both countries. In turn, domestic IPs affect innovation in all the non-tradeable sectors, but only through domestic demand. By the symmetry of sector allocation, these two effects cancel out so trade does not affect the innovation-benefits of IPRs.

Trade openness does affect the costs of IPRs, which are given by the price effect. As the share of domestically produced goods in consumption falls with trade, and the import share increases, domestic consumers bear a smaller share of the costs of higher domestic IPRs. Note that this effect depends on how wages, and hence the relative price of the imports, react to IP differences, as summarized by ϵ.

Solving for the equilibrium level of IPRs in equation (2.21) we obtain the symmetric Nash-equilibrium level of IPRs as

$$\hat{\lambda} = 1 + \frac{1}{\sigma - 2}\frac{1}{2 - t(1-\epsilon)} \tag{2.22}$$

As expected, the equilibrium IP provision increases with trade, as long as wages are not fully elastic to IPRs ($\epsilon < 1$). Note that the strategic IPR regulation becomes binding only if it restricts the monopolistic mark-up $\hat{\lambda} < \mu$. This is the case if the elasticity of substitution is sufficiently high, $\sigma > \frac{3-2t(1-\epsilon)}{1-t(1-\epsilon)}$. The limit cases of *Separation* and *Specialization* mark the range of the possible IPR levels.

Separation When trade is impossible *or* if countries have no incentives to trade because their productivity differences are uniform across sectors, then IPRs are lowest and given by

$$\hat{\lambda}_{separation} = 1 + \frac{1}{2}\frac{1}{\sigma - 2} \tag{2.23}$$

Specialization If at the other extreme trade is possible in all sectors and driven by strong productivity differences, then the equilibrium level of IPRs is highest and equal to

$$\hat{\lambda}_{specialization} = 1 + \frac{1}{\sigma - 2} \tag{2.24}$$

If a country behaves strategically, it will not internalize the beneficial innovation-effect of its Intellectual Property Rights on the welfare of the individuals in the other country. This gives the country's policymaker an incentive to weaken the protection on innovations. If both countries behave strategically, then an underprovision of IPRs with respect to the choice of an integrated government will occur. However, strategically behaving governments might also view the negative price effect of IPRs differently than one integrated government would. Namely if production in the countries is specialized, then the each countries' IPRs also exert a negative welfare effect on the other countries' citizens, which the policymakers also not internalize. In the limit of a complete specialization driven by free trade and a strong pattern of comparative advantage, countries would choose exactly the same, optimal level of IPRs that also an integrated government would choose.

2.4 Conclusion

Open countries tend to provide more Intellectual Property Rights because part of the associated monopolistic distortion costs are borne by foreign consumers, raising incentives for strong domestic IP protection. The mechanism builds on the fact that a patent grants an exclusive right not only to sell in a given market, but also to produce there. The stronger the differences in the production costs across countries and sectors, the more important control on a country's cost structure becomes for determining world-wide prices.

We conclude by discussing two possible extensions. First, the paper has assumed that innovations take place in intermediate inputs which can not be traded, but need to be locally assembled into the then tradeable, final goods. While this assumption seems to be a reasonable description for the production of many complex products where different locally produced and patentable parts and processes are combined, it is apparently challenged by the outsourcing observed in other industries. The difference is relevant. If the intermediate inputs themselves are traded, then they must comply with the patent protection in the country where the good is produced *and* with the IPRs in the country where the good is sold. This gives rise to an asymmetry in the 'spillover' effects of national IPRs; only the country with the higher IPR protection can shift some of the associated costs to its neighbor, which causes even identical countries to choose different levels of IPR protection, thereby introducing an additional and endogenous source of IPR variation.

Second, trade openness has been taken as given, whereas in reality the openness of a country is, to a large extent, shaped by its trade policies. While so far the paper has established a causal effect of trade openness on IPR policy, an extension will explore the reverse causality of IPR protection on trade policy. The argument builds on the strategic trade policy literature, which has shown how a restriction of trade can lead to a welfare-improving change in a country's terms-of-trade. On the downside, those restrictions cause domestic firms to enter sectors with a comparative disadvantage. However, innovations in these sectors continue to take place in the low-cost country. If patterns of comparative advantage in production and in innovation are aligned, then the domestic firms that entered these sectors need to buy their licenses from foreign innovators. These transfers are higher for stronger domestic IP protection, reducing the terms-of-trade gains from trade restrictions and shifting the balance towards freer trade. If strong IPRs favor a free-trade policy and free trade favors strong IPR protection, then the integration of IPRs into trade agreements can be seen as a way to coordinate on the policy equilibrium that efficiently combines free-trade and IPR-protection.

Chapter 3

Linkage between trade and regulation policy agreements

3.1 Introduction

Countries share specialization benefits through trade, but they also share public-good benefits, such as a global climate or a global technology frontier, through product regulation. However, any agreements lowering tariffs or strengthening environmental or patent protection provide incentives for deviation. Each country gains individually by imposing optimal tariffs that improve its terms-of-trade and weaker regulation that lowers its cost of production. Among sovereign countries, these deviations can only be discouraged through the threat of canceling the agreement. The self-enforceability can be improved by linking the issues in one single agreement, so that a deviation in either or in both issues is retaliated by a break-down of the cooperation in both issues.

