THÈSE

En vue de l'obtention du

DOCTORAT DE L'UNIVERSITÉ DE TOULOUSE

Délivré par l' Université Toulouse 1 Capitole
Discipline : Sciences Economiques

Présentée et soutenue par

Juan Felipe BERNAL URIBE

Le 5 juillet 2012

Titre :

Innovation, Intellectual Property Rights and International Knowledge Diffusion

---

JURY

André GRIMAUD, professeur, Université Toulouse 1 Capitole
Gilles SAINT-PAUL, professeur, Université Toulouse 1 Capitole
Jacobus A. SMULDERS, professeur, Université de Tilburg (rapporteur)
Emmanuel THIBAULT, professeur, Université de Perpignan (rapporteur)

Ecole doctorale : Toulouse School of Economics
Unité de recherche : LERNA - TSE
Directeur de Thèse : André GRIMAUD

Contents

List of Figures

Acknowledgments

> "My meaning simply is, that whatever I have tried to do in life, I have tried with all my heart to do well; that whatever I have devoted myself to, I have devoted myself to completely; that in great aims and in small, I have always been thoroughly in earnest." Charles Dickens, *David Copperfield*

There is the people who have made this whole life experience a lot easier and enjoyable, and there is the people who have simply made it possible.

Without the example and support from my parents I could have never done any of the things that I consider now as milestones in my life. To them I dedicate this research and this day, as a token of the less tangible things that cannot be given away.

To those who have been around me during these years in France, I can only express my gratitude. Some have come and then go, and some have stayed, but all have had an impact in my life.

To the professors who have generously spare some of their time with their valuable advice. My advisor, M. Grimaud, who tought me that clarity and organization are not additions to research but indispensable inputs in it. M. Saint-Paul, whose councel and insights have always proved of the greatest relevance. He has taught me that economics is a pointless sciences when it fails to be of practical use, and that technical exploits are meaningless if no direct implications for the improvement of society can be drawn out of them.

Introduction

One of the most distinguishable characteristics of modern societies is the pace at which knowledge seems to evolve. This knowledge is translated into the arrival of new ideas or inventions that provide value to agents in the society. Indivuals give value to ways of satisfying their needs that are newer or better than the ones they know. For instance, the need for communication is now satisfied by means of mobile devices or electronic mails that provide additional advantages compared to "ancestors" such as telephones requiring landlines or air mail (although fixed telephones and air mail were already improvements from telegraphs and Pony Express). Not only we enjoy new ways to communicate but we can also choose from a myriad of options regarding the way we want to use them. In order to have a conversation with someone in a different geographical location we may use a cell phone, Skype, Facetime or any other software intended to that purpose. Our cell phone may be produced by Nokia, Samsung, Apple or Blackberry; each one of these firms supplying different models, of different colors and specifications. Consumers value being able to find and purchase the specific model of the right color and with the specifications they need from their desired brand at the price they would be willing to pay. A similar analysis might be done for firms that need to acquire production inputs in order to manufacture their goods. Either including new and/or better inputs into the set of intermediate goods they use, or learning better ways to combine the inputs they already possess, is valuable to firms as long as it allows them to increase their productivity and obtain higher profits.

The informal discussion above is illustrative of the link relating new pieces of knowledge and the creation of economic value, which is crucial to the modern treatment of technological progress as driven by innovation. As far as new ideas are valued by agents, there exist economic incentives to allocate valuable resources into their production. The perspective of the appropriation of the value derived from a new idea would provides ex-ante incentives for the agent to invest in its production.

This is not to say that commercially motivated research is the only source of new knowledge. Besides commercial Research and Development (R&D) firms, we find other institutions such as universities and public-funded research centers. Although they play an important role in providing new knowledge (specially on basic science), and that the concept of a publicly funded research sector is an appealing one from an economic perspective, the focus of this thesis lies entirely on the analysis of commercially motivated R&D firms.

The output of the R&D sector (ideas, blueprints or prototypes of goods new to the economy) is different in nature and utilization from most goods and services produced in the economy. It is different in nature because knowledge can be naturally classified as a public good (i.e. an idea is simulaneously non-rivalrous and non-excludable). It is non-rivalrous because the utilisation of an idea does not exhaust it or prevent others from fully enjoying it; and it is non-excludable if the inventor is unable to deter others from producing goods were this piece of knowledge is embodied.

Knowledge also differs from conventional goods in its utilization, since new ideas might be translated into new varieties of consumption or intermediate goods (this would happen in the case of radical innovation), in improved versions of already existing goods (incremental innovation), or in better ways of makings use of already existing ideas (process innovation). But ideas also make part of the set of knowledge of the society, and in that respect become available to other producers of ideas and used as production inputs in the sector composed of R&d firms. To sum up, ideas are simultaneously public goods and they may generate positive externalities on other inventors. Both these features are known in economic theory as "market failures", and are translated into a provision of ideas that is not Pareto efficient.

A set of very heterogeneous goods and services such as the latest computer game, a piece of designer's clothing, the yellow M symbol from McDonald's, Aspirine or a very sophisticated and specialized piece of machinery share a common feature: they all are the product of creative effort. They correspond to ideas and are manufactured by rent seeking firms. A crucial feature of all these goods is that fixed, and often high, costs are involved in the creative process. Once the latest computer game is finished, the code in which all its contents are confined can be expressed as a sequence of binary characters and be made available for any programmer in the world, who can then create as many copies of the game as he wants at a very low production cost. It is the original inventor who bears the bulk of the initial fixed cost leading to the development of the idea. Incentives to undertake expensive and often risky R&D activities must come in the shape of some sort of positive remuneration accruing to the inventor.

Nonetheless, economic theory teaches us that the existence of multiple producers competing against one another for supplying a given good leads to a situation were all of them sell at the competitive price (corresponding to the marginal cost of production). How then can inventors make positive profits while competing with other producers? The short answer is: "They cannot". If all producers share the same production costs, and if innovations are available to other producers at the same time they arrive into the market, the absence of defined property rights over creative output hinders innovation.

Modern societies rely mainly on the attribution of what are called Intellectual Property Rights (IPRs) as means to create incentives for innovative activities. The economic rationale behind IPRs comes from a more general study for the efficient supply of goods in the presence of market failures stated in Coase (1960). By attributing property rights over goods for which there are no markets, contracts can be written and enforced and agents can bargain the surplus coming from production in a way such that efficiency is restored. By awarding exclusivity rights of production to the inventor (or to a third firm subscribing a licensing agreement with the said inventor), the previously non excludable idea becomes partially or totally excludable. Indeed by giving a legal right to be the only producer of a good, the market of this good moves from a situation of potential perfect competition to one of monopoly.

As stated by Arrow (1962), ideally one would want to design a mechanism able to reconcile two seemingly opposite actions. On the one hand it is desirable to create ex ante incentives to innovative activity. On the other hand, because they are non-rivalrous goods, we would want ideas to disseminate as much as possible once they have been created. By providing exclusive production rights to inventors, the IPRs system allows them to price the goods were ideas are embodied at higher prices than the production cost, which reduces the dissemination of ideas by curbing the quantities of goods demanded under the monopolistic price. On the brighter side, by allowing the inventor to appropriate part of the social value of the idea, the IPRs system partially succeeds to attain the first goal mentioned above, and generates some incentives to innovative activity. We proceed to explain why these incentives might fall short of inducing an efficient amount of R&D.

There are at least two arguments to show that although the existence of IPRs helps to alleviate, to some extend, the appropriability problem, it remains unlikely that inventors are able to recover the full social value of ideas. In the first place, as was discussed above, all ideas (old ones belonging to the public domain, as well as the ones that have recently been discovered) form the body of knowledge of the society. This is why inventors use existing ideas to create new ones without infringing on any particular property right. As quoted from the seventeenth-century scientist Isaac Newton "*If I have seen further, it is by standing on the shoulders of giants*".

Steam engines, internal combustion, the laser technology or the arrival of personal computers are examples of ideas that fall into this category. All of them have been the basis of newer generations of goods in which these ideas are embodied and that serve for multiple purposes. In this example, by creating a new idea, an innovator is also imposing an externality, although a positive one, on the rest of inventors who may potentially make use of that idea. In general, goods suffering from positive externalities are under provided by the market economy.

Even in the cases were no externalities were generated there is a second, more general, argument against the idea that IPRs create enough incentives for innovation. Let us consider the case of the arrival of a new idea under two different competition regimes. In the first one there are many firms competing agains each other (i.e. perfect competition), and in the second one only one firm undertakes the total supply of the good (i.e. monopoly). Under perfect competition, the good where the new idea is embodied would be sold at the production cost. Under the second case, the monopolist would face the whole market demand and set a price corresponding to a markup over the production cost. It is therefore the case that monopolistic prices are higher than prices arriving under perfect competition. Microeconomic theory tells us that moving from the first to the second case generates a transfer of surplus from consumers to the monopoly. Furthermore, as long as the demand for the good is downward sloping (i.e. any negative and finite price elasticity), the loss in surplus suffered by consumers is higher in absolute value than the increase in profits for the producer. The difference between the two is called a "deadweight loss". In other words, society would be willing to give the innovator a remuneration equivalent to the consumer surplus arising from the arrival of the new idea to the economy, nonetheless the remuneration implied by IPRs corresponds to a lower value equivalent to this consumer surplus minus some positive "deadweight loss".

Within the general concept of creative output that is protected by IPRs it has been necessary to create categories of IPRs that are adequate to goods exhibiting some common features. Creative goods of industrial application are protected by patents, as artistic ideas are protected by copyrights. The names and identifying characteristics of brands are protected under trademarks. These are the three most used tools provided in IPRs legislations, although not the only ones (for instance there are specific IPRs for the protection of plant varieties and geographical origin of certain goods).

Until the mid nineties, each country separately specified the extend of its IPRs system. Although some international treaties (i.e. the Berne, Paris and Madrid Conventions[1]) drew some lines on the subject. It wasn't until 1988 when the first comprehensive international treaty concerning IPRs came into existence. The Trade-Related Aspects on Intellectual Property Rights (TRIPS) agreement drew the contents of the minimum standards of IPRs that must be met by member countries of the WTO. The time that was given to countries to implement the measures contained in the agreement depended on the degree of development of each economy. Rich countries were given one year starting from 1995, while most developing and transition economies were given five years. Least-developed countries are expected to implement the TRIPS agreement by 2013 in general matters and 2016 for the pharmaceutical industry.

This thesis studies the effects of the Intellectual Property Rights (IPRs) system in economic activity. Throughout this document it is my intention to supply a further understanding on the main effects of IPRs mainly on innovative and productive activities

[1] Respectively: "The Berne Convention for the Protection of Literary and Artistic Goods" (1886); "The Paris Convention for the Protection of Industrial Property" (1883); and "The Madrid Agreement Concerning the International Registration of Marks" (1891).

as well as occupational choice of skilled workers. In order to do so I develop a congruous set of models that allows us to consider IPRs under several specifications of the world. In particular we focus on general equilibrium models where technological progress comes from the arrival of new ideas that are embodied in varieties of horizontally differentiated intermediate goods that are demanded by firms in the Final sector for the production of consumption goods. These varieties of intermediate goods come from investments in Research and Development (R&D) activities. Inventors are rewarded with costless infinitely living patents granting exclusive production rights over the physical units of intermediate goods where the idea is embodied.

The first chapter of this thesis considers a closed economy were there are fixed endowmens of two types of labor: high and low ability workers. Those with high ability move freely between the R&D and Final sectors, while those workers with low innate ability are engaged in the Final sector exclusively. I assimilate the degree of IPRs in this economy as the probability of imitation faced by a patent owner from a particular intermediate variety in one period. It is therefore the case that perfect enforcement of IPRs are translated into a zero risk of imitation and the highest remuneration accruing to inventors (patents would be, under this case, effectively infinitely living). On the other hand, complete absence of IPRs imply that patent owners face competition from imitators at every period after the arrival of the idea and are therefore unable to obtain any positive profits from it. In order to characterize the allocation of skilled labor into the R&D and Final sectors we study the intersectoral relative wage and assume that skilled workers care only about relative wages at the moment of choosing in which sector they work. We find that there is a threshold value of IPRs above which the wage for skilled labor in the R&D sector is higher than the wage in the Final sector. In this case all skilled labor is allocated into the R&D sector and unskilled labor into the Final sector. As a consequence of this "separating equilibrium" the rate of growth of the economy (corresponding to the rate of technological progress and depending exclusively on the level of skilled workers in the R&D sector) is irresponsive to changes in the IPRs regime of the economy. I turn to the study of the welfare implications of IPRs for skilled and unskilled labor separately. Since there are no transitional dynamics in this model, the consumption profile for high and low-ability workers can by fully recovered by the inital level of consumption and the rate of growth of the economy. We conclude that welfare for skilled labor is maximized under strong IPRs while welfare for unskilled labor is maximized under a weaker regime of IPRs.

Whenever the degree of IPRs in a country is lower than the threshold mentioned before, wages for labor in the R&D and Final sectors are equalized. The economy moves out of the "separating equilibrium" to an "endogenous equilibrium" where skilled labor is endogenously allocated between the R&D and Final sectors. Increases in IPRs are translated into a higher remuneration for labor in the R&D relative to the Final sector that is overturned by a reallocation of skilled labor out of the latter and into the former until wage equality is restored. In this case, unlike the "separating equilibrium", changes in IPRs do affect the rate of growth of the economy by reallocating skilled labor into R&D activities. Conversely, stronger IPRs decrease consumption both for the skilled and the unskilled (i.e. intersectoral equality in wages implies intersectoral equality in per capita consumptions). This decrease is the consequence of two different effects: first, stronger IPRs increase the price level (i.e. in average a higher fraction of intermediate good are priced by monopolists); and second, the counterpart of the reallocation of skilled labor going to R&D is the reduction in labor allocated to the Final sector. Both effects act to reduce output and therefore per capita consumptions. The trade off characterizing the effect of IPRs on welfare is very different from the one arising under the previous equilibrium case. We find the traditional trade off concerning IPRs as being simultaneously a dynamic incentive for growth, and a source of price distortions for IPRs' sensitive goods. Nonetheless, we find a close link between the size and the composition of the economy in terms of total population and population endowments (i.e. skilled and unskilled labor). This link is summarized as follows: the positive effect of IPRs on welfare comes from the dynamic effects on technological progress, since the goods that are protected by IPRs are non-rivalrous goods (i.e. ideas, inventions, blueprints) the weight of this positive effect increases with the size of the population who benefits with new ideas; whereas the negative effect of IPRs on welfare comes from the distortionary effects of monopolistic pricing, wich are independent of the size of the economy. This means that larger economies benefit more from higher IPRs than smaller economies.