The most prominent example of a linkage in the enforcement of a trade and a non-trade, product-regulation issue is the TRIPS agreements on Intellectual Property Rights in the WTO. By linking these issues, the compliance with the prescribed standards on patent and copyrights can be enforced via retaliatory tariffs and, vice versa, compliance in the agreed trade measures can be enforced via retaliatory measures in IPRs. The ongoing attempts to form an international agreement on the reduction of climate-changing gas emissions renews the interest in the issue of linking trade and environmental regulations.[1] In a

[1] *It is not in the WTO that a deal on climate change can be struck, but rather in an en-*

recent contribution focused on the legal aspects of the relationship between the WTO rules and climate-change agreements, Charnovitz et al. (2009) explicitly propose using the WTO's dispute settlement mechanism to enforce compliance in any global agreement on climate change.
The case for linking the agreements on two issues is more obvious if the issues are related, for example in the case of trade in CO_2-intensive products. Advantages from linkage are less obvious when the two issues are independent, which is the case when trade policies do not have any effect on the amount of the public good provided and when the regulation has no effect on trade. In this case, linkage of issues among symmetric countries either does not bring any benefits or it improves the cooperation in one issue at the expense of a worse cooperative outcome in the other issue, as shown in a general, game-theoretic context by Spagnolo (2001) and in the context of a trade model by Limão (2005). This reflects the concern among some policymakers that the incorporation of non-trade issues in the WTO might well improve cooperation in these issues, but only at the expense of reduced efforts to liberalize trade.

I analyze the welfare benefits and policy effects when issues are independent, but countries are asymmetric. I argue that this is the relevant case to consider since most of the situations where trade and non-trade issues are linked or discussed to be linked involve (blocs of) countries that are asymmetric with respect to (economic) size: the developing and the developed countries. The Intellectual Property Rights were incorporated in the WTO at the demands of the US and other developed countries and against objections from countries such as India, South Africa and other 'Southern' countries. The debate on a common climate-policy agreement in the Copenhagen summit also exhibited a similar division between the so called developed and developing countries.

I show that a difference between the size of the negotiating countries is in itself an important source of gains when linking the agreements across issues. The relative size of a country has a different effect on its ability to cooperate in a trade or in a regulation agreement. Larger countries internalize better the effect of their regulation on the global, public good, while smaller countries have stronger free-ride incentives. Hence, any common level of regulation will

vironmental forum, such as the United Nations Framework Convention on Climate Change. Such an agreement must then send the WTO an appropriate signal on how its rules may best be put to the service of sustainable development; in other words, a signal on how this particular toolbox of rules should be employed in the fight against climate change.
Director-General Pascal Lamy in a speech at the Informal Trade Ministers' Dialogue on Climate Change in Bali on 8-9 December 2007, in: WTO News, Speeches, DG Pascal Lamy, www.wto.org

be easier enforceable in the larger country. In trade, this size effect is not present or even goes the other way if the small country has little chance of improving its terms-of-trade by imposing optimal tariffs. Linking the issues then allows the large country to reduce its tariff and the small country to increase its regulation beyond what would have been possible under a separation of the issues.

In the literature on trade negotiations, product regulation issues were mostly treated as purely domestic externalities, such as in Bagwell and Staiger (2001) and Ederington (2001a). The effects of linking two issues that both exhibit cross-border externalities were first investigated outside the trade literature, namely in the literature on industrial organization - see Bernheim and Whinston (1990), and in the political science literature - see Sebenius (1983). In a general set-up, Spagnolo (2001) analyzes the effect of linking two symmetric issues among two symmetric players; he shows that when issues are independent, gains from linkage only come from shifting enforcement power from one issue, where cooperation is worsened, to the other issue, where cooperation is improved. Ederington (2001b) and Limão (2005) confirm this result in a genuine trade model with the environment as the global, public good.
Linkage among issues and asymmetric countries is analyzed in Cesar and de Zeeuw (1996) and in Limão (2005). However, and in difference to my model, in both of these papers the asymmetry is directly imposed on the countries' preferences and technology. Cesar and de Zeeuw show that if each country only cares about one issue, the issues need to be linked to achieve any cooperation. In Limão's model, only the larger country cares about the public good and can set tariffs; this set-up allows him to analyze whether regional agreements between a large and a small country, that link the trade with the regulation issue, are stepping stones or stumbling blocs for a multilateral trade liberalization between various pairs of large and small countries.

The rest of the paper is structured as follows. Section 3.2 presents the model, Section 3.3 the structure of self-enforcing policy agreements. Section 3.4 presents the results and Section 3.5 concludes.

3.2 The Model

The world is populated by a continuum of individuals (individual persons, or individual regions) i, whose mass is normalized to one: $i \in [0, 1]$. A fraction

$s \in [0,1]$ lives in the home country (h), $1-s$ are living in the foreign country (f).

3.2.1 Preferences and Technology

All individuals have the same, time-separable preferences and the same discount factor, $\delta \in [0,1]$.

$$U = \sum_{t=0}^{\infty} \delta^t u_t; \tag{3.1}$$

Contemporaneous utility is derived from the consumption of a public good (A), an aggregate of differentiated goods (X), and a homogeneous good (y); when possible and convenient, we drop the time subscript to simplify notation.

$$u = A + X + y \tag{3.2}$$

The common, public good A is produced from intermediate goods with an elasticity of substitution greater than one ($\mu > 1$).

$$A = \frac{\mu}{\mu - 1} \int_i a_i^{\frac{\mu-1}{\mu}} di \tag{3.3}$$

Similarly, the private good X is produced from differentiated, intermediate goods with an elasticity of substitution greater than one ($\sigma > 1$).

$$X = \frac{\sigma}{\sigma - 1} \int_i x_i^{\frac{\sigma-1}{\sigma}} di \tag{3.4}$$

Each individual can produce the homogeneous good, one variety of the differentiated, private good and one variety of the differentiated, public good. Hence, s of the differentiated goods are produced at Home and $1-s$ are produced at Foreign. It takes one unit of labor to produce one unit of any good; and each individual is endowed with l units of labor. Labor is the only factor of production.

3.2.2 Regulation and Trade Policies

Regulation and Trade policies are national policies that are determined by each country on their own. The public good production is regulated. For each

l units of labor, $r \in [0, l]$ units must be used in the production of the public good, and only the remaining $l - r$ units of labor can be used for the production of the private goods. The aggregate, global public good is then determined by the national regulations, weighted with their relative population share.

$$A = \frac{\mu}{\mu - 1}\left[s r_h^{\frac{\mu-1}{\mu}} + (1-s) r_f^{\frac{\mu-1}{\mu}} \right] \tag{3.5}$$

Examples for regulations that share this public good character are regulations on the use of abatement techniques or restrictions on pollution in case that the public good is the global environment, or regulation on patent protection or copyrights in case that the public good is the global rate of innovation. The elasticity μ then determines the extent to which the 'contributions' of each country are substitutable.