The second chapter of this thesis focuses also on the effects of IPRs and the determination of the welfare maximizing degree of IPRs in the economy under a different specification of the world economy. In particular, we no longer consider our target country as a closed economy but insted study the case of a small country that benefits from ideas produced by domestic researchers as well as ideas coming from research undertaken in a big and more advanced economy. This case is better suited to draw conclusions on the extension of IPRs institutions to developping countries.

A fundamental change in the trade offs mentioned above (and considered in the literature on the subject) takes place under this specification. In particular, the existence of knowledge spillovers taking place within the R&D sector imply convergence in rates of growth between the two economies. In the case of a small and big economies, it is reasonable and standard to think that the small economy has little or no effect on the big economy. It is therefore the case that convergence in rates of growth takes the specific form of the small economy converging to the rate of growth of the big economy. This convergence result does not depend on the IPRs regime of the small economy. Thusly, the dynamic effect of IPRs on technological progress is no longer present in this formulation. Is this enough to assess that small countries should only focus on eliminating the negative effects of IPRs on welfare through static distortions by getting rid of IPRs? The answer to this question provided in this chapter is a negative one. Even in the absence of dynamic effects through the rate of growth of the economy, IPRs determine the "technological gap" of the small economy relative to the big one. If we believe that the small economy engages in the adaptation or reproduction of goods already discovered in the big economy then the "technological gap" is assimilated as the absortion rate. In fact, the positive effect of IPRs on the "technological gap" dominates the negative effect coming both from monopolistic price distortions and the reallocation of skilled labor out of the Final sector. I work again under the assumption there are two types of labor that differ in the sectors they can supply their labor endowments. Under the "separating equilibrium", skilled workers see their welfare maximized under complete protection of IPRs, while unskilled workers would prefer a strictly weaker IPRs regime. Under the "endogenous equilibrium" case both skilled and unskilled labor would prefer to have complete enforcement of IPRs. It is also worth noting that the introduction of knowledge spillovers introduce transitional dynamics into a model that otherwise lacks for them. The transition of this economy is governed by the interregional relative technological gap.

In order to introduce into the analysis an important mechanism of technological diffusion, chapter three develops a model of two interdependent economies that are allowed to trade. In order to be sure to target exclusively changes in the economy coming from variations in the IPRs regime I assume both economies have access to identical productive technologies both in the R&D and Final sectors. The only dimensions of heterogeneity between the two regions lie on labor endowments and the degree of protection of IPRs. In particular, I assume that the developed country has a larger endowment of skilled labor and a stronger protection of IPRs than the developing economy. Skilled labor is assumed to be heterogeneous in their productivities regarding the manufacturing of physical units of intermediate goods and we assume that productivity parameters are drawn from identical probability density functions in both countries.

This chapter studies the endogenous allocation of skilled labor within the R&D sector between innovators and imitators, and how this allocation is shaped by the institutions related to IPRs. I expand the traditional model of growth with horizontal innovation by introducing a second productive activity within the R&D sector: that of imitation. Skilled workers are allowed to choose: the productive sector (i.e. R&D or Final); the productive activity within the R&D sector (i.e. innovation or imitation); and the exporting status for firms in the R&D sector. In a world composed of a developing South and a developed North, an increase in the degree of protection of IPRs in the South produces a reallocation of skilled labor out of imitation and into innovation. Firms in the North interpret this reduction in the number of imitators in the South as a lower risk of imitation coming from that location were they to export. For northern firms, the value of exporting to the South (equivalent to the discounted flow of future profits in the southern market) increases as the South strengthens its IPRs protection. More northern producers are willing to incur into the fixed cost that is required for exporting. This mechanism provides a rationale for the empirical link between a developing country's IPRs regime and the value of imports arriving to this economy from developed countries.

I consider the main contribution of this chapter to be the modelization of imitation as a costly activity that must therefore be profitable for workers engaged in it. The resulting allocation of skilled labor consists of workers being distributed between the Final and R&D sectors; and within the latter, in imitators and innovators. Following empirical evidence on the costs of imitation, I assume the production function of imitations to require the same inputs as the production function of innovations (namely, skilled labor and the world stock of knowledge). Nonetheless, as stated in the empirical literature, I assume that any unit of skilled labor is more productive at producing imitations than innovations. The empirical estimation of the costs associated with imitation (mainly through the process of reverse engineering) relative to innovation is 65%. On the other hand, imitators face a "punishment" corresponding to a fine equivalent to the present value of future profits coming from the punished imitated variety. The hazard rate of punishment is what stands as a proxy of the strength of IPRs in this model. For instance, a total absence of IPRs is translated as a zero probability of punishment faced by imitators, whereas complete enforcement of IPRs corresponds to the case where imitators are punished In practical terms, the degree of IPRs is thusly translated into the life expectancy of an imitation. The trade off faced by skilled workers when choosing activities in the R&D sector comes then from weighting the productivity advantage in imitation and the shorter life of imitations relative to innovations in the determination of per period remunerations.

By focusing on a particular initital configuration of IPRs parameters in the North and the South (i.e. complete enforcement in the North and weak in the South) l am able to replicate the pattern of northern-based innovation and southern-based imitation that we observe in modern society.

I make use of this framework to study how stronger IPRs in the South affect the patterns of trade, imitation and innovation in each region and the world economy. I focus on such a situation since it is consistent with the recent implementation of the TRIPS agreement undertaken by member countries of the WTO. Stronger IPRs in the South decrease the remuneration of imitators at every productivity parameter relative to innovation or the wage in the Final sector. The most productive imitators become innovators and the least productive become production workers.

The reallocation of skilled workers has a direct impact on the North economy, since it decreases the risk of imitation faced by northern innovators if they were to export to the South. It is standard in the recent developments of trade theory to take into account the presence of fixed costs related to exporting activity. The decision to export to a given location depends then on the comparison between these fixed costs and the value of that foreign market (i.e. the expected present value of the flow of profits coming from that market). A reduction in the risk of imitation increases the value of the market undertaking the change in IPRs and therefore induces new trade from firms that were not willing to do so under the previous level of IPRs.

Chapter 1

Enforcement of Intellectual Property Rights and Population in a Closed Economy

1.1 Introduction

From 1986 to 1994 what was considered as the biggest comercial negotiation ever undertaken and the largest reform to the world's trade system, since the creation of the GATT, took place in the city of Punta del Este. It is known as the Uruguay Round.

The set of measures regarding the protection of Intellectual Property Rights (IPRs) arising from this negotiation gave shape to the Agreement on Trade-Related Aspects of Intellectual Property Rights, best known under the acronym of TRIPS. The conclusions achieved by the TRIPS Agreement rely almost entirely on the implementation of the World Intellectual Property Organization's (WIPO) previous agreements; namely, those from the Paris Convention for the Protection of Industrial Property and the Berne Convention for the Protection of Literary and Artistic Works. The first of them focused on the protection of inventions (by patents), industrial designs and trade secrets as well as the protection of trademarks and geographical indications; whilst the latter covered copyrights and rights related to copyright.

It was stated that a minimum level of IPRs ought to be guaranteed by every fellow WTO member. Furthermore, this protection was to be accorded on the basis of national treatment (no distinction between nationals and foreigners) and most-favoured-nation (equal treatment for nationals of all trading partners in the WTO). The grounds on which these measures were designed are summarized in the following excerpt of the TRIPS text:

> "The protection and enforcement of intellectual property rights should contribute to the promotion of technological innovation and to the transfer and dissemination of technology, to the mutual advantage of producers and users

of technological knowledge and in a manner conducive to social and economic welfare, and to a balance of rights and obligations." (Agreement on Trade-Related Aspects of Intellectual Property Rights, page 5, Article 7)

It is precisely the mechanism leading from higher Intellectual Property Rights (IPRs) standards concerning industrial property to social welfare what is going to become the main interest of the present work. Does an increase in the general enforcement of patents, irrespectively of the economic characteristics of a given country, automatically lead to the enhancement of social welfare for its population?

The matter of patent optimality has been addressed in the past. Judd (1985) discussed the economic consequences of regimes with finite and infinitely lived patents. Gilbert and Shapiro (1990) and Klemperer (1990) studied the problem of patent breadth versus patent length, while Goh and Olivier (2002) considered the optimal patent regime in an economy composed of two productive sectors (upstream and downstream). Another set of works such as those of Deardorff (1992) and Grossman and Lai (2004) analysed the determination of international patent regimes and its welfare effects.

It is in at least two ways that the present document attempts to enlarge the scope of previous results while providing some other original considerations. I take a Romer (1990)-like three-sector model of endogenous growth as reference and include: (i) imperfect enforcement of IPRs as the probability of intermediate production inputs protected by patents being imitated by other intermediate firms and sold at the competitive price, and (ii) agents exogenously endowed with one of two levels of ability, i.e. high and low. I work under the assumption that individuals with high ability can choose whether they work in the Final sector (producing consumption goods) or in R&D (producing innovations); whereas individuals with low ability are constrained to work exclusively in the Final sector.

The result of this exercise points to the conclusion that the main determinant of the welfare maximizing degree of enforcement of IPRs is the relationship between total population and the endowment of individuals with high ability. This result is in part explained by the presence of scale effects, since it is the size of the total population that determines the weight of the negative dynamic effect of a relaxation of IPRs in the discounted value of future utilities.

The organization of the article is as follows. Section 2 introduces the basic one-country model of endogenous growth, IPRs protection and workers with heterogeneous abilities. Section 3 tackles the question of the equilibrium welfare maximizing IPRs regime for workers in each preoductive sector and stablishes the dependence of this IPRs regime to an expression relating total population and population with high ability. Section 4 concludes.

1.2 The Basic Model

The model presented in this section is a simplified version of Romer (1990). Endogenous growth is driven by technological change undertaken by the private sector and motivated by potential economic rents. Unlike Romer's original article, I consider the case in which the owner of a patent for producing a variety of intermediate good faces an exogenous probability of this good being imitated. It is also assumed that individuals are heterogenous in terms of their innate levels of ability, and this determines the type of labor they become (skilled in the R&D sector and unskilled and skilled in the production of final goods).

There are three sectors in the economy producing goods of different nature: homogenous good (used for consumption and investment) by the Final sector, intermediate goods (used as inputs in the production of the homogeneous good) by the Intermediate sector, and innovations (new varieties of intermediate goods) by the R&D sector. Growth is driven by the arrival of horizontally differentiated varieties of intermediate goods from research in the R&D sector.

1.2.1 Technologies, Preferences and Institutions

The homogenous final good is considered to be a conventional good (rival and excludable) produced according to the following production function proposed by Ethier (1982):

$$Y_{i,t} = AL_{i,t}^{1-\alpha} \sum_{j=1}^{N_t} x_{i,j,t}^{\alpha}, \text{ for all } t \text{ and } i \in [1, M] \text{ with } \alpha \in (0,1) \tag{1.2.1}$$

$Y_{i,t}$ represents the amount of final good produced by firm i, using labor ($L_{i,t}$), and intermediate goods ($x_{i,j,t}$) as inputs. A is a parameter of productivity considered to be fixed over time. N_t is the number of different varieties of intermediate goods available up to time t. The production function has constant returns to scale and all intermediate goods have additively separable effects on output.

M is assumed to be large enough to provide perfect competition in this sector. At any time the total number of workers in all firms equals the labor force in the final good sector, $L_{Y,t}$:

$$\sum_{i=1}^{M} L_{i,t} = L_{Y,t} = L - L_{R,t} \tag{1.2.2}$$

Which, in turn, is equal to the whole population (L) excluding the labor force in the R&D sector ($L_{R,t}$). The economy is endowed with population L assumed to be constant in time.

There are as many firms in the sector producing intermediate goods as the number of differentiated varieties of intermediate goods in the economy. The production technology is a one-to-one relation between the final good and the intermediate good. This means one unit of final good Y is needed for producing one unit of any intermediate good.

There is imperfect competition in this sector due to the particular nature of innovations[1]. Once a new variety is invented, the inventor in the R&D sector obtains a free patent that grants the right to be the only producer of that particular variety. Patents are then sold to firms in the Intermediate sector. The monopolist (i.e. the patent owner) charges the profit maximizing price for the intermediate good.

Nonetheless, I consider a scenario in which the owner of the patent also faces a probability of the good being imitated by other firms in the sector seeking to steal existing monopolistic rents (Bertrand competition in prices). For a given firm, the level of enforcement of Intellectual Property Rights (IPRs) is given by the probability of holding the monopoly status (i.e. not being imitated). It faces one of the two situations described below:

$$x_{j,t} = \begin{cases} \text{Monopoly status} & ; \text{ with probability } \quad \nu \\ \text{Imitated} & ; \text{ with probability } \quad 1-\nu \end{cases} \tag{1.2.3}$$

The R&D (Research and Development) sector produces knowledge (indistinctly called "inventions", "technologies", "innovations" or "ideas") understood as new varieties of intermediate goods. New inventions enlarge the span of the stock of current knowledge and previous technologies do not disappear or become obsolete. New ideas arrive to the economy deterministically according to the accumulation function:

$$\frac{\partial N_t}{\partial t} = \dot{N}_t = \frac{N_t L_{R,t}}{\eta} \tag{1.2.4}$$

New ideas come from the interaction of the current stock of ideas (N_t) and the labor force in the R&D sector ($L_{R,t}$) where η is a constant technological parameter[2].

There is free-entry in this sector. The economy is endowed with an initial stock of knowledge:

$$N(0) = N_0 \tag{1.2.5}$$

The infinitely living representative household derives utility from the consumption of homogeneous final good. Preferences are represented by a logarithmic utility function[3]

[1] As it is written in Romer (1990):

> "The distinguishing feature of the technology as an input is that it is neither a conventional good nor a public good; it is a nonrival, partially excludable good. Because of the nonconvexity introduced by a nonrival good, price-taking competition cannot be supported. Instead, the equilibrium is one with monopolistic competition".

[2] Regarding notation, along this document the partial derivative of any time dependent variable with respect to time is introduced as a dot over the variable, e.g. $\frac{\partial x_t}{\partial t} = \dot{x}_t$

[3] A logarithmic utility function is a particular case of a CIES utility function with a coefficient of risk-aversion equal to the unity.

defined by:

$$U(c_t) = \ln c_t \tag{1.2.6}$$

Each household is endowed with the same initial amount of financial assets and one unit of labor which is inelastically supplied. Population with high ability is $L(a_h)$, and the one with low ability as $L(a_l)$. The composition of population into these two groups is exogenous and independent of time. It is always the case that:

$$L = L(a_l) + L(a_h) \tag{1.2.7}$$

It is assumed the $L(a_h)$ population can work for either R&D or final good sector while $L(a_l)$ is allowed to work exclusively for the final sector.

Households also get part of their income from the remuneration of financial assets in their possession.

1.2.2 Equilibrium

We are interested in the characterization of the competitive equilibrium of an economy such as the one previously described.

Final Sector

A firm in the final sector chooses the profit maximizing quantities of intermediate goods and labor taken prices ($p_{j,t}$ and $w_{Y,t}$ respectively) as given. The price per unit of final good is normalized to one. The result of this profit maximization yields firm i's intermediate goods and inverse labor demand functions.

$$x_{i,j,t} = L_{i,t} \left(\frac{A\alpha}{p_{j,t}} \right)^{\frac{1}{1-\alpha}} \tag{1.2.8}$$

$$w_{Y,t} = (1-\alpha) A L_{i,t}^{-\alpha} \sum_{j=1}^{N_t} x_{i,j,t}^{\alpha} \tag{1.2.9}$$

Intermediate Sector

Firms in the intermediate sector undertake a similar profit maximization process. Two situations might arise depending on whether the intermediate good is imitated or not.

Case 1.2.1 *The status of monopoly is preserved*

With probability ν intermediate variety j is not imitated in period t. The patent owner chooses the profit maximizing price $\left(p^*_{j,t}\right)$ according to the demand of the good given in equation 1.2.8.

$$p_{j,t}^{*} = p^{*} = \frac{1}{\alpha} > 1, \text{ for any } j \text{ and } t \tag{1.2.10}$$

This price is higher than one, representing a markup over the marginal cost, and is independent of j (i.e. it is the same for every intermediate good) and time, t.

Given the price, the demand of any intermediate good by firm i is then,

$$x_{i,t}(p^{*}) = L_{i,t}\left(A\alpha^{2}\right)^{\frac{1}{1-\alpha}} \tag{1.2.11}$$

Therefore the total demand of each intermediate good by all firms in the final sector is,

$$x_{t}(p^{*}) = \sum_{i=1}^{M} x_{i,t}(p^{*}) = \left(A\alpha^{2}\right)^{\frac{1}{1-\alpha}} L_{Y,t} \tag{1.2.12}$$

There are positive profits, $\pi_{I,t}(p^{*})$, for intermediate firms since the gap between price and marginal cost is positive.

$$\pi_{I,t}(p^{*}) = \left(\frac{1-\alpha}{\alpha}\right)\left(A\alpha^{2}\right)^{\frac{1}{1-\alpha}} L_{Y,t} \tag{1.2.13}$$

Case 1.2.2 *The good is imitated*

With probability $1-\nu$ intermediate good j is imitated. The patent owner of an imitated good is no longer able to charge the monopolistic price p^{*}. Other intermediate firms would enter the market and compete in prices *à la Betrand* leading prices equal marginal costs and the exhaustion of monopolistic rents.

The demand for any intermediate good given the price being equal to one (which is the marginal cost of production) is

$$x_{t}(1) = (A\alpha)^{\frac{1}{1-\alpha}} L_{Y,t} \tag{1.2.14}$$

To sum up, the following table presents the main results for the two possible scenarios cases studied above concerning any existing variety of intermediate good j:

Monopoly status	Probability	Price	Quantity	Profit
Yes	ν	$\frac{1}{\alpha}$	$(A\alpha^{2})^{\frac{1}{1-\alpha}} L_{Y,t}$	$\left(\frac{1-\alpha}{\alpha}\right)(A\alpha^{2})^{\frac{1}{1-\alpha}} L_{Y,t}$
No	$1-\nu$	1	$(A\alpha)^{\frac{1}{1-\alpha}} L_{Y,t}$	0

From now on, variables are expressed in expectations given the Bernoulli distribution presented above.

R&D Sector

Firms in the R&D sector develops innovations and sell patents to firms in the intermediate sector. A patent is an asset that yields a return at each period. Its value at time t corresponds to the present value of expected future monopolistic rents discounted by the average interest rate between times t and τ, $\bar{r}_{t,\tau}$[4]

$$V_t = \int_t^{\infty} \nu \left(\frac{1-\alpha}{\alpha}\right) \left(A\alpha^2\right)^{\frac{1}{1-\alpha}} L_{Y,\tau} \exp - \left[\bar{r}_{t,\tau} \cdot (\tau - t)\right] d\tau \tag{1.2.16}$$

In the case where $\nu = 0$ the patent is worthless; imitation always occurs and the R&D sector is unable to retrieve any profits.

There is free entry in the R&D sector. At every period, aggregate income in this sector is given by the value of new innovations. The costs consist of the remuneration of the labor used as production factor (wage for researchers). The free-entry condition holds, drawing profits down to zero.

$$\pi_{R,t} = V_t \dot{N}_t - w_{R,t} L_{R,t} = 0 \tag{1.2.17}$$

The equilibrium interest rate equals the value of the innovations in equations 1.2.16 and 1.2.17.

By computing the time derivative in equation 1.2.16, the following value equation for the spot interest rate is obtained,

$$r_t = \frac{\pi_t}{V_t} + \frac{\dot{V}_t}{V_t} \tag{1.2.18}$$

This non arbitrage equation states that the instantaneous interest rate should equal the return to investing in a patent, this is its dividends $\left(\frac{\pi_t}{V_t}\right)$ plus the value gains.

Households

The representative household faces the problem of maximizing intertemporal utility conditional on the sector from which labor income comes from (R and Y representing the R&D and the final good sector respectively), which can be written as:

$$Max \int_0^{\infty} U\left(c_{k,t}\right) \exp\left(-\rho t\right) dt \text{ for } k = R, Y \tag{1.2.19}$$

[4] Mathematically the average interest rate is defined by the following equation:

$$\bar{r}_{t,\tau} = \frac{1}{\tau - t} \int_t^{\tau} r_s ds \tag{1.2.15}$$

Subject to the profile of budget constraints,

$$\dot{b}_{k,t} = w_{k,t} + r_t b_{k,t} - c_{k,t} \text{ for } k = R, Y \text{ and all } t \tag{1.2.20}$$

Where $\rho > 0$ is a constant subjective rate at which households discount future utility. In a different context it might be thought as a parameter representing "altruism" towards future generations' utilities.

In the constraint, $\dot{b}$ represents the household's asset accumulation. Asset accumulation (ie. financial wealth) is represented by shares on intermediate firms and can be assimilated to ownership of knowledge-based assets. It results from the difference between total income (wage plus returns to capital) and total expenses (consumption).

The solution of this maximization program gives the usual Euler equation.

$$\gamma_{c,t} = \frac{\dot{c}_{R,t}}{c_{R,t}} = \frac{\dot{c}_{Y,t}}{c_{Y,t}} = r_t - \rho \tag{1.2.21}$$

This expression holds for workers in both R&D and final sector.

The following equilibrium results and macroeconomic identities are necessary in order to characterise the steady-state in the next section.

First, given the equilibrium demand of intermediate goods and the production function in equations 1.2.1 and 1.2.11, total production in the economy is,

$$Y_t = \sum_i Y_{i,t} = A^{\frac{1}{1-\alpha}} \alpha^{\frac{2\alpha}{1-\alpha}} L_{Y,t} N_t \tag{1.2.22}$$

On the aggregate demand side, both households and intermediate firms demand final output. The former consume it and the latter use it to produce intermediate goods, corresponding to the amount of new discoveries during that period times the equilibrium demand of each input made by firms in the final sector. Hence,

$$Y_t = C_t + N_t x_t = C_t + (A\alpha)^{\frac{1}{1-\alpha}} L_{Y,t} N_t \left[\nu \alpha^{\frac{1}{1-\alpha}} + (1-\nu) \right] \tag{1.2.23}$$

1.2.3 Steady State

The steady state of this economy is characterized by a vector of prices (wages in both sectors, interest rate, price of intermediate inputs and the value of the patent for innovations) such that the rates of growth of the economic variables (production, consumption in both sectors, technological growth and financial assets) and the partitions of the population ($L_{Y,t}$ and $L_{R,t}$) are constant.

Proposition 1.2.1 *In the steady state equilibrium, aggregate consumption, total produc-*

tion of final good, and technology plus labor in the final sector grow at the same rate.

$$\frac{\dot{Y}_t}{Y_t} = \frac{\dot{C}_t}{C_t} = \frac{\dot{N}_t}{N_t} = \gamma^* \tag{1.2.24}$$

Proof. The equality between the first and third terms comes straightforward from the equilibrium output in equation 1.2.22. Because total population is constant, the only rate of growth of $L_{Y,t}$ and $L_{R,t}$ that is consistent in the steady state with the constancy of total population is zero. The second equality is obtained by equating the right hand side of equation 1.2.22 with the right hand side of 1.2.23, dividing each term by $L_{Y,t}N_t$, taking logarithms and deriving with respect to time. ■

Wages

The determination of wages in the steady state must go through the differentiation of two possible cases: one in which wages in the Final and R&D sectors are equal, and the other in which wages in the R&D sector are higher than those in the Final sector. According to the assumption under which workers with high ability are able to be engaged either in the Final of R&D sector, the case where the Final sector pays higher wages than the R&D is not comtemplated as it never arises. If this was the case, an endogenous reallocation of high-ability workers out of R&D and into the Final sector would take place, restoring wage equality.

If wages in the R&D sector are higher than those in the Final sector, the former becomes more attractive to the labor force. As a result of this situation, all skilled individuals (those endowed with high innate ability) prefer to work as researchers and those with low innate ability (unskilled labor) become production workers. I call this case a "separating equilibrium".

When wages are equal in both sectors, the allocation of workers in each one is endogenously determined by the model. This case will be known as "endogenous equilibrium".

I proceed to solve for the steady state under the two cases mentionned above without explaining the determinants that make a given economy to be subject to one or the other scenarios. It will be shown in the next section that this depends on the interaction of exogenous endowments and parameters, in particular the size of the total population and of that of skilled labor.

Case 1 ***"Separating Equilibrium"*** Whenever this case holds, the allocation of workers is given by the following set of equalities:

$$L_{R,t} = L(a_h) \tag{1.2.25}$$

$$L_{Y,t} = L(a_l) \tag{1.2.26}$$

The equilibrium wage in the Final sector corresponds to the marginal productivity of labor given in equation 1.2.9 once the expected equilibrium demand for durables is taken into account,

$$w_{Y,t} = (1-\alpha)\, A^{\frac{1}{1-\alpha}} N_t \alpha^{\frac{\alpha}{1-\alpha}} \left[\nu \alpha^{\frac{\alpha}{1-\alpha}} + (1-\nu)\right] \tag{1.2.27}$$

Notice that the wage in the Final sector is independent of the amount of labor engaged in the production of final output. The specific choice of the production function implies that a change in the number of final labor has two effects on its marginal productivity: on the one hand more workers decrease marginal productivity since the production function has decreasing returns on each productive input, this effect alone implies a decrease in the wage; on the other hand, a larger number of production workers increase the demand for intermediate inputs, increasing the marginal productivity of labor. Both effects cancel out leaving the wage independent of $L_{Y,t}$.

However, a change in the parameter representing IPRs has a non ambiguous effect over final wages. A higher value of ν increases the patent owner's market power reducing the demand of intermediate goods by firms in the Final sector. Less intermediate inputs reduce the productivity of labor in the sector, reducing wages.

The derivation of the wage in the R&D sector is somehow less straightforward. From the non arbitrage condition in equation 1.2.18 (noting that in the steady state the value of a patent is constant, i.e. $\frac{\dot{V}_t}{V_t} = 0$) the value of a patent is equal to the discounted flow of future monopolistic profits. However, the interest rate in that expression is the one equating the rate technological growth and the rate of growth of consumption from the Euler equation in 1.2.21. Once the value of the patent is found in this way, it suffices to replace it in the free-entry condition in equation 1.2.17. The following expression for the R&D wage is obtained.

$$w_{R,t} = \frac{\nu (1-\alpha) \left(A\alpha^2\right)^{\frac{1}{1-\alpha}} L(a_l)\, N_t}{\alpha \left[L(a_h) + \rho\eta\right]} \tag{1.2.28}$$

Stronger protection of IPRs increases the value of the output of the R&D sector, thusly increasing R&D wages.

Both equilibrium wages grow at the rate of growth of technology.

Case 2 ***"Endogenous Equilibrium"*** This case is characterized by the equality among wages in both sectors, which in turn are determined by the marginal productivity of labor in the Final sector.

$$w_{k,t} = (1-\alpha)\, A^{\frac{1}{1-\alpha}} N_t \left[\nu \alpha^{\frac{2\alpha}{1-\alpha}} + (1-\nu)\, \alpha^{\frac{\alpha}{1-\alpha}}\right] \text{ for } k = R, Y \tag{1.2.29}$$

Strengthenings in the IPRs regime reduce wages for both types of workers (i.e. skilled and unskilled) since the distortion introduced by monopolistic pricing increases with ν.

Although relative wages are unchanged, this change in ν implies a reallocation of skilled labor from the Final to the R&D sector as will be shown below.

Auxiliary wage function I compute the relative wage between the R&D and Final sectors by using the ratio of equations 1.2.27 and 1.2.28 in order to construct the following auxiliary relative wage function,

$$\frac{w_{a_h,t}}{w_{a_l,t}} = \frac{L(a_l)}{L(a_h) + \eta\rho}\Phi(\nu) \tag{1.2.30}$$

Where,

$$\Phi(\nu) = \frac{\nu\alpha^{\frac{1}{1-\alpha}}}{\nu\alpha^{\frac{\alpha}{1-\alpha}} + (1-\nu)} \tag{1.2.31}$$

Function $\Phi(\nu)$ verifies $\Phi(0) = 0$, $\Phi(1) = \alpha$ and $\Phi'(\nu) > 0$.

The relative wage is ruled by the auxiliary function according to this expression,

$$\frac{w_{R,t}}{w_{Y,t}} \begin{cases} > 1 & \text{if} \quad \frac{w_{a_h,t}}{w_{a_l,t}} > 1 \quad \Leftrightarrow \quad L > \frac{L(a_h)[\Phi(\nu)+1]+\eta\rho}{\Phi(\nu)} \\ = 1 & \text{if} \quad \frac{w_{a_h,t}}{w_{a_l,t}} \leq 1 \quad \Leftrightarrow \quad L \leq \frac{L(a_h)[\Phi(\nu)+1]+\eta\rho}{\Phi(\nu)} \end{cases} \tag{1.2.32}$$

Whether the economy is characterized by a "Separating" or "Endogenous" equilibrium depends on exogenous parameters of the economy, specifically the IPRs regime, the size of each partition of the population by ability level and the total population.

Consumption, Interest rate, labor allocation and growth

I proceed now to compute the steady state results for the two cases distinguished before.

A result from the solution of the dynamic optimization problem faced by households is used to describe the steady state consumption.