The private goods are produced in competitive markets within each country. Trade of the differentiated goods is subject to an export tariff, t. The revenues from the tariff are distributed lump-sum to the individuals of the country. Trade in the homogeneous good is unrestricted and serves to balance the accounts.

Trade policy determines the good prices. The price of the homogeneous good is normalized to one. The prices of the differentiated goods are then given by

$$\begin{array}{rclrcl} p_{h,h} & = & 1; & p_{h,f} & = & t_f \\ p_{f,h} & = & t_h; & p_{f,f} & = & 1 \end{array} \tag{3.6}$$

where the first subindex denotes the place of consumption and the second one denotes the place where the differentiated good is produced.

3.2.3 Market Equilibrium

Individuals maximize their utility in equation (3.2), subject to the constraint of balancing their budget each period. The budget constraint for a home-country individual is then given by

$$y_h + s p_{h,h} x_{h,h} + (1-s) p_{h,f} x_{h,f} = l - r_h + q_h \tag{3.7}$$

where the left-hand side of the equation sums the expenditure on the private goods and the right-hand side the labor income, $(l - r_h)$, and the tariff revenue share, q_h; a similar condition holds for the foreign individual´s budget constraint. Given that the income is sufficient to purchase at least some of the homogeneous good the demand of the differentiated goods is given by

$$x_{i,j} = p_{i,j}^{-\sigma} \tag{3.8}$$

The tariff revenue that is distributed to each individual is given by the total demand for the exported goods times the difference between the foreign and the domestic prices. Evaluating at the prices and the demand in equations (3.6) and (3.8), the per-person tariff revenue is determined as

$$\begin{array}{rcl} q_h & = & (1-s)(1-t_h^{-1})t_h^{1-\sigma} \\ q_f & = & s(1-t_f^{-1})t_f^{1-\sigma} \end{array} \tag{3.9}$$

Collecting the terms in equations (3.5) to (3.9), we can express the utility as a function that is linearly separable in the trade and regulation policies.

$$\begin{array}{rcccccc} u_h & = & l & + & R_h(r_h, r_f) & + & T_h(t_h, t_f) \\ u_f & = & l & + & R_f(r_h, r_f) & + & T_f(t_h, t_f) \end{array} \tag{3.10}$$

The value of the regulation policies for each country is the difference between the common, public good and the national, private contributions.

$$\begin{array}{rcccc} R_h & = & A & - & r_h \\ R_f & = & A & - & r_f \end{array} \tag{3.11}$$

Similarly, the value of the trade policies can be written as the sum of the tariff revenue plus the consumer surplus on all varieties of the differentiated good.

$$\begin{array}{rcccc} T_h & = & s+(1-s)(1-t_h^{-1})t_h^{1-\sigma} & + & \left(s+(1-s)t_f^{1-\sigma}\right)/(\sigma-1) \\ T_f & = & 1-s+s(1-t_f^{-1})t_f^{1-\sigma} & + & \left(1-s+st_h^{1-\sigma}\right)/(\sigma-1) \end{array} \tag{3.12}$$

3.3 Policy Agreements

3.3.1 Non-cooperative Policy Equilibrium

If countries do not cooperate when determining their regulation and trade policies, they will choose the policies that maximize the welfare of their citizens, irrespective of the externality that their choice imposes on the individuals in the other country.

The domestically optimal, best-response level of regulation that maximizes equation (3.11) is given by

$$\begin{aligned} r_h^d &= s^\mu \\ r_f^d &= (1-s)^\mu \end{aligned} \qquad (3.13)$$

Note that since the domestically optimal regulation does not depend on the regulation in the other country, it is also the Nash-equilibrium level of regulation. This regulation depends on the relative size of the country. The larger the country, the more it internalizes the effect of its national regulation on the level of the global, public good. More precisely, the effect of the relative size on the domestically optimal level of regulation depends on the elasticity of substitution between the contributions of each individual, μ. The more substitutable the contributions are - the higher μ - the better can a country free-ride on the contributions of the other country and hence the stronger is the relative size effect; the elasticity of the optimal regulation with respect to the relative size is just equal to the substitution elasticity of the contributions: $\frac{\partial r_h^d}{\partial s}\frac{s}{r_h^d} = \mu$.

Positive export tariffs serve to transfer foreign consumers' surplus to domestic consumers. Maximizing (3.12), governments set the tariffs in the absence of coordination equal to

$$\begin{aligned} t_h^n &= \sigma/(\sigma-1) \\ t_f^n &= \sigma/(\sigma-1) \end{aligned} \qquad (3.14)$$

As with the level of regulation, the domestically optimal tariff rate does not depend on the other country's tariff rate, so that this best-response tariff rate is also the Nash-equilibrium tariff rate. Note also that this optimal tariff rate is the usual mark-up over the marginal costs, where the size of the mark-up depends on the elasticity of substitution.

3.3.2 Self-enforcing policy agreements

Policy agreements do not by themselves remove the policy externalities. In order to be stable, any agreement needs to be self-enforcing. One way to achieve a self-enforceability is by using trigger strategies which condition the current actions on past behavior.