Proposition 1.2.2 *Steady state consumption per worker is:*

$$c_{k,t} = w_{k,t} + \rho b_t, \text{ where } k = R, Y \tag{1.2.33}$$

Proof. By definition, financial assets (patents) grow with technology, therefore $\dot{b}_t = \gamma^* b_t$. By replacing this expression in the household's intertemporal budget constraint we obtain:

$$c_{k,t} = w_{k,t} + \rho b_t$$

The optimal consumption profile is given by consuming the wage plus the excess return of financial assets over the steady state rate of growth. From the Euler equation 1.2.21 applied to the steady state $r^* - \gamma^* = \rho$. Therefore the optimal consumption profile is given by consuming the wage at each period plus a constant fraction ρ of total asset holdings. ■

Case 1 ***"Separating Equilibrium"*** $\Leftrightarrow L > \frac{L(a_h)[\Phi(\nu)+1]+\eta\rho}{\Phi(\nu)}$

Proposition 1.2.3 *In the steady state, output (Y_t), technology (N_t) and per capita consumption for workers in the R&D ($c_{R,t}$)and the Final sector ($c_{Y,t}$) grow at the same constant rate.*

$$\gamma_y^* = \gamma_N^* = \gamma_{c_R}^* = \gamma_{c_Y}^* = \gamma^* \tag{1.2.34}$$

Proof. Comes directly from equations 1.2.33 and 1.2.24 taking into account that the rate of growth of the population in the Final sector is zero since its level is exogenously given by the population with high ability ■

The equilibrium steady state main results in this case are summarized in the following proposition,

Proposition 1.2.4 *The steady state interest rate, rate of growth and allocation of the population among the R&D and Final sectors for an economy in which there is a "Separating Equilibrium" is given by:*

1. *The interest rate is determined by the Euler equation and the rate of growth of innovations.*

$$r^* = \frac{L(a_h)}{\eta} + \rho \tag{1.2.35}$$

2. *The number of workers in the R&D and Final sectors are exogenously given.*

$$L_R^* = L(a_h) \tag{1.2.36}$$
$$L_Y^* = L(a_l) \tag{1.2.37}$$

3. *The rate of growth of product, consumption and technology is determined by the endowment of workers with high innate ability*

$$\gamma^* = \frac{L(a_h)}{\eta} \tag{1.2.38}$$

Both the equilibrium interest rate and the rate of growth are independent of the IPRs regime. The main determinant of the steady state results is the exogenous endowment of population with high ability.

Since wages differ across sectors, so do per capita consumptions. Two consumptions must be considered: one for households with high ability working in the R&D sector and another one for the rest of the labor force in the final good sector. Aggregate consumption plus aggregate savings equal aggegate output. Aggregate savings are represented by the total value of patents (i.e. the value of all financial assets). According to equations 1.2.27,

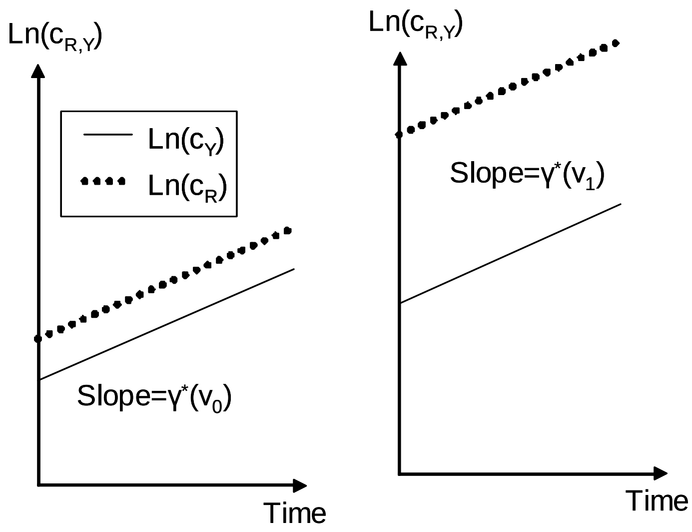


Figure 1.2.1: The effect of an increase in ν from ν_0 to ν_1 in t_0. There is a decrease in per-capita consumption for workers in the final sector and an increase in the consumption of those in the R&D sector. The steady state rate of growth is unchanged.

1.2.28, 1.2.33 and the total resource constraint ($Y_t = N_t X + C_t$),

$$c_{a_l,t} = (1-\alpha) A^{\frac{1}{1-\alpha}} N_t \left[\nu\alpha^{\frac{2\alpha}{1-\alpha}} + (1-\nu)\alpha^{\frac{\alpha}{1-\alpha}} + \frac{L(a_l)\alpha^{\frac{1+\alpha}{1-\alpha}}\eta\rho\nu}{L[L(a_h)+\eta\rho]} \right] \tag{1.2.39}$$

And,

$$c_{a_h,t} = \frac{\nu(1-\alpha) A^{\frac{1}{1-\alpha}} \alpha^{\frac{1+\alpha}{1-\alpha}} L(a_l) N_t (L+\eta\rho)}{L[L(a_h)+\eta\rho]} \tag{1.2.40}$$

Both expressions might be interpreted as containing two different determinants of consumption: on the one hand the wage, and in the other the excess returns of financial assets over the steady state growth rate.

A higher wage allows individuals to consume more. A tightening in the IPRs enforcement reduces the wage in the final sector by reducing the demand of durables and therefore the marginal productivity of labor while increasing the price of the patents, thus the wage in the R&D sector. On the other hand, the level of knowledge-based assets is a positive function of the degree of IPRs protection.

The effect of a decrease in imitation on the level of consumption for workers in the final sector is then negative since the negative effect on wages dominates the positive effect on asset accumulation. Conversely, the two effects move in the same direction for R&D labor, increasing per capita consumption. Figure 1.2.1 provides a graphical representation of this situation.

Case 2 ***"Endogenous Equilibrium"*** $\Leftrightarrow L \leq \frac{L(a_h)[\Phi(\nu)+1]+\eta\rho}{\Phi(\nu)}$ This case represents an equilibrium in which the whole population with low ability works for the final sector while those individuals with high ability are endogenously distributed between the R&D and the final sector, earning the same remuneration in both sectors, i.e. $w_{R,t} = w_{Y,t} = w_t$. The results obtained in the first case no longer hold. The new results are summarized in the following couple of propositions.

Proposition 1.2.5 *The steady state interest rate, rate of growth and allocation of the population among the R&D and Final sectors for an economy in which there is a "Endogenous Equilibrium" is given by:*

1. *The interest rate:*
$$r^* = \frac{(L - L_R^*)}{\eta}\Phi(\nu) \tag{1.2.41}$$

2. *The number of workers in the R&D and Final sectors are constant and endogenously determined.*
$$L_R^* = \frac{L\Phi(\nu) - \rho\eta}{\Phi(\nu)+1} \tag{1.2.42}$$
$$L_Y^* = \frac{L + \rho\eta}{\Phi(\nu)+1} \tag{1.2.43}$$

3. *The rate of growth of product, consumption and technology increases with total population (scale effect).*
$$\gamma^* = \frac{L\Phi(\nu) - \rho\eta}{\eta[\Phi(\nu)+1]} \tag{1.2.44}$$
The interest rate, labor in the R&D sector and the steady state rate of growth increase with ν. Labor in the Final sector decreases with ν.

Proof. I proceed to proof each one of the previous results:

1. By taking the free-entry condition in the R&D sector and plugging in the expression for the wage in the final sector given by 1.2.27 the value of an innovation is obtained. Using this value along with the expression for profits in the Intermediate sector and using the value equation in 1.2.18 the equilibrium interest rate is obtained.

2. Replacing the value of the equilibrium interest rate in equation 1.2.41 in equation 1.2.21 and then using the result stating that in the steady state the rate of growth of consumption is equal to the rate of growth of innovations (given in 1.2.4) it is possible to find the expression of L_R^* in terms of the parameters. An increase in the enforcement of IPRs has a positive effect over the equilibrium distribution of the labor force. Final labor is given by the difference between total population and the equilibrium R&D population.

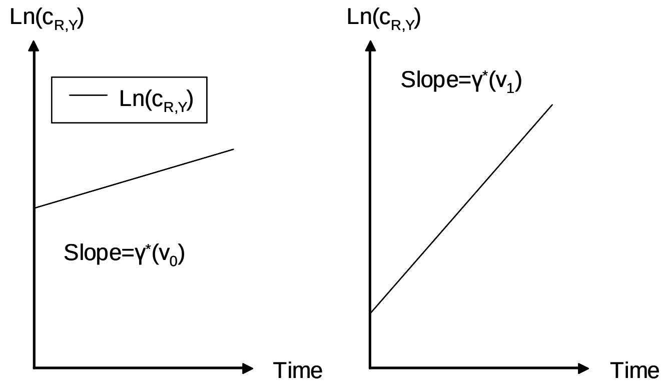


Figure 1.2.2: An increase in IPR protection (ν) generates a negative inmediate decrease in per capita consumption as well as an increase in the steady state rate of growth.

3. Replacing the expression for the number of workers in the research sector defined by 1.2.42 in 1.2.4 it is possible to obtain the rate of growth of the main variables in the economy as a function of the parameters. As the enforcement of property rights increases so does the equilibrium rate of growth. The expression for the rate of growth contains the variable corresponding to the total population. This represents the scale effect.

■

Per capita consumptions are, as wages in the "endogenous equilibrium", equal for households in each sector $k = Y, R$.

$$c_{k,t} = \frac{N_t \left(L + \rho\eta\right) A^{\frac{1}{1-\alpha}} \left(\alpha^{\frac{\alpha}{1-\alpha}} - \alpha^{\frac{1}{1-\alpha}}\right)}{L\left[\Phi\left(\nu\right) + 1\right]} \left[\nu\left(\alpha^{\frac{\alpha}{1-\alpha}} - \alpha^{\frac{1}{1-\alpha}}\right) + (1-\nu)\right] \tag{1.2.45}$$

Per capita consumption decreases with positive changes in the IPRs protection. Two negative effects take place: first, the "intermediate price effect" that is related to the increase in the monopolistic market power of intermediate firms; second, as IPRs protection increases, less labor is allocated to the final sector, curbing the production of consumption good.

Figure 1.2.2 represents the rate of growth and levels of consumption in the steady state following a rise in the IPRs parameter ν. There is an inmediate fall on per capita consumption along with the increase in the steady state rate of growth of the economy.

1.3 Optimal IPRs regime

Up to now we have studied the way intellectual property (understood as the probability of a good protected by a patent being imitated) can be introduced in a general equlibrium model of endogenous growth following the same lines of Romer (1990). Although in order to obtain explicit results I use the assumptions and functional forms of this model, it is most likely that the main conclusions presented here hold for any other first-generation R&D-based models[5]. The characteristic feature of these models is the presence of "scale effects", i.e. the steady state rate of growth of per capita output is proportional to the amount of resources invested in R&D.

Intuitively, the rate of imitation of any final or intermediate good is the result of the interaction of both endogenous and exogenous factors. One may think, for instance, that more recent generations of consumption goods are more likely to be imitated than older generations because the goods in which this new ideas are embodied have become less and less rivals as new technologies emerge. If one accepts this hypothesis as the only cause of imitation, there is little that can be achieved by anti-piracy policies to reverse this situation. Imitation comes from technological intrinsic characteristics peculiar of new generations of consumption goods and nothing can be done to prevent it without altering the good itself. Therefore, one should wonder if the most convenient way of dealing with the probability of imitation is to define an explicit dynamic process governing its evolution and then focusing on the steady state results of such a formulation.

On the other hand, it may also be argued that even if new generations of ideas are embodied in almost non rival goods, there is still room for public intervention in order to control imitation. Following this stream of thought, on October 13th 2008 the U.S. government signed into law the PRO-IP Act. This bill, massively supported by the Recording Industry Association of America as well as the Motion Picture Association of America and the U.S. Chamber of Commerce, envisages the hardening of penalties for movie and music piracy at the federal level. Along with penalties, it is also included in the text the appointment of an "Intellectual Property Czar" (reporting directly to the US president), and the possibility of civil lawsuits being filed by the Justice Department against infringers. Similar measures have been adopted in other OECD countries. Recently, the French National Assembly approved what is considered to be the most radical piece of anti-piracy legislation currently in force. What is also called as the "three-strikes" bill considers the suspension of internet services for customers caught illegally sharing copyrighted material after two warnings. Controversy is, however, not absent from the discussion, since the European Parliament opposes the termination of a customer's internet access without a court order for any E.U. government. According to the entity, internet access is a fundamental right standing side by side to freedom of expression or access to information. If we believe the IPRs regime in an economy is indeed a policy variable, and if the costs of implementing a certain level of property protection (e.g. creating the necessary institutions, monitoring potential infractors, designing and implementing new anti-piracy

[5]Other such models are Grossman and Helpman (1991), Segerstrom et al. (1990) and Aghion and Howitt (1992).

technologies) and its benefits are measurable, then it should be the case that this level is the result of a cost-benefit analysis undertaken by some appropriate authority.

The purpose of this section is to do neither one of the two proposed ways of modelling the IPRs regime , i.e. including a law of motion for the probability of imitation and compute its steady state level; or defining a cost function which increases in the IPRs level and then deriving the corresponding optimum level of imitation. These might be the subject of future research in the field but are out of the scope of this article.

Both the recent OECD legislation and the TRIPS agreement seem to indicate that full protection of IPRs is a desirable goal *per se*, and its achievement a public concern. In the first case this set of measures have proved to be extremely impopular among voters since it is not clear whether it might have negative implications on the users' fundamental rights. Imposing the same measures on developing countries adds another negative effect whenever imitation is the only access to vital goods such as generic medicines.

I intent to use the equilibrium results from the previous section in order to verify or deny the ubiquitous agreement with respect to the desirability of the strong and homogeneous enforcement of IPRs contemplated in the TRIPS. Considering both the static and dynamic implications of changes in the IPRs regime in the two wage scenarios, I find a continuous (although not differentiable) function of the optimal probability of non imitation as the value of ν that maximizes the expected discounted future utilities derived from the equilibrium consumption growing at the equilibrium rate of growth. In other words, my results might be interpreted as the answer given by an agent working for the R&D or Final sectors to the question: In the context of decentralized equilibrium and given the endowments (population size, ability distribution of individuals and initial technology) and the parameters of this economy, what level of Intellectual Property Protection would you prefer?

1.3.1 Derivation

Case 1 ***"Separating Equilibrium"*** $\Leftrightarrow L > \frac{L(a_h)[\Phi(\nu)+1]+\eta\rho}{\Phi(\nu)}$ In this case, from equations 1.2.40 and 1.2.39 it is straightforward to show that perfect protection of IPRs maximizes welfare for workers in the R&D sector ($\nu_R^* = 1$) whereas workers in the Final sector prefer the lowest possible IPRs regime.

Welfare maximization is written as the value of discounted intertemporal utilities starting from an arbitrary period $t = 0$. In the steady state per capita consumption grows at a constant rate γ^*.

$$\nu_i^* = \arg\max_{\nu} \int_0^{\infty} U\left[c_{a_i,0}(\nu)\exp(\gamma^* t)\right]\exp(-\rho t)\, dt \text{ for } i = l, h \tag{1.3.1}$$

The steady state rate of growth and interest rate are both independent of ν. It is then only through consumption (equations 1.2.39 and 1.2.40) that IPRs protection affects welfare. Since per capita consumption in the R&D (Final) sector is a positive (negative) function of ν, workers in this sector maximize welfare under the highest (lowest) possible IPRs regime. There is thus a conflict of interests in the choice of the IPRs standard for workers with different levels of ability.

Notice that in this case the lowest possible IPRs regime is not $\nu = 0$ since the relative wage is a positive function of ν. In other words, setting $\nu = 0$ implies that the "separating equilibrium" no longer holds. There is a strictly positive value of ν (called $\bar{\nu}$) that verifies the auxiliary equation in 1.2.30 with equality[6]. This value corresponds to:

$$\bar{\nu} = \frac{L(a_h) + \eta\rho}{\alpha^{\frac{1}{1-\alpha}} L + \left(1 - \alpha^{\frac{\alpha}{1-\alpha}} - \alpha^{\frac{1}{1-\alpha}}\right) L(a_h) + \left(1 - \alpha^{\frac{\alpha}{1-\alpha}}\right) \eta\rho} \tag{1.3.2}$$

As ν goes down, so does the relative wage; whenever ν reaches $\bar{\nu}$, the relative wage attains the unity and the economy moves to the second case.

Case 2 ***"Endogenous Equilibrium"*** $\Leftrightarrow L \leq \frac{L(a_h)[\Phi(\nu)+1]+\eta\rho}{\Phi(\nu)}$ This case is characterized by a trade-off between consumption and rate of growth. Given that wages in both sectors are equal, there is no longer a conflict of interest among workers. Now there is a representative worker whose welfare characterizes the preferences of labor both in the R&D and final sector.

We are interested in the ν that maximizes the discounted future utility given by:

$$\nu^* = \arg\max_{\nu} \int_o^{\infty} U\left[c_{a_i,0}(\nu) \exp\left[\gamma^*(\nu) t\right]\right] \exp(-\rho t)\, dt \text{ for } i = l, h \tag{1.3.3}$$

Where per capita consumption is given by 1.2.45 and the steady state rate of growth γ^* by 1.2.44.

Equation 1.3.3 summarizes the traditional trade-off regarding optimal IPRs protection. On the one hand, a higher ν decreases welfare at two levels: first, it increases the distortion due to monopolistic pricing in the intermediate sector; and second, it decreases the production of the final good by allocating less workers to the Final sector. On the other hand, welfare is affected positively by IPRs protection via the higher rate of growth of consumption induced by more workers in the R&D sector.

Solving the maximization program in 1.3.3 yields the optimal level of IPRs (v^*) implicitly as the solution of the following reduced-form quadratic equation:

$$A\nu_i^{*2} + B\nu_i^* + C = 0 \text{ for } i = l, h \tag{1.3.4}$$

[6] $\bar{\nu}$ verifies $L(a_h) = \frac{L(a_l)\Phi(\bar{\nu}) - \eta\rho}{\theta}$ this is to say that $\bar{\nu} = \Phi^{-1}\left[\frac{L(a_h)\theta + \eta\rho}{L(a_l)}\right]$ which together with the fact that $L = L(a_h) + L(a_l)$ gives the desired result.

With,

$$A = \rho\eta\left(\alpha^{\frac{1}{1-\alpha}}+\alpha^{\frac{\alpha}{1-\alpha}}-1\right)^2\left(\alpha^{\frac{\alpha}{1-\alpha}}-1\right) \tag{1.3.5}$$

$$B = \alpha^{\frac{1}{1-\alpha}}\left[L\left(\alpha^{\frac{1}{1-\alpha}}-1\right)-\rho\eta\alpha^{\frac{1}{1-\alpha}}\right] \tag{1.3.6}$$

$$+\rho\eta\left(\alpha^{\frac{1}{1-\alpha}}+2\alpha^{\frac{\alpha}{1-\alpha}}-2\right)\left(\alpha^{\frac{\alpha}{1-\alpha}}+\alpha^{\frac{1}{1-\alpha}}-1\right) \tag{1.3.7}$$

$$C = \alpha^{\frac{1}{1-\alpha}}L+\rho\eta\left(\alpha^{\frac{\alpha}{1-\alpha}}+\alpha^{\frac{1}{1-\alpha}}-1\right) \tag{1.3.8}$$

According to the optimality condition 1.3.4, total population L determines the optimal degree of imitation. For instance, having every innovation being imitated with a probability one (i.e. $v^*=0$) is optimal for a country of size L_0 or lower, defined as:

$$L_0=\frac{\eta\rho\left(1-\alpha^{\frac{\alpha}{1-\alpha}}-\alpha^{\frac{1}{1-\alpha}}\right)}{\alpha^{\frac{1}{1-\alpha}}}>0 \tag{1.3.9}$$

Applying the Implicit Function Theorem to the quadratic function determining ν^* in 1.3.4 it is possible to compute the effect of changes in the population size over the optimal IPRs regime. As population increases so does ν^*. The reason why it is optimal for workers in bigger economies to have stronger IPRs comes from the very nature of the role it plays on the determination of welfare. The positive effect arising from higher IPRs protection goes through its dynamic effect on the rate of growth of the economy. Since the rate of growth is determined by the size of the population so does the magnitude of the positive effect mentioned before. Economies with larger populations experience a higher increase in welfare coming from higher degrees of IPRs than smaller economies. Yet the negative effects (monopolistic pricing and allocation of the workforce among the two sectors) are independent of the size of the population.

Following the same procedure it is possible to find the level of population for which perfect enforcement of IPRs (i.e. $\nu^*=1$)is desirable. Hereafter designed as L_1 it is defined by:

$$L_1=\eta\rho\left[\left(1-\alpha^{\frac{\alpha}{1-\alpha}}-\alpha^{\frac{1}{1-\alpha}}\right)\left(\frac{1+\alpha}{\alpha}\right)+1\right] \tag{1.3.10}$$

Workers living in a country of at least size L_1 maximize their intertemporal welfare by setting IPRs protection as high as possible.

1.3.2 Graphical representation of the optimal IPRs protection

Figure 1.3.1 relates the optimal degree of IPRs protection and the size of the economy. The dashed line represents the IPRs protection that maximizes intertemporal utility for workers in the R&D sector (ν_R^*), and continuous line for workers in the final sector (ν_Y^*).

A total population lying between the origin and $\frac{L(a_h)(1+\alpha)+\eta\rho}{\alpha}$ corresponds to the case

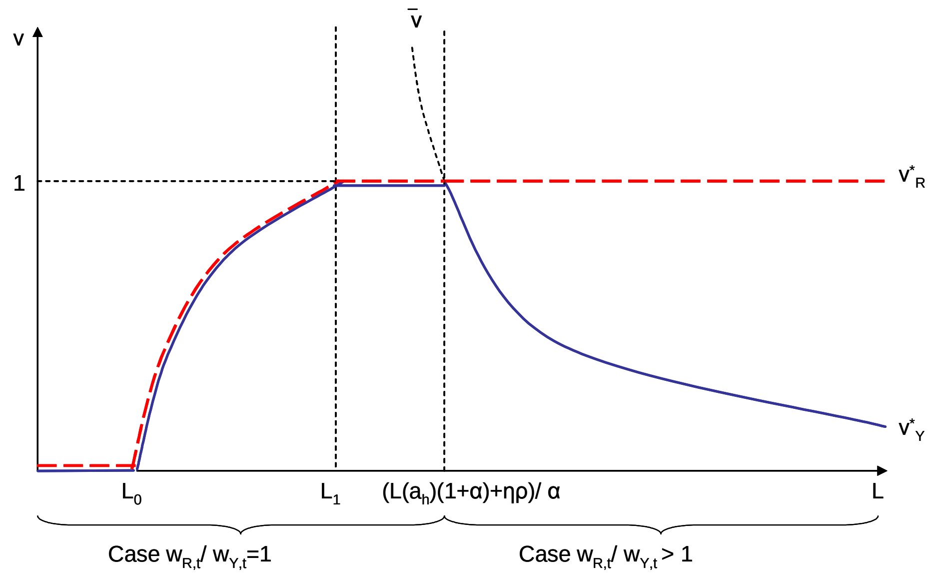


Figure 1.3.1: The dashed line (ν_R^*) represents the optimal degree of IPRs for workers in the R&D sector. The continuous line (ν_Y^*) is its analogous for workers in the Final Sector.

in which the relative wage is equal to one and the optimal degree of IPRs is a positive and concave function of the size of the economy. This segment is shared by workers in both sectors. Once the population is higher than the threshold given by $\frac{L(a_h)(1+\alpha)+\eta\rho}{\alpha}$ the economy moves into the "separating equilibrium" in which the optimal degree of IPRs is no longer the same for workers in different sectors. Those individuals in the R&D sector maximize their future utility by setting ν as high as possible, but for the rest of the labor force utility maximization implies reducing IPRs standard to its lowest possible level while still being in the "separating equlibrium". For instance, if the total population was somewhere at the rigth of $\frac{L(a_h)(1+\alpha)+\eta\rho}{\alpha}$ and the current IPRs protection was given by $\nu = 1$, workers in the final sector would be better off with less stringent IPRs. As the standard decreases, so does the relative wage. When the relative wage attains the unity it is no longer desirable to curb IPRs protection any further since additional reductions would make the economy move to the case with equal wages in the two sectors. IPRs protection in this environment would act as a policy variable aimed to eliminate wage inequalities. The value of the lowest ν which verifies $\frac{w_{R,t}}{w_{Y,t}} = 1$ is a decreasing function of L and it is represented by the function $\bar{\nu}$.

According to what has been discussed, the **position** of the economy in the horizontal axis is given by the total population whereas the **shape** of the graph is defined by the population with high ability. It is therefore the composition of the population what matters for the determination of the optimal degree of IPRs. A very big economy in terms of its total population with a very reduced number of highly skilled individuals is more likely to fall in a "separating equilibrium" than an economy of the same size with less low-skilled workers.

Proposition 1.3.1 *Given the total population in the economy and the allocation of its population among the two productive sectors (R&D and consumption good), one of two scenarios might be observed:*

- *For "balanced" economies (those with a high enough number of high-skilled individuals, represented by the "endogenous equilibrium") the optimal IPRs standard is an increasing function of the total population. Wages are the same in both sectors and workers with high ability are allocated in the R&D and final sector.*
- *For "unbalanced" economies (those with a small number of high-skilled workers relative to the total population, represented by the "separating equilibrium") the optimal IPRs protection is the highest possible for workers in the R&D sector. For workers in the Final sector it is a decreasing function of the total population, reaching a complete absence of IPRs asymptotically.*

1.4 Conclusions

The model discussed in the present document follows Romer's (1990) model of technological change. There are three sectors in the economy: R&D (blueprints of intermediate goods), intermediate goods (manufacturing of intermediate goods) and final good (production of consumption good). Economic growth is driven by technology understood as an enlargement of the set of horizontally differentiated varieties of intermediate goods. New varieties might be imitated and sold at their marginal cost with a probability related to the standards of protection of IPRs (Intellectual Property Rights). The population is exogenously divided into individuals with high and low ability (the first are able to work in R&D or production of final goods and the latter only in the final sector).

Being faced with the situation of a variation on the enforcement of Intellectual Property Rights may result (depending on the relative wage) in a trade-off between consumption today and tomorrow or a conflict of interests between population working for the R&D or the final sector.

If we are in the situation in wich the relative wage equals one, the IPRs regime affects both consumption today and consumption tomorrow in opposite ways. On the one hand tightening IPRs has a positive effect on the rate of growth of the product, technology and, most importantly, consumption. Nonetheless this measure has a negative contemporaneous effect over society's welfare by increasing the prices of intermediate goods and, consequently, reducing their demand. The reduction on demand causes a fall in the amount of final good produced and consumed by households. The choice between increasing current consumption and consuming more in the future must be made, and the result of this decision is affected by the degree of impatience of agents or, alternatively, the degree of altruism across generations.

The other possible situation in the economy is when the relative wage is higher than one, with the labor force being distributed between the R&D and the Final sector depending on their levels of innate ability. The results from the previous section imply that welfare is affected by IPRs only through its effects on consumption. However, this effect on consumption is negative for labor used as production factor in the final good technology, and positive for workers producing innovations. One might think the final decision will depend on which one of the two groups is bigger (in the case of the IPRs regime being decided democratically), or on the weights given by the policy makers (social planner) to the consumption of each partition of the labor force.

Chapter 2

Enforcement of Intellectual Property Rights, Knowledge Diffusion and Heterogeneous Labor

2.1 Introduction

The Trade-Related Aspects of Intellectual Property Rights (TRIPS) agreement is considered as the most ambitious effort regarding Intellectual Property Rights (IPRs) protection ever taken. It was proposed in the framework of the last and largest round of the GATT organization, the Uruguay Round (from 1986 to 1994), leading also to the creation of the World Trade Organization (WTO) taking effect on the 1st January 1995.

The TRIPS agreement covers all areas of intellectual property[1]. Its principles are based on previous agreements on specific areas of intellectual property such as the Paris Convention for the Protection of Industrial Property (patents, industrial designs, etc), and the Berne Convention for the Protection of Literary and Artistic Works (copyrights and related rights). They share common features with other treaties undertaken outside the WTO, which are basically non-discriminatory provisions such as "national treatment" (i.e. no distinction between locals and foreigners), and "most-favoured-nation (i.e. no distinction between all trading partners within the WTO). In particular, the treaty defines minimum standards of protection and enforcement of IPRs to be provided by each signatory country, and a set of dispute settlement procedures between fellow members.

The main motivation behind the existence of such institutional framework is a rather simple one: the spur of private innovation through the appropriation of economic rents. Indeed, any form of IPRs is intended to help alleviate what Schumpeter referred to as the "appropriability problem" faced by innovators. This is to say, the difficulty of the owner

[1] These areas are copyrights and related rights, trademarks, geographical indications, industrial designs, patents, layout-designs of integrated circuits, and undisclosed information.

to extract the social value (or part of it) from a piece of knowledge in order to recover the costs associated with its production.