Here, we consider simple trigger strategies in which a single deviation triggers a permanent reversion to the Nash-equilibrium. Under these strategies, a

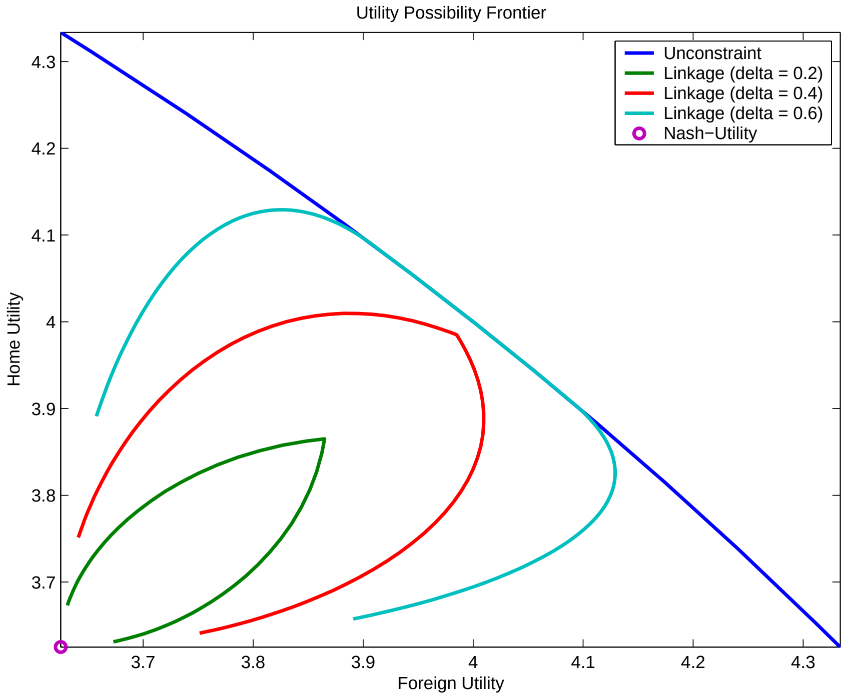

Figure 3.1: Utility possibility frontiers when countries are symmetric. Elasticity of substitution in public good: $\mu = 2$. Elasticity of substitution in the private good: $\sigma = 2$. Countries are symmetric with $s = 0.5$.

policy cooperation is stable if the utility from a continuous cooperation is larger or equal to the utility from a one-period deviation followed by a permanent Nash policy equilibrium. Since future outcomes are discounted at the rate δ as given in equation (3.1), the value of cooperation is the discounted sum of a permanent cooperation in all periods, $u_c/(1-\delta)$, whereas the value from a deviation is given by $u_d + \delta/(1-\delta)u_n$, so that cooperation can be sustained via the trigger mechanism as long the per-period value from cooperation is not smaller than the average between the Nash and the deviation utilities, weighted by the discount factor.

$$u_c \geq \delta u_n + (1-\delta)u_d \tag{3.15}$$

Equation (3.15) illustrates that the extent to which cooperation is possible depends fundamentally on the discount factor δ. If individuals are completely patient ($\delta = 1$), any combination of policies that are at least as good as the non-cooperative Nash-policies can be implemented as a cooperative equilibrium.

Contrary, if individuals are completely impatient, no meaningful cooperation is possible since the only 'cooperative' policies that comply with condition 3.15 under $\delta = 0$ are the Nash-policies themselves. Figure 3.1 shows the effect of the discount factor on the possibilities for cooperation.

3.4 Linkage of Policy Agreements

The enforcement of the policy agreement can be linked across issues or the issues can be treated separately. If the enforcement is linked across issues, then a deviation in any of the two issues will be punished by a reversion to the Nash-equilibrium policies in *both* issues. Hence and by condition (3.15), the discount-factor weighted sum of any deviation plus the utility under no-cooperation must not exceed the utility of cooperation. Since this incentive compatibility constraint must hold for any deviation, it suffices to test whether is holds for the strongest deviation, that is, a simultaneous deviation in both issues that maximizes the contemporaneous utility of the country that is breaking the agreement. From the policy-utility functions in (3.10) and from the best-response tariff and regulation rates in equations (3.13) and (3.14), it follows that the enforcement constraints under linkage, for Home and Foreign, can be expressed as follows

$$\begin{array}{rcl} R_h(r_h^c, r_f^c) + T_h(t_h^c, t_f^c) & \geq & \delta\left[R_h(r_h^d, r_f^d) + T_h(t_h^d, t_f^d)\right] \\ & + & (1-\delta)\left[R_h(r_h^d, r_f^c) + T_h(t_h^d, t_f^c)\right] \\ R_f(r_h^c, r_f^c) + T_f(t_h^c, t_f^c) & \geq & \delta\left[R_f(r_h^d, r_f^d) + T_f(t_h^d, t_f^d)\right] \\ & + & (1-\delta)\left[R_f(r_h^c, r_f^d) + T_f(t_h^c, t_f^d)\right] \end{array} \quad (3.16)$$

where the cooperative policies are marked with a super-index c.
If policy agreements are separated, then a deviation in both issues must be detered by a reversion to the Nash-equilibrium policies in both issues, as in the case under linkage above. However and in addition to the linkage case, the breakdown of cooperation in only one issue must be sufficient to deter a deviation in that same issue. Hence, a deviation from the cooperative tariffs that is retaliated only with tariffs - as well as a deviation from the agreed-upon regulation rates that is punished only with changes in regulation - must *also* be discouraged. This creates the following, *additional* enforcement constraints

under separation

$$
\begin{array}{rcrcl}
R_h(r_h^c, r_f^c) & \geq & \delta R_h(r_h^d, r_f^d) & + & (1-\delta)R_h(r_h^d, r_f^c) \\
R_f(r_h^c, r_f^c) & \geq & \delta R_f(r_h^d, r_f^d) & + & (1-\delta)R_f(r_h^c, r_f^f) \\
T_h(t_h^c, t_f^c) & \geq & \delta T_h(t_h^d, t_f^d) & + & (1-\delta)T_h(t_h^d, t_f^c) \\
T_f(t_h^c, t_f^c) & \geq & \delta T_f(t_h^d, t_f^d) & + & (1-\delta)T_f(t_h^c, t_f^f)
\end{array}
\tag{3.17}
$$

where similar conditions holds for the Foreign country. The fact that the policy cooperation under separation entails two additional enforcement constraints for each country implies that the welfare from an agreement under linkage can not be worse than the welfare from an agreement under separation.

3.4.1 Welfare gains and policy changes when countries are symmetric

In this section we consider symmetric agreements for countries that are symmetric in size and bargaining power. In this situation, the enforcement restrictions under linkage in equation (3.16) reduce to one, the enforcement restrictions under separation in (3.17) reduce to two and the optimal, cooperative policy under these constraints is the same across countries, $r_h^c = r_f^c$ and $t_h^c = t_f^c$. This reduction in the number of constraints and the fact that the policies are linearly separable implies that the constraints hold with equality in the optimal, cooperative policy equilibrium, for the linkage case in (3.16) as well as for the case under separation in (3.17).

If linking two previously separate agreements entails any welfare gains, then the cooperative policies that are optimal under linkage are different from the ones that are optimal under separation, $r_{link}^c \neq r_{sep}^c$ and $t_{link}^c \neq t_{sep}^c$. This, together with the linearity of the constraints implies that under the optimal linkage policies one separation constraint is violated while the other one is slack, whereas under the optional separation policies both separation constraints are binding. A separation constraint that becomes slack when moving from the separation to the linkage equilibrium implies that the cooperation in this issue is decreasing, while cooperation in the other issue is increasing. It follows that any welfare gain that is realized by linking the two issues is caused by a better cooperation in one issue at the expense of a worse cooperation in the other issue.

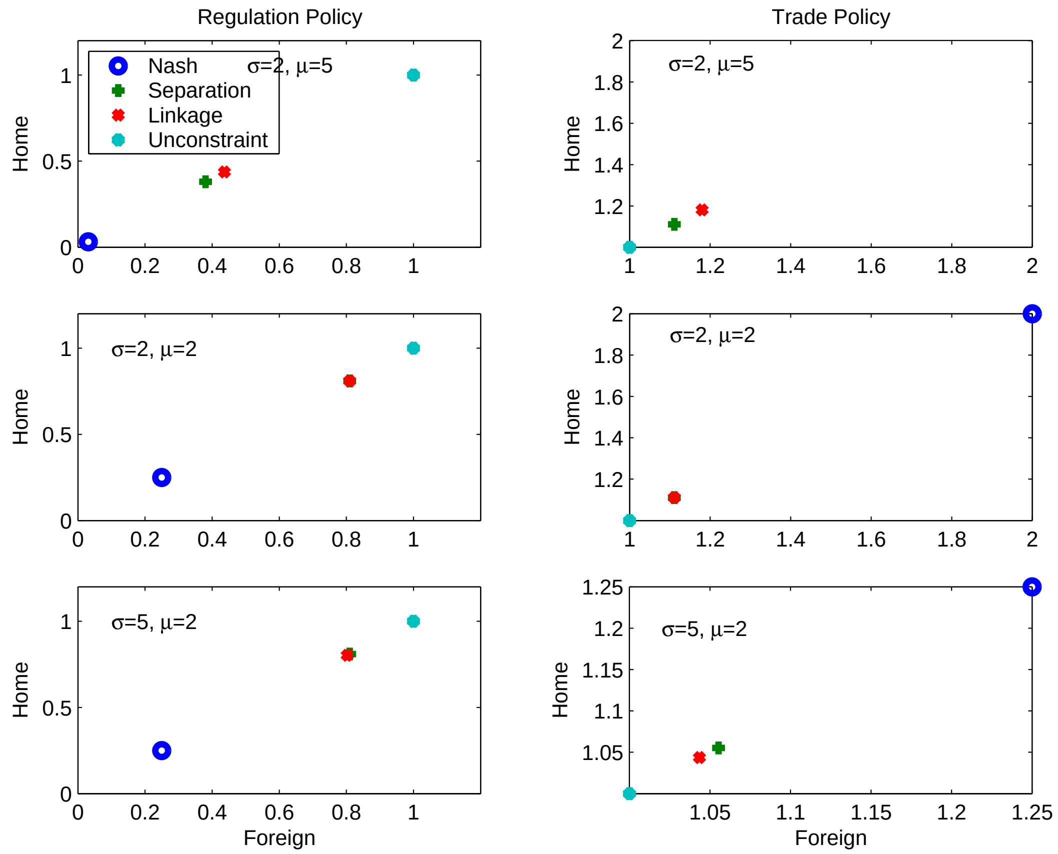

Figure 3.2: Shifting of cooperation across issues due to linkage when countries are symmetric.

The graph shows the optimal, cooperative policies under linkage, separation and with no enforcement constraints as well as the Nash-equilibrium policies. Depending on the elasticity of substitution in the private and the public good, σ and μ, linkage can (i) improve cooperation in regulation at the expense of cooperation in trade (upper panel), (ii) improve cooperation in trade at the expense of cooperation in regulation (lower panel) or (iii) have no effect on the cooperation in trade nor in regulation (middle panel).