The intensity and relevance of the debate surrounding the role played by IPRs in modern economies has not decreased ever since. A sector of the opinion in the developed world fears the arrival of new technologies that facilitate unauthorized exchanges of goods protected by IPRs, and the consequent erosion of incentives for innovation. The film, literary and music industries put forward the extensive spread of internet and file-sharing technologies all over the world, and the difficulties to regulate its contents, as a thread to the future of creative activities. Voices from policymakers and private firms in developed countries plead for more stringent IPRs, while the costs of doing so seem to increase over time. Even though most of the measures contained in the TRIPS agreement existed already in their legal systems, the treaty allowed developed countries a one-year period for the implementation of those that were lacking.

In order to ensure their laws and practices were in line with the TRIPS, developing and (under some conditions) transition economies were given until 2000; while least-developed countries (LDCs) have until 2013 in all areas except for pharmaceutical patents and undisclosed information (i.e. 2016 in these cases). Everything seems to indicate that after 15 years of TRIPS experience the debate regarding the implications of strengthening IPRs in developing countries and LDCs is far from making a consensus among different sectors of the society.

The goal of this chapter is to contribute to this discussion by shedding light on the role played by international knowledge spillovers on the R&D activity within a country. Economic theory has identified two channels through which IPRs affect economic activity in a closed economy. In the first place, static distortions created by the market power given by IPRs; secondly, the incentives for innovation coming precisely by the perspectives of monopolistic rents. In the case where interactions between countries in an open economy are present, these relations may not hold and/or some new may arise. We consider the case in which a small economy benefits from the stock of knowledge accumulated by a larger and technologically advanced country. In particular we assume that this small economy undertakes R&D activities, and that researchers in the R&D sector use the world's stock of knowledge to create new goods. Alternatively, one might interpret the R&D process taking place in the developing world as one where the adaptation of varieties of intermediate goods developed in the developed world is a costly activity that requires similar inputs as a the innovative activity itself. This case may correspond both to developing countries and LCDs interacting with developed economies. We find that this simple modification of the innovation function implies that all regions of the world converge to the same steady state rate of technological progress independently of the strength of the institutions related to IPRs. While this result is already present in neoclassical models of growth with capital accumulation, our result is driven by interregional technological spillovers within the R&D

sector. Furthermore, even when the world rate of technological progress is independent of the degree of protection of intellectual property rights in the developing and less-developed countries, there may still be dynamic incentives for these economies to strengthen IPRs in order to catch-up with the more developed world. In fact, the benefits from doing so may dominate the negative "market power" effects discussed above. Another interesting finding is that the traditional tradeoff of static distortions versus dynamic incentives of IPRs may be replaced by a different one regarding per capita consumption for skilled versus unskilled workers. This situation arises for a range of IPRs strength in which all skilled labor is allocated into the R&D sector. In this case welfare for unskilled labor is maximized for an IPRs regime that is weaker than the one that maximizes welfare for skilled labor. The difference between these two measures of strength of IPRs is a function of the size of the economy, in particular the composition of the labor force between skilled and unskilled labor.

To sum up, the presence of interregional knowledge spillovers can affect the traditional analysis regarding the optimality of a given policy affecting the degree of IPRs in the developing world.

This chapter continues a research thread on the manner IPRs affect economic activity. Judd's (1985) seminal work laid down the formal basis of what became the main warhorse on this area. He proposed a general equilibrium model of expanding varieties with monopolistic competition. It is shown that in a world with CES preferences, identical innovation costs for all goods and constant marginal costs of production, infinitely living patents are sufficient for the optimum to be implemented by the decentralized equilibrium. This result is partially consistent with findings by Gilbert and Shapiro (1990). Their work focuses on the optimal combination of two dimensions of patent design: length and breadth. They find that the socially cost-effective way to achieve a given reward to innovators is to have infinitely-lived patents with the minimum market power necessary to attain the required reward level.

This basic framework for analyzing the desirability of IPRs coming from the comparison of the negative welfare effects of market power and the positive effects on innovation in a closed economy needs to be modified for the case of several linked economies. Consider a world composed of a given number of separated but interacting regions with potentially asymmetric regimes of intellectual property protection. In the context of the TRIPS we can focus our attention to a situation in which there are only two regions: a developed region, "the North"; and a developing one, defined as "the South". Let us assume the North's IPRs system are stronger than the one in the South. What incentives does the South have to increase its IPRs standards? The WTO claims that by doing so, the South would "contribute to the promotion of technological innovation and the transfer and dissemination of technology... in a manner conductive to social and economic welfare" (TRIPS Agreement, article 7).

Some academic work points out to the same direction. Diwan and Rodrik (1991) argue that an increase in the IPRs regime of the South gives incentives to innovative firms in the North to produce varieties closer to the South's specific tastes. Taylor (1994) focuses on the implications of the "national treatment" principle in a global context. He finds that the implementation of this principle (such as it is included in the provisions of the TRIPS) has a positive effect on the world's innovation rate that benefits both the North and the South. However, for the South, this dynamic effect comes at the cost of a once and for all fall in wages. The total welfare effect is therefore positive for the North and ambiguous for the South. A similar result is obtained by Deardorff (1992) for the effects of an expansion of IPRs from the innovative region to the rest of the (non innovative) world. Even though the world gains as a whole at the beginning of the process, these gains are unevenly shared by the different participants. Indeed, in the absence of interregional transfers, welfare for the innovative region increases at the expense of the other region.

Helpman (1993) considers a world in which all innovation is undertaken in the North, while the South engages exclusively in costless imitation. He concludes that the enforcement of IPRs in the South is always harmful for that region, while it may or not benefit the North. A more recent work by Grossman and Lai (2004) considers the strategic behavior of the IPRs standards for the North and the South in a context in which those regions differ on market size and in productivity of their R&D sectors. It is shown that the optimal degree of patent protection in the South is always lower than the one in the North. Given this results it is straightforward to see that any international treaty conducing to IPRs harmonization (to a level that corresponds to the optimal one from the North's perspective) implies a deviation of the South's optimal behavior and, therefore, harms welfare.

In the present work we allow the South to engage in innovation (a parallel interpretation of this formulation is that the adaptation of existing goods is costly and requires the same inputs and shares the same technology as the innovation process) and to benefit from the stock of knowledge developed in the North. Our model provides a description of the effects of an increase in the IPRs regime for workers with different levels of ability, allowing for intersectoral reallocation of productive inputs. We argue that the present exercise helps to further understand the desirability of such measures as the ones contained in the TRIPS by focusing on the general equilibrium implications of IPRs in the realistic case of free flows of knowledge between the R&D sectors of all regions in the world.

The organization of the article is as follows. Section 2 introduces the basic model focusing on the particular production technologies and preferences of the different agents in the economy, and the existing set of institutions (regarding IPR protection in particular). Section 3 presents the behavior of agents in the decentralized equilibrium. We distinguish among the two cases regarding relative wages between the Final and R&D sectors in order to characterize the behavior of the technological gap between the two regions, the steady state results and the effects of an increase in the IPR regime. Second best optimality regarding IPR regimes is tackled in section 4. Finally, section 5 concludes.

2.2 Basic Model: Technologies, Preferences and Institutions

The present model enlarges the scope of our previous research on incomplete enforcement of IPRs with heterogeneity in innate ability in a closed economy by considering the interactions between two asymmetric economies. It corresponds to a "North-South" setup composed of a "big" and a "small" economies.

The South is modelled as an economy consisting of three productive sectors. A final/consumption/homogeneous good is produced in a competitive Final sector from the combination of labor and intermediate inputs. These intermediate inputs are produced in the Intermediate sector. With some probability each variety of intermediate differentiated inputs is produced by a monopolist who owns a patent for each particular variety. Otherwise costless imitation occurs and Bertrand competition drives profits down to zero and prices to marginal costs. Finally, the R&D sector produces blueprints of intermediate varieties by means of skilled labor and the stock of knowledge in the world. Households in this economy are composed by infinitely living agents that can be of two types: unskilled and skilled. Unskilled labor works exclusively for the Final sector in the production of the homogeneous good; whereas skilled labor can be engaged in the production of the homogeneous good or participate in R&D activities.

Although the basic lines of the model come from Romer (1990) there are three main differences between the two models: (i) Instead of considering homogeneous agents with equal productivity in the production of homogeneous good or the discovery of new intermediate inputs, we consider a simple case of heterogeneity in abilities; (ii) we consider the case in which an intermediate good is produced by a firm other than the patent owner and we associate the probability of this situation arising to the level of protection of IPRs in the economy (in Romer the probability of imitation is zero); and finally, (iii) R&D labor in the South uses the world's stock of knowledge to produce blueprints of new intermediate inputs (or alternatively, adapting already existing varieties developed in the North) whereas Romer analyzed the case of a closed economy in which the only available stock of R&D was composed of the set of domestic past innovations.

Coe and Helpman (1995) show that the productivity in a country is not only affected by domestic R&D but also by R&D activities undertaken by trade partners. This effect is stronger, the larger the share of imports in GDP. We go one step further by assuming that world knowledge (i.e. the output of R&D activities) is publicly available from any geographical location to labor engaged in R&D. New generations of Information Technologies and the public character of patents provide an argument in favor of this assumption.

As explained before, what follows concerns only the behavior of our "small" economy. As it is usually used in this kind of literature, this economy represents the South, as opposed to the "big" economy representing the North. Superscripts are not used except fot the variables representing the stock of ideas in the North and the South (N_t^N and N_t^S, respectively), the accumulation of them ($\dot{N}_t^N$ and $\dot{N}_t^S$) and the rate of growth of the North (γ^N).

The homogenous final good is considered to be a conventional good (rival and excludable) produced according to the following production function proposed by Ethier (1982):

$$Y_{i,t} = AL_{i,t}^{1-\alpha} \int_0^{N_t^S} x_{i,j,t}^{\alpha} dj, \text{ for all } i \text{ with } \alpha \in (0,1) \tag{2.2.1}$$

$Y_{i,t}$ represents the amount of final good produced by firm i at time t, using labor ($L_{i,t}$), and intermediate goods ($x_{i,j,t}$) as inputs. A is a productivity parameter fixed over time. N_t^S is the number of different varieties of intermediate goods that have been developed in the South up to time t. The production function has constant returns to scale and all intermediate goods have additively separable effects on output.

The number of firms in this sector is assumed to be large enough in order to have perfect. The total number of workers in all firms is equal to the labor force in the final good sector, $L_{Y,t}$:

$$\sum L_{i,t} = L_{Y,t} = L - L_{R,t} \tag{2.2.2}$$

Which, in turn, is equal to the whole population (L) excluding the labor force in the R&D sector ($L_{R,t}$). The economy is endowed with population L assumed to be constant. We assume no interregional movements of labor.

There are as many firms in the Intermediate sector as the number of intermediate goods in the economy. The production technology is a one-to-one relation between the final good and the intermediate good, i.e. one unit of final good is transformed into one unit of any variety of intermediate good.

There is imperfect competition due to the particular nature of innovations[2]. In other words, although knowledge itself is a purely public good, goods used as production inputs in which a particular piece of knowledge is embodied are protected by patents and are therefore rival and excludable goods. Once a new variety has been invented, the R&D sector sells a patent that grants the right to be the only producer of that particular good. The monopolist charges the price for the intermediate good that maximizes its profits.

[2] As it is written in Romer (1990):

> "The distinguishing feature of the technology as an input is that it is neither a conventional good nor a public good; it is a nonrival, partially excludable good. Because of the nonconvexity introduced by a nonrival good, price-taking competition cannot be supported. Instead, the equilibrium is one with monopolistic competition"

Incomplete enforcement of IPRs is represented by the probability of a particular patent being violated, and the input protected by it being imitated and sold at its competitive price. From now on we assume that there is a probability ν faced by the owner of a given patent to act as a monopoly. Therefore, there is a probability $1-\nu$ of an intermediate good being imitated. All patents face the same probability of imitation, by the Law of Large Numbers as the amount of available technologies increases, the fraction of intermediate firms whose patent is imitated converges to the actual probability of imitation.

The R&D sector produces new varieties of intermediate goods represented by blueprints.(indistinctly called knowledge, inventions, technologies, or ideas) understood as varieties of intermediate goods that were previously not used in the economy. New inventions enlarge the span of the stock of knowledge. Previous technologies do not disappear or become obsolete[3]. The function governing the accumulation of knowledge is given by:

$$\dot{N}_t^S = \frac{N_t^W L_{R,t}}{\eta} = \frac{\left(N_t^N + N_t^S\right) L_{R,t}}{\eta} \tag{2.2.3}$$

Technological progress comes from the interaction of the current stock of ideas in the world[4] ($N_t^W = N_t^N + N_t^S$) and the labor force in the R&D sector ($L_{R,t}$) where η is a constant technological parameter.

The rate of technological growth γ_t, can be expressed as:

$$\frac{\dot{N}_t^S}{N_t^S} = \gamma_{N^S,t} = (1 + z_t) \frac{L_{R,t}}{\eta} \tag{2.2.4}$$

With $z_t = N_t^N / N_t^S$ represents the North-South technological gap as the ratio between the stock of knowledge developed in the North and in the South.

There is free-entry in this sector. The economy is endowed with a stock of knowledge at time zero.

$$N^S(0) = N_0^S \tag{2.2.5}$$

The infinitely living representative household obtains utility from the consumption of homogeneous good. This consumption comes from the wage in the Final or R&D sectors and from the return of asset holdings. Following this idea it is convenient to distinguish between consumption for workerd in the Final and R&D sectors. Preferences are represented by a logarithmic utility function[5] defined by:

$$U\left(c_{k,t}\right) = \ln c_{k,t} \text{ where } k = Y, R \tag{2.2.6}$$

[3]Each variety of intermediate goods enters separately in the production function and verifies the Inada conditions.

[4]Defined as the joint stock of ideas in the North and the South.

[5]A logarithmic utility function is a particular case of a CIES utility function with a coefficient of risk-aversion equal to the unity.

In the expression above Y and R represent the Final and R&D sectors respectively.

Financial assets represent claims over the ownership of firms in the Intermediate sector. Each household is endowed with the same initial amount of financial assets and one unit of labor which is inelastically supplied.

2.3 Decentralized Equilibrium

We are interested now in the characterization of the decentralized equilibrium of an economy such as the one described above. We proceed as follows: we describe the behavior of the different agents in the economy and we present a set of preliminary results. In order to find the remaining results it will be necessary to consider two different cases regarding R&D and Final sector relative wages. We describe the transitions of the model (implied by the evolution of the North-South technological wage) to the steady state for each one of the two equilibria. Once all results are presented we use them in order to derive the model's implications regarding an increase in the overall level of IPRs in the South. This situation is expected to arise under the implementation of the TRIPS agreement. Finally we present the conditions on the economy for one or the other equilibria mentioned before to apply.