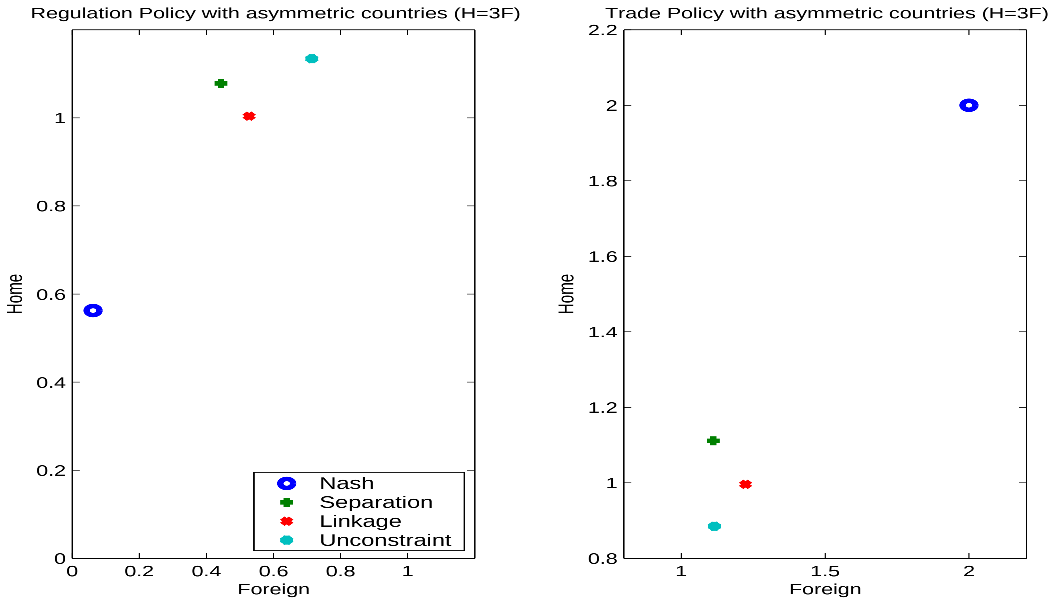

Figure 3.3: Non-cooperative Nash and Nash-Bargaining policies when countries are asymmetric
The Figure shows the Nash-Bargaining policies under the separation enforcement constraints, under the linkage enforcement constraints and in the unconstrained case. The elasticity of substitution in the public good is set to $\mu = 2$, the elasticity of substitution in the private good at $\sigma = 2$. Home is three times larger than Foreign: $s = 0.75$.

3.4.2 Welfare gains and policy changes when countries are asymmetric

In this section we consider the effect of linkage on the welfare on the policies for countries for different size. Figure 3.3 shows the cooperative policies and the Nash equilibrium policies when Home has three times the population of foreign ($H = 3F$). Cooperation takes the form of a Nash Bargaining, so that the resulting, cooperative policies are those that maximize the product of the increase in the utility of each countries' representative individual with respect to the non-cooperative Nash outcome: $NBS = (u_h^c - u_h^n)(u_f^c - u_f^n)$.

Size has an effect on the regulation issue. The larger country better internalizes the effect of the domestic regulation in the global, public good, while the smaller country has a strong incentive to free-ride on the regulation efforts of the larger country. Consequently, the non-cooperative, Nash regulation rates are larger for the bigger country, as shown in equation (3.13). By construction, there is no size effect in the trade issue as the number of differentiated goods produced in each country is fixed and proportional to the population; hence, the non-cooperative tariff rates are independent of size and just a function of the substitution elasticity of the traded goods. The difference in the non-cooperative policies between countries and issues carries over to the cooperative policies under separation, where the regulation rate is higher for larger country, but where the tariff rates are the same.

By linking the issues the countries can reduce these relative differences across policies. To entice the smaller country to increase its regulation, it is offered a better deal on the trade issue, so that it cooperates in regulation in order to maintain a more favorable trade agreement. Likewise, the larger country lowers its tariff in order to preserve a better cooperation on the regulation issue. The possibility to exchange policies is welfare improving. The left panel in Figure 3.4 shows the increase in utility possibility set that asymmetric countries can achieve by linking their policy choices. The right panel shows the difference in the social, Nash-Bargaining welfare under linkage and under separation as a function of the size difference between the countries.

3.5 Conclusion

A difference in the enforceability of cooperation across countries and issues is increasing the welfare gains from linking the issues. The contribution of this paper is to show that this asymmetry arises naturally in the context of a large and a small country that agree on trade and on the regulation of a public good. This result should alleviate concerns against using the WTO 'toolbox' to achieve cooperation in non-trade issues such as the fight against climate change. The enforcement-shifting effect, by which linkage increases the cooperation in one issue but weakens cooperation in the other issue, is less pronounced among asymmetric countries, which 'exchange' concessions across issues when moving from separate to linked agreements.
This yields a practical prediction with regard to a climate-change agreement. If the WTO dispute settlement tool is used to improve compliance, the agreed CO_2 reduction goals will less depend on the economic development of each country than in a stand-alone agreement; the division of countries into developed and developing ones, respectively into annex-I and non-annex countries,

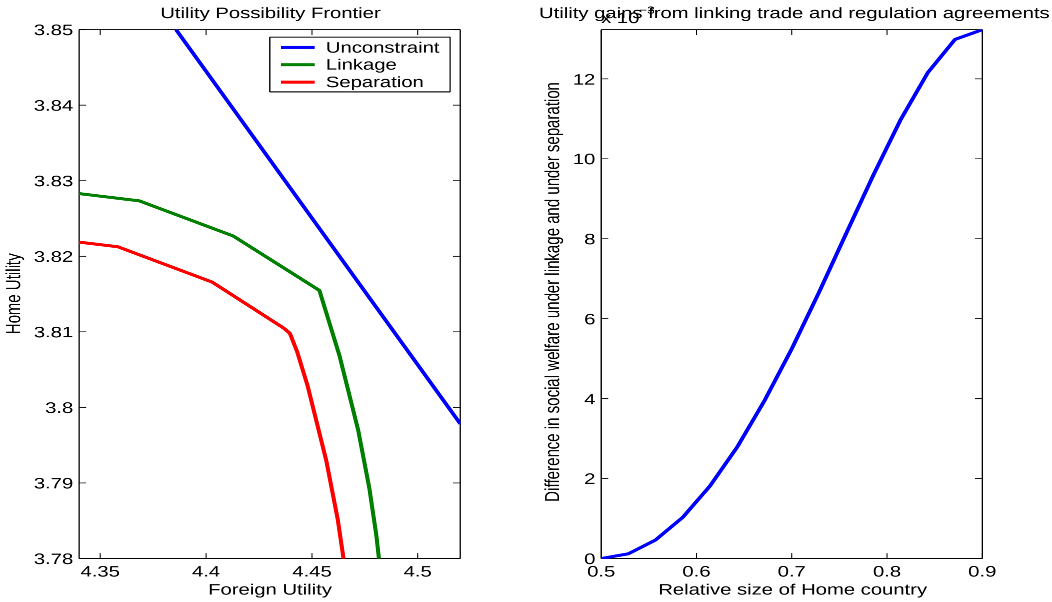

Figure 3.4: Welfare gains from linkage when countries are asymmetric. The elasticity of substitution in public goods is set to $\mu = 2$. The elasticity of substitution in the private good is set to $\sigma = 2$. Countries are asymmetric with $s = 0.75$ in the left panel. The right panel shows the utilitarian social welfare increase due to linkage.

will be less important for the climate policies. At the same time, richer countries will need to make trade concessions.

Two extensions come to mind. First, in the present model differences in size affect the non-cooperative level of regulation, but not the non-cooperative tariff rates. This results from assuming a specialization that is independent of the market size: in the model, each individual produces one differentiated good no matter how large the market. In a model with endogenous specialization - as in the standard CES-trade model where producing a variety requires a fixed cost - optimal non-cooperative tariffs would intuitively decrease with size. It might be worthwhile investigating how in such a set-up the cooperative policies change when moving from separation to linkage.
Second, the model has assumed what could be called a 'power-based' (Nash-Bargaining) approach to negotiations on trade and non-trade issues. Bagwell and Staiger (2002) argue that real-world trade negotiations in the WTO are better characterized as 'rules-based' following the principle of reciprocity. It

would be interesting to see how a reciprocity principle could be extended to the case of non-trade, global goods and what effect such a principle could have on the negotiated policies.

Ginarte-Park Index on Intellectual Property Rights

To measure the level of Intellectual Property Rights the index devised by Ginarte and Park (1997) is used. The index covers 110 countries with observations in 5-year intervals for the period 1960-1990. An update for 1995 was kindly provided by Walter Park. The index is constructed to measure the strength of the legal patent protection in each country. The authors examine the national patent laws along different categories which include patentability of innovations in pharmaceuticals, food, plants, animals and microorganisms, membership in international patent agreements, conditionality of patent protection[2], enforcement of patent protection and patent duration. Points were awarded on whether and how strong these different features are present in the national patent regulations. These points are scaled in a way such that the cumulative score, the index of patent protection, takes values between 0, for a complete absence of patent protection, and 5 for the highest possible patent protection. A few countries in the sample yield zero points, the US patent laws score highest with 4.52, the mean value is around 2.4.

[2]National patent regulations may require for patent protection that the good is produced domestically (working requirement) or that licenses to domestic producers are issued (compulsory licensing).

Country	1960	1965	1970	1975	1980	1985	1990	1995
Algeria	3.05	3.05	3.38	3.38	3.38	3.38	3.38	3.38
Angola	0	0	0	0	0	0	0	1.65
Argentina	1.93	1.93	2.26	2.26	2.26	2.26	2.26	3.19
Australia	2.9	2.9	2.9	2.9	3.23	3.23	3.32	3.86
Austria	3.38	3.38	3.48	3.48	3.81	3.81	4.24	4.57
Bangladesh	1.99	1.99	1.99	1.99	1.99	1.99	1.99	2.32
Belgium	3.05	3.38	3.38	3.38	3.38	4.05	3.9	3.9
Benin	2.05	2.05	2.52	2.52	2.52	2.52	2.86	2.86
Bolivia	2.12	2.12	1.98	1.98	1.98	1.98	1.98	2.31
Botswana	1.7	1.7	1.7	1.7	1.9	1.9	1.9	1.9
Brazil	1.64	1.64	1.64	1.51	1.85	1.85	1.85	3.05
BurkinaFaso	1.76	2.1	2.24	2.24	2.24	2.24	2.24	2.57
Burundi	2.52	2.52	2.52	2.52	2.86	2.86	2.86	2.86
Cameroon	1.76	2.1	2.24	2.24	2.57	2.57	2.57	2.57
Canada	2.76	2.76	2.76	2.76	2.76	2.76	2.76	3.57
Central African Republic	1.76	2.1	2.24	2.24	2.57	2.57	2.57	2.57
Chad	2.05	2.38	2.38	2.38	2.71	2.71	2.71	2.71
Chile	1.98	1.98	2.41	2.41	2.41	2.41	2.41	3.07
China								1.55
Colombia	2.08	2.08	1.62	1.8	1.12	1.12	1.12	2.57
Congo, Dem. Rep.	2.52	2.52	2.52	2.86	2.86	2.86	2.86	2.86
CongoRep	1.76	2.1	2.24	2.24	2.57	2.57	2.57	2.57
Costa Rica	2.19	2.19	1.76	1.76	1.94	1.47	1.47	1.8
Cote d'Ivoire	2.05	2.38	2.52	2.52	2.52	2.52	2.52	2.52
Cyprus	1.9	1.9	2.24	2.24	2.24	2.24	2.24	2.24
Denmark	2.33	2.66	2.8	2.8	3.62	3.76	3.9	4.05
Dominican Republic	2.26	2.26	2.41	2.41	2.41	2.41	2.41	2.41
Ecuador	1.94	1.94	1.66	1.66	1.54	1.54	1.54	2.71
Egypt	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99
El Salvador	2.19	2.19	2.19	2.19	2.19	2.19	2.19	2.86
Ethiopia	0	0	0	0	0	0	0	0
Fiji	2.01	2.01	2.01	2.01	2.01	2.01	2.01	2.01
Finland	1.99	1.99	2.14	2.14	2.95	2.95	2.95	4.19
France	2.76	3.1	3.24	3.24	3.9	3.9	3.9	4.05
Gabon	1.76	2.1	2.24	2.24	2.57	2.57	2.57	2.57
Germany	2.33	2.66	3.09	3.09	3.86	3.71	3.71	3.86
Ghana	2.23	2.23	2.37	2.37	2.9	2.9	2.9	2.07
Greece	2.46	2.46	2.46	2.46	2.46	2.46	2.32	2.65
Grenada	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
Guatemala	1.94	1.94	1.08	1.08	1.08	0.75	1.08	1.08
Guyana	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42
Haiti	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19
Honduras	2.05	2.05	2.05	2.05	1.76	1.76	1.76	2.1
Hong Kong	2.04	2.04	2.04	2.04	2.24	2.57	2.57	2.57
Iceland	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.45
India	1.85	1.85	1.42	1.62	1.62	1.62	1.48	1.51
Indonesia	0.33	0.33	0.33	0.33	0.33	0.33	0.33	1.24
Iran	2.38	2.38	2.38	2.38	2.38	2.38	2.38	2.38
Iraq	2.13	2.13	2.13	2.13	2.46	2.46	2.46	2.46
Ireland	2.23	2.56	2.99	2.99	2.99	2.99	2.99	3.32
Israel	3.04	3.37	3.57	3.57	3.57	3.57	3.57	3.57
Italy	2.99	3.32	3.32	3.46	3.71	4.05	4.05	4.19
Jamaica	3.09	2.86	2.86	2.86	2.86	2.86	2.86	2.86
Japan	2.85	3.18	3.32	3.61	3.94	3.94	3.94	3.94
Jordan	1.52	1.52	1.52	1.86	1.86	1.86	1.86	2.19
Kenya	2.37	2.37	2.37	2.37	2.57	2.57	2.57	2.9
Korea	2.8	2.8	2.94	2.94	3.28	3.61	3.94	4.2