Definition 2.3.1 *A private equilibrium is defined as vectors of quantities and prices at each date* $\{t\}_0^\infty$ *such that:*

- *Firm i in the Final sector chooses the amounts of intermediate inputs* $\{x_{i,j,t}\}_{j=0}^{N_t^S}$ *and Final labor* $\{L_{i,t}\}$ *that maximize Final profits taking factor prices* $\{p_{j,t}; w_{Y,t}\}_{j=0}^{Nt^S}$ *respectively, as given.*

- *Firm j in the Intermediate sector chooses the price of intermediate variety j,* $\{p_{j,t}\}$*, that maximizes its profits given the demands for intermediate inputs from firms in the Final sector.*

- *The R&D sector sells patents for blueprints of intermediate inputs to the Intermediate sector at a value* $\{V_{j,t}\}_{j=0}^{\dot{N}_t^S}$*, subject to the free-entry (or no-profit) condition in the sector and taking the profile of interest rates* $\{r_t\}$ *as given.*

- *Households choose the consumption profile* $\left\{c_{k,t}^h\right\}_{h=1}^L$*, where* $k = Y, R$*, that maximizes intertemporal utility under the dynamic resource constraint taking the profile of interest rates* $\{r_t\}$ *and wages* $\{w_{k,t}\}$ *as given.*

The price of the final good is normalized to the unity and taken as the numeraire.

2.3.1 Results

We present the results derived from Definition 3.1. Long-term general equilibrium results (i.e. the division of population between the Final and R&D sectors, the interest rate and rate of growth of the economy) are presented in a subsequent section. This set of results along with the ones from the steady-state will allow us to compute an expression for households' discounted utility and undertake the welfare analysis of the different IPRs regimes for skilled and unskilled workers.

The equilibrium demands for intermediate good j by firm i in the final sector and the equilibrium inverse labor demand function are given by the following two expressions.

$$x_{i,j,t} = L_{i,t} \left(\frac{A\alpha}{p_{j,t}} \right)^{\frac{1}{1-\alpha}} \tag{2.3.1}$$

$$w_{Y,t} = (1-\alpha) A L_{i,t}^{-\alpha} \int_0^{N_t^S} x_{i,j,t}^{\alpha} dj \tag{2.3.2}$$

With probability ν, firm j in the intermediate sector sets a price $p_{j,t}^*$ for intermediate good j according to a profit maximization process facing the demand for intermediate goods by the firms in the final sector in equation 2.3.1.

$$p_{j,t}^* = p^* = \frac{1}{\alpha} > 1, \text{ for any } j \in \left[1, N_t^S\right] \text{ and any } t \tag{2.3.3}$$

Where p^* is the monopolistic equilibrium price. This price is higher than the marginal cost (i.e. one) representing the monopolistic markup and is independent of j (i.e. it is the same for every intermediate good). In more general terms, the markup equals the inverse elasticity of demand.

Given the monopolistic price, the demand of every intermediate good by firms in the final sector becomes:

$$x_t(p^*) = \left(A\alpha^2\right)^{\frac{1}{1-\alpha}} L_{Y,t} \tag{2.3.4}$$

There are positive profits, $\pi_{I,t}$, for intermediate firms since the gap between price and marginal cost is positive.

$$\pi_{I,t}(p^*) = \left(\frac{1-\alpha}{\alpha} \right) \left(A\alpha^2\right)^{\frac{1}{1-\alpha}} L_{Y,t} \tag{2.3.5}$$

With probability $1-\nu$ intermediate good j is imitated. The patent owner no longer acts as a price-setter. Instead, other intermediate firms start producing intermediate good j and engage in Bertrand competition with the patent owner drawing the price down to the marginal cost.

Under imitation, the demand for intermediate good j by firms in the Final sector increases and monopolistic rents vanish.

$$x_t(1) = (A\alpha)^{\frac{1}{1-\alpha}} L_{Y,t} \tag{2.3.6}$$

$$\pi_{I,t}(1) = 0 \tag{2.3.7}$$

The following table presents a summary of the expectation of the price, demand and profits from good j, and the wage of labor in the Final sector. The column on the right shows the effect of an increase in IPRs (i.e. a higher ν) on the corresponding row-variable.

Variable	Expected Value	$\frac{d(\cdot)}{d\nu}$
p	$\nu\left(\frac{1-\alpha}{\alpha}\right)+1$	$+$
x_t	$(\alpha A)^{\frac{1}{1-\alpha}} L_{Y,t}\left[\nu\alpha^{\frac{1}{1-\alpha}}+(1-\nu)\right]$	$-$
$\pi_{I,t}$	$\nu\left(\frac{1-\alpha}{\alpha}\right)\left(A\alpha^2\right)^{\frac{1}{1-\alpha}} L_{Y,t}$	$+$
$w_{Y,t}$	$(1-\alpha)A^{\frac{1}{1-\alpha}}\alpha^{\frac{\alpha}{1-\alpha}}N_t^S\left[\nu\alpha^{\frac{\alpha}{1-\alpha}}+(1-\nu)\right]$	$-$

(2.3.8)

A tightening of IPRs increase the average price level as well as monopolistic profits going to patent owners. On the other hand both the demand for intermediate inputs and the Final wage are reduced.

The R&D sector develops innovations and sell patents to the intermediate sector. The value of a patent at time t, V_t, is given by the present value of future monopolistic rents discounted by the cumulative interest rate between any period t and τ, $r^S_{\tau,t}$[6].

$$V_t^e = E(V_t) = \int_t^\infty \nu\left(\frac{1-\alpha}{\alpha}\right)\left(A\alpha^2\right)^{\frac{1}{1-\alpha}} L_{Y,\tau}\exp\left(-r^S_{\tau,t}\right)d\tau \tag{2.3.10}$$

Differentiating this expression with respect to time one obtains the no arbitrage condition relating the spot interest rate, monopolistic profits and the value of a patent.

$$r_t^S = \frac{\dot{V}_t^e}{V_t^e} + \frac{E(\pi_{I,t})}{V_t^e} \tag{2.3.11}$$

At any period t an agent must be indifferent between purchasing a patent that delivers an expected profit of $E(\pi_{I,t})$ and expected value gains of $\dot{V}_t^e$, or the return from the riskless interest rate r_t paid in the domestic financial market.

The aggregate income of the R&D sector is given by the value of new innovations. The costs are given by the remuneration of the production factor (labor force in research). The

[6] The cumulative interest rate is given by

$$r^S_{\tau,t} = \int_t^\tau r_q dq \tag{2.3.9}$$

free-entry condition holds, drawing profits in the sector ($\pi_{R,t}$) down to zero.

$$\pi_{R,t} = V_t^e \dot{N}_t^S - w_{R,t} L_{R,t} = 0 \tag{2.3.12}$$

Thus the wage for workers in the R&D sector corresponds to the average income per worker in the R&D sector.

Wages in both sectors represent the marginal productivity in the production of final good and innovations.

$$w_{R,t} = \frac{V_t N_t^W}{\eta} \tag{2.3.13}$$

Households in sector k, face the problem of maximizing intertemporal utility.

$$Max_{c_{k,t}} \int_t^\infty U\left(c_{k,\tau}\right) \exp\left[-\rho\left(\tau - t\right)\right] d\tau \tag{2.3.14}$$

Subject to the profile of budget constraints,

$$\dot{b}_t = w_{k,t} + r_t^S b_t - c_{k,t} \text{ for } k = Y, R \tag{2.3.15}$$

In equation 2.3.14, ρ is the constant rate at which households discount future utility. In a different context it might be thought as a parameter representing "altruism" towards the utility of future generations.

In the constraint, $\dot{b}$ represents the household's asset accumulation. Accumulation of assets is the difference between total income (wage plus returns to capital) and total expenses (consumption).

The solution of this maximization program results in the usual Euler's equation relating the evolution of per capita consumptions to the path of interest rates.

$$\gamma_{c,k,t} = \frac{\dot{c}_{k,t}}{c_{k,t}} = r_t^S - \rho \text{ for } k = R, Y \tag{2.3.16}$$

Per capita consumptions for workers in the R&D and Final sectors are presented in the following proposition.

From the fact that total population is constant, the only rate of growth of $L_{Y,t}$ and $L_{R,t}$ that is feasible in the long-term is zero. Therefore we consider these populations to be constant in the steady state and we hereafter drop the time subscripts.

Proposition 2.3.1 *The optimal steady-state consumption profile for households engaged in sector $k = R, Y$ consists on consuming the wage plus a fraction ρ of asset holdings.*

$$c_{k,t} = w_{k,t} + \rho b_t \textit{ for } k = R, Y \tag{2.3.17}$$

Proof. Consider the budget constraint in equation 2.3.15. Households buy financial assets issued by firms in the Intermediate sector, the value of the assets is used by those firms to acquire patents at the price V_t. In return for their investment, households obtain a dividend (represented by the monopolistic profits) and the variation of the price of the patent. Thus, one innovation requires the issue of one financial asset. Therefore there are as many financial assets as intermediate goods at any time t, $N_t^S = b_t$. Equality in levels implies equality in rates of growth.

We make use of this fact and replace $\dot{b}_t$ by $\gamma_{N_t^S} b_t$ in the household's budget constraint.

Optimality of this consumption profile is imposed when we replace $r_t^S - \gamma_{N_t^S}$ by ρ (see equation 2.3.16). This can be done if the rate of growth of technology and per capita consumption are equal (this is, if $\gamma_{N_t^S} = \gamma_{c_{k,t}}$) It will be shown that the steady-state verifies this condition. ■

At this point of the development it is necessary to consider two possible cases regarding the relative wage between the R&D and Final sectors $w_{R,t}/w_{Y,t}$. Our assumption about skilled workers being allowed to work for any of the two productive sectors (i.e. R&D and Final), while unskilled workers are restricted to work for the Final sector guarantees that the relative wage between skilled and unskilled labor cannot be lower than one. Intuitively, if the equilibrium wage in the R&D sector is higher than the one in the Final sector, skilled workers would prefer working for the R&D sector while unskilled workers are forced to remain in the Final sector. The wage being higher in the Final sector than in the R&D sector is not a possible equilibrium outcome since skilled workers can also work for the Final sector. In that case skilled labor would switch sectors until both wages equalize. Whether the relative wage is higher or equal than one will be shown to depend on fundamental parameters of the economy, in particular total population and the size of skilled labor. For the time being let us consider the two cases separately and study their steady states.

2.3.2 The relative wage is equal to one ($w_{R,t} = w_{Y,t} = w_t$)

According to the previous discussion, this case corresponds to a situation in which a fraction of skilled labor is engaged in the production of the final good and the remaining fraction in the R&D sector.

We start by computing the steady-state behavior of this economy. As it will be clear below, it turns out that the assumption of international knowledge spillovers adds transitional dynamics to a model that otherwise lacks for them. The variable governing the transition of the economy to the steady state is the North-South technological gap z_t $(= N_t^N/N_t^S)$. Once the long-term value of this variable is found, we can solve for the long-term values of the rest of the variables of interest in this economy, i.e. rate of growth, per capita consumptions, distribution of the skilled population between the Final and R&D sectors, etc. We can use the results from this section to analyze the behavior of these variables in response to an increase in the parameter representing IPRs, in order to simulate the situation arriving to developing economies after the implementation of the measures contemplated under the TRIPS agreement.

Preliminary Steady State Results

Notice that from equation 2.3.17 equalization of wages implies equalization of per capita consumptions, as a consequence we omit the subscript distinguishing between the R&D and Final sectors.

Proposition 2.3.2 *In the steady state the level of final good, number of innovations and per capita consumption grow at the same constant rate.*

$$\gamma^*_{Y,t} = \gamma^*_{N^S_t} = \gamma^*_c = \gamma^* \tag{2.3.18}$$

Proof. The first equality comes from the fact that in the steady state:

$$Y_t = A^{\frac{1}{1-\alpha}} L_Y N^S_t \alpha^{\frac{\alpha}{1-\alpha}} \left[\nu \alpha^{\frac{\alpha}{1-\alpha}} + (1-\nu) \right] \tag{2.3.19}$$

This is obtained by aggregating the production function in equation 2.2.1 and replacing x^α by its equilibrium value in 2.3.8. Only Y_t and N^S_t are time dependent variables[7]. By taking logarithms and differentiating with respect to time the first part of the proposition is obtained. For the second equality it is sufficient to look at the aggregate demand identity, in which all product must be used either for consumption or for the production of intermediate goods,

$$Y_t - N^S_t x = C_t \tag{2.3.20}$$

Since the left hand side of 2.3.20 exhibits the same rate of growth in the steady state as technology does, the same holds true for the right hand side, i.e. consumption and hence percapita consumption since population is fixed. ■

The following proposition summarizes the results for the interest rate, R&D labor, technological progress in the South and the value of innovations as a function of the technological gap z_t.

Proposition 2.3.3 *The value of a patent, interest rate, R&D labor and the rate of technological progress in the South as function of the North-South technological gap z_t and its evolution $\dot{z}_t$ are given by:*

[7] The demand of a particular intermediate good by all firms in the Final sector, x, is now independent of time since it has been stablished that the steady state labor in R&D and production of final good is also time independent.

1. *Value of a patent:*

$$V_t = \frac{\eta (1-\alpha) A^{\frac{1}{1-\alpha}} \alpha^{\frac{\alpha}{1-\alpha}} \left[\nu \alpha^{\frac{\alpha}{1-\alpha}} + (1-\nu)\right]}{(1+z_t)} \tag{2.3.21}$$

2. *Interest rate:*

$$r_t^S = \frac{(1+z_t) L_{Y,t}}{\eta} \Phi(\nu) - \frac{\dot{z}_t}{1+z_t} \tag{2.3.22}$$

3. *R&D labor:*

$$L_{R,t} = \frac{L\Phi(\nu)}{1+\Phi(\nu)} - \frac{\rho\eta}{(1+z_t)[1+\Phi(\nu)]} - \frac{\eta \dot{z}_t}{(1+z_t)^2 [1+\Phi(\nu)]} \tag{2.3.23}$$

4. *Rate of technological progress:*

$$\gamma_{N_t^S} = \frac{(1+z_t) L\Phi(\nu)}{\eta [1+\Phi(\nu)]} - \frac{\rho}{1+\Phi(\nu)} - \frac{\dot{z}_t}{(1+z_t)[1+\Phi(\nu)]} \tag{2.3.24}$$

Where

$$\Phi(\nu) = \frac{\nu \alpha^{\frac{1}{1-\alpha}}}{\nu \alpha^{\frac{\alpha}{1-\alpha}} + (1-\nu)}$$

is a positive function increasing in the degree of IPRs that verifies $\Phi(0) = 0$ *and* $\Phi(1) = \alpha$.

We are now interested in the characterization of the steady state values of the interest rate, R&D labor, the rate of growth of the economy and the value of innovations.