Table 3.1: GP-Index of Intellectual Property Rights, Part I

Country	1960	1965	1970	1975	1980	1985	1990	1995
Liberia	2.19	2.19	2.19	2.19	2.19	2.19	2.19	2.86
Lithuania								2.9
Luxembourg	2.29	2.29	2.71	2.71	3.05	3.05	3.05	3.05
Madagascar	1.05	1.38	1.52	1.52	1.86	1.86	1.86	2.27
Malawi	2.37	2.7	2.7	2.7	3.04	3.24	3.24	3.24
Malaysia	2.37	2.37	2.37	2.37	2.57	2.9	2.37	2.85
Mali	1.9	1.9	1.9	1.9	1.9	2.57	2.57	2.57
Malta	1.56	1.56	1.89	1.89	1.89	1.89	1.89	1.89
Mauritania	1.76	2.1	2.24	2.24	2.24	2.57	2.57	2.57
Mauritius	2.56	2.56	2.56	2.56	2.89	2.89	2.89	2.89
Mexico	1.7	1.7	1.99	1.99	1.4	1.4	1.63	2.86
Morocco	2.38	2.38	2.38	2.38	2.38	2.38	2.38	2.38
Mozambique	0	0	0	0	0	0	0	0
Myanmar	0	0	0	0	0	0	0	0
Nepal	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52
Netherlands	2.85	3.18	3.18	3.18	3.32	3.32	3.32	3.86
New Zealand	2.95	3.29	3.61	3.47	4.24	4.24	4.24	4.38
Nicaragua	1.78	1.78	0.92	0.92	0.92	0.92	0.92	0.92
Niger	1.76	2.1	2.24	2.24	2.24	2.24	2.24	2.57
Nigeria	2.71	3.05	3.05	3.05	3.05	3.05	3.05	3.05
Norway	2.66	2.66	2.8	2.8	3.29	3.29	3.29	3.9
Pakistan	0	0	0	0	0	0	0	0
Panama	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99
Papua New Guinea	2.41	2.41	2.41	2.41	2.41	2.41	2.41	3.52
Paraguay	1.8	1.8	1.8	1.8	1.8	1.8	1.8	2.8
Peru	1.17	1.17	1.31	1.31	1.02	1.02	1.02	2.71
Philippines	2.19	2.52	2.67	2.67	2.67	2.67	2.67	2.67
Portugal	1.98	1.98	1.98	1.98	1.98	1.98	1.98	2.98
Romania								2.71
Russia								3.04
Rwanda	2.52	2.52	2.52	2.52	2.52	2.86	2.86	2.86
Saudi Arabia	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05
Senegal	1.76	2.1	2.24	2.24	2.24	2.57	2.57	2.57
Sierra Leone	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52
Singapore	2.37	2.37	2.37	2.37	2.57	2.57	2.57	3.9
Slovakia								3.19
Somalia	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
South Africa	3.04	3.37	3.37	3.37	3.57	3.57	3.57	3.57
Spain	2.95	3.29	3.29	3.29	3.29	3.29	3.62	4.05
Sri Lanka	2.6	2.6	2.6	2.6	2.79	3.12	3.12	3.12
Sudan	2.86	2.86	2.86	2.86	2.86	3.52	3.52	3.52
Swaziland	2.19	2.19	2.19	2.19	2.19	2.19	2.19	2.86
Sweden	2.33	2.66	2.8	2.8	3.47	3.47	3.9	4.24
Switzerland	2.38	2.71	3.14	3.14	3.8	3.8	3.8	3.91
Syria	2.46	2.46	2.46	2.46	2.46	2.46	2.46	2.46
Tanzania	2.7	2.7	2.7	2.7	2.9	2.9	2.9	2.9
Thailand	1.51	1.51	1.51	1.51	1.85	1.85	1.85	2.24
Togo	1.9	1.9	2.24	2.24	2.24	2.24	2.24	2.57
Trinidad and Tobago	3.01	3.01	3.01	3.01	3.01	3.01	3.01	3.35
Uganda	2.04	2.37	2.37	2.37	2.57	2.57	2.57	2.9
United Kingdom	2.7	3.04	3.04	3.04	3.57	3.57	3.57	3.57
United States	3.86	3.86	3.86	3.86	4.19	4.52	4.52	4.86
Uruguay	1.79	1.79	2.26	2.26	2.26	2.26	2.26	2.6
Venezuela	1.35	1.35	1.35	1.35	1.35	1.35	1.35	2.9
Vietnam								3.13
Zambia	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52
Zimbabwe	2.37	2.37	2.37	2.37	2.9	2.9	2.9	2.9

Table 3.2: GP-Index of Intellectual Property Rights, Part II

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