We have confined the sources of time variation to come exclusively from the technological gap z_t and its evolution $\dot{z}_t$. Stationnarity requires the convergence of the technological gap to a constant value. The next section analyses the dynamic behaviour of the technological gap and presents its value in the steady state.

Technological Gap (z_t)

Starting from the definition of z_t, it is straightforward to compute its dynamic behavior. Since this variable represents the ratio of ideas between the North and the South, its rate of growth $\dot{z}_t/z_t$, corresponds to the difference between technological progress in both regions.

$$\frac{\dot{z}_t}{z_t} = \frac{\dot{N}_t^N}{N_t^N} - \frac{\dot{N}_t^S}{N_t^S} = \frac{\eta (1+z_t) \left[\gamma^N [1+\Phi(\nu)] + \rho\right] - (1+z_t)^2 L\Phi(\nu)}{\eta [1+\Phi(\nu)(1+z_t)]} \tag{2.3.25}$$

Where γ^N is the exogenous and constant rate of growth of the North, unaffected by economic variables in the South.

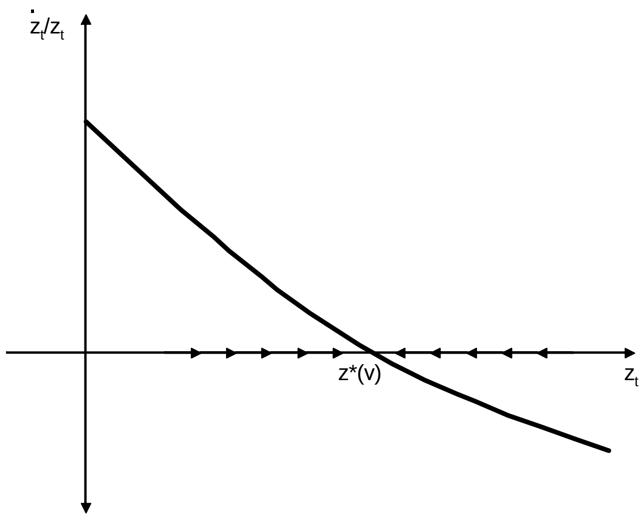


Figure 2.3.1: The stable steady state technological gap in the "Endogenous Equilibrium" is given by $z^*(\nu)$.

The solution of the differential equation 2.3.25 can be seen using a graphical representation. Figure 2.3.1 represents this equation in the $(\dot{z}_t/z_t, z_t)$ plane. The vertical intercept corresponds to the difference of the rates of growth between the North and the South that would occur in autarky, i.e. if there were no knowledge spillovers in the production of new innovations. As the North is assumed to be a larger economy than the South, in autarky this difference should be positive. The function crosses the horizontal axis at one point only. This crossing point represents an equilibrium of the system and determines the steady state value of the North-South technological gap, $z^*(\nu)$. This equilibrium is stable since the slope of the function is negative when evaluated at the point $z^*(\nu)$.

$$z^*(\nu) = \frac{\gamma^N [1 + \Phi(\nu)] \eta + \rho\eta}{L\Phi(\nu)} - 1 > 0 \tag{2.3.26}$$

The number of intermediate varieties in southern economies with larger populations and stronger IPRs regimes is closer to its counterpart in the North (technological leader). As it will be shown this effect of property rights on the long-term convergence of relative technologies plays a relevant role on the attractiveness of a particular IPRs regime.

Because of the stability of this equilibrium, this model predict that the technology ratio attains its long-run value, $z^*(\nu)$, indepently of the initial technological gap. As the z_t variable evolves in time, all results which are functions of that variable also attain their long-run, steady state values.

Results

The following proposition summarizes the steady state results for the value of a patent, R&D labor, the interest rate and the rate of growth for the South. Results are obtained by evaluating equations 2.3.21, 2.3.22, 2.3.23, and 2.3.24 at the long-term technological gap in equation 2.3.26.

Proposition 2.3.4 *The following results represent the steady state for the South:*

1. *The value of a patent:*

$$V^* = \frac{LA^{\frac{1}{1-\alpha}} (1-\alpha)\, \alpha^{\frac{1+\alpha}{1-\alpha}} \nu}{\gamma^N [1 + \Phi(\nu)] + \rho} \tag{2.3.27}$$

2. *The number of workers in the R&D and Final sectors:*

$$L_R^* = \frac{L\Phi(\nu)\, \gamma^N}{\gamma^N [1 + \Phi(\nu)] + \rho} \tag{2.3.28}$$

$$L_Y^* = \frac{L\left(\gamma^N + \rho\right)}{\gamma^N [1 + \Phi(\nu)] + \rho} \tag{2.3.29}$$

3. *The interest rate:*

$$r^{S*} = \gamma^N + \rho \tag{2.3.30}$$

4. *The rate of growth of product, consumption and technology:*

$$\gamma^* = \gamma^N \tag{2.3.31}$$

The value of a patent as well as labor in the R&D sector increase with the IPRs regime, whereas labor in the Final sector decreases with stronger IPRs. The steady state rate of growth of the economy, as well as the interest rate, depend on the rate of growth of the North.

This results imply that the South converges to the rate of growth of the North independently of its initial amount of knowledge. Let us assume that the initial technological gap between the two economies is large enough so that the rate of growth of technology in the South is higher than the one in the North, i. e. the variable z_t is arbitrarily large in equation 2.2.4 so that the initial rate of growth in the South is higher than the exogenous constant γ^N. According to the definition of the technological gap, if the South grows faster than the North, then the variable z_t decreases. This situation takes place until the technology in both economies grows at the same rate. The convergence of the rates of growth of the two regions in this context results from the interaction of each region's technological stock in the R&D sector.

The interest rate exhibits a similar behavior. According to equation 2.3.22 the initial high level of the technological gap implies a level of the interest rate superior than its steady state value. The fist term in the RHS represents the profit flow going to the patent owner and the second term stands for the change in the value of the patent. The variables z_t and $\dot{z}_t$ affect the interest rate through the profits and the value gains on the transitional path. As z_t falls, the monopolistic profit as a fraction of the total value of an innovation decreases. The same reduction is observed over the value of the patent (the change in prices is smaller and smaller until it attains zero in the long-run).

It is worth mentioning the absence of scale effects regarding the long-term value of the rate of growth of the economy. Indeed, Romer's model established the fact that the rate of growth is a linear function of the total population. In a model such as the one proposed in this article, by modifying the function $\dot{A}_t$ (i.e. assuming firms use not only the stock of domestic knowledge but also the stock of knowledge of the other economy) Romer's "scale effect" in the South vanishes. From the perspective of the South, technological change is exogenously determined by the rate of growth of the technological leader. Population affects the dynamics of the model, thus the speed of convergence to the steady state but not the steady state results.

Per capita consumption

Equation 2.3.20 represents total consumption using the resource constraint. We replace total output Y_t and total demand for intermediate good x from equations 2.3.19 and 2.3.8 and we divide total consumption by population, L. We obtain:

$$c_t^* = \frac{C_t}{L} = \frac{A^{\frac{1}{1-\alpha}} L_Y^* N_t^{S*} \left(\alpha^{\frac{\alpha}{1-\alpha}} - \alpha^{\frac{1}{1-\alpha}}\right)}{L} \left[\nu \left(\alpha^{\frac{\alpha}{1-\alpha}} + \alpha^{\frac{1}{1-\alpha}}\right) + (1-\nu)\right] \tag{2.3.32}$$

According to this expression, per capita consumption in the steady state depends positively on the fraction of the labor force in the Final sector ($\frac{L_Y^*}{L}$) and the amount of intermediate varieties available for the production of homogeneous good at time t (N_t^S).

The effect of total population on per capita consumption is twofold. On the one hand, a larger population means that a given output must be shared among a larger amount of indivuals, thus per capita consumption falls. On the other hand, a higher population implies that the equilibrium number of workers in each one of the sectors is higher. In the equilibrium, the ratios $\frac{L_Y^*}{L}$ and $\frac{L_R^*}{L}$ are irresponsive to changes in total population.

It is also clear from equation 2.3.20 that having more intermediate varieties increases labor productivity. In other words, workers in the Final sector use all intermediate inputs available to produce final good, therefore a larger N_t^S increases total product for any given level of L_Y.

The effect of the IPRs regime on per capita consumption is subtler. There is a direct effect coming from by the determination of the price level, i.e. the term in brackets in the RHS of equation 2.3.32. At the same time, there is an indirect effect that goes through the determination of Final labor and N_t^S. A higher IPRs regime is represented by a lower probability of imitation, thus a higher fraction of intermediate goods produced by monopolies. This is the negative effect of IPRs on welfare recognized in previous partial equilibrium literature. The indirect effect going through the equilibrium allocation of workers cannot be understood in such a framework (i.e partial equilibrium models) since it requires some degree of dependence of real wages on IPRs.

From equation 2.3.29, an increase in ν leads to a reduction in the number of workers in the Final sector and the opposite in the R&D sector. The reason for this effect is twofold: first, stronger IPRs decrease the demand of intermediate goods by firms in the Final sector, hence labor productivity and wages; second, as ν increases, so does the value of the patent V_t in equation 2.3.27. Since we are in the case in which the relative wage is one, this change in the relative wage implied by the new IPRs regime makes skilled workers that were working in the Final sector to switch sectors drawing the relative wage down to one.

The last channel through which IPRs affect consumption in this model is the equilibrium number of intermediate varieties, N_t^S. The number of intermediate goods in the North grows according to the exogenous rate γ^N. This means that the number of innovations in the South is determined by the ratio between the exogenous N_t^N and the steady state value of the technological gap, z^*.

$$N_t^{S*} = \frac{N_t^N}{z^*} = \frac{N_t^N L\Phi(\nu)}{\gamma^N \eta [1+\Phi(\nu)] + \rho\eta} \tag{2.3.33}$$

The inverse of the technological gap is then an index of technological development of the South with respect to the technological leader. Stronger IPRs create incentives for research in the South, thus decrease the technological gap and increase the number of available intermediate inputs in the steady state. This change is not immediate since it follows the law of motion of z_t in equation 2.3.25.

Once we replace the steady state values of L_Y^* and N_t^S in the expression of per capita consumption, we obtain its steady state value in terms of the parameters, namely the parameter representing the level of enforcement of IPRs and the rate of growth of the North.

$$c_t^*(\nu) = \frac{A^{\frac{1}{1-\alpha}} L \left(\gamma^N + \rho\right) \Phi(\nu) N_t^N \left(\alpha^{\frac{\alpha}{1-\alpha}} - \alpha^{\frac{1}{1-\alpha}}\right)}{\eta \left[\gamma^N [1+\Phi(\nu)] + \rho\right]^2} \left[\nu \left(\alpha^{\frac{\alpha}{1-\alpha}} + \alpha^{\frac{1}{1-\alpha}}\right) + (1-\nu)\right] \tag{2.3.34}$$

This expression is the reduced form of per capita consumption. It includes both the direct effects of ν on prices and the indirect effects over the distribution of labor between sectors and the number of available varieties of intermediate outputs.

For instance, consider a decrease in the probability of imitation (i.e. a higher ν). This situation may be comparable to the requirement imposed to the developing economies under the TRIPS agreement. On the one hand this change entails a negative effect on consumption coming from the increase in the price level and a lower allocation of labor in the Final sector. The first effect is straightforward. The second comes from the fact that higher IPRs mean an increase in the value of a patent, thus the productivity of R&D labor. A higher wage in the R&D sector induce a fraction of workers in the Final sector to switch sectors. This labor mobility between sectors takes place until wages equalize once again.

On the other hand, stronger IPRs reduce the technological gap between the two regions. This means that the number of intermediate varieties of the technological follower is closer to the one of the technological leader. More intermediate inputs increase the marginal productivity of Final labor, thus total output and consumption.

It is necessary to stress the fact that we are referring to changes in the levels of the North-South technological gap and not in the rate of technology. In the long term, technology in both regions grow at the same pace (the ratio N_t^N/N_t^S is constant) but the value of that ratio is a function of the degree of protection of IPRs in the South.

In order to account for the total effect of the IPRs regime on per capita consumption it is necessary to compute which one of the effects mentionned before dominates. Simple numerical simulations point out that an increase in the level of enforcement of IPRs increases per capita consumption for relevant values of the parameters[8]. This implies that the positive effect of IPRs on consumption going through the increase in the availability of intermediate inputs tends to dominate the negative effects implied by stronger intermediate monopolies and an inferior allocation of labor in the production of consumption goods.

The previous result provides an original argument in favor of the long term convenience of strong IPRs for a developing economy. Most literature on the subject focuses mainly on the trade-off between static monopolistic distortions and dynamic benefits on the incentives to create knowledge. The first one represented by the level of prices and the second one in the steady state rate of growth of the economy. A first look at the steady state results presented at the beginning of this section may induce to think that this trade-off is absent in a North-South model with knowledge spillovers, such as the one presented in this article. Since the model predicts convergence of the rates of growth of both regions in the long term for any level of protection of IPRs, one may think the dynamic positive effect of IPRs on the rate of growth in the South is no longer present. One

[8] For instance, $\frac{dc_t^*}{d\nu} < 0$ can only be true if both ν and α are close to one, e.g. combinations of (ν, α) for which $\nu \geq 0.92$ and $\alpha \geq 0.74$. In those cases it is necessary to consider particular values for the rate of growth of the North and the discount rate in the South, γ^N and ρ, in order to make further assertions. Nonetheless, a value of α outside the interval implied by the upper bound of 0.74 seems implausible.

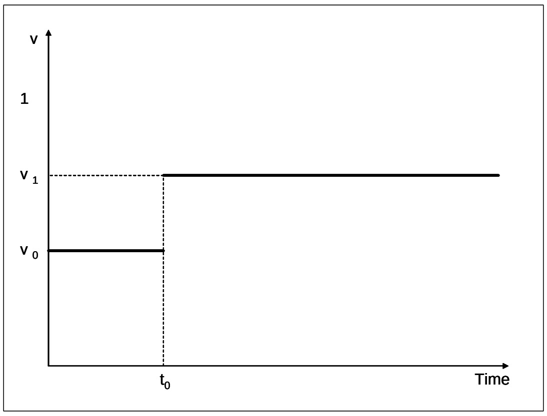
could have expected that in order to maximize per capita consumption in this economy it is sufficient to focus on eliminating the static monopolistic distortion, i.e. a case in which every intermediate input is imitated with probability one. Nonetheless, the model suggests that stronger IPRs not only affects the rate of growth of technology but its level in the South with respect to the level of technology in the North. The smaller the North-South technological gap the more productive intermediate inputs and labor used in the production of final/consumption output in the South.

Effect of a change in the IPRs regime (ν)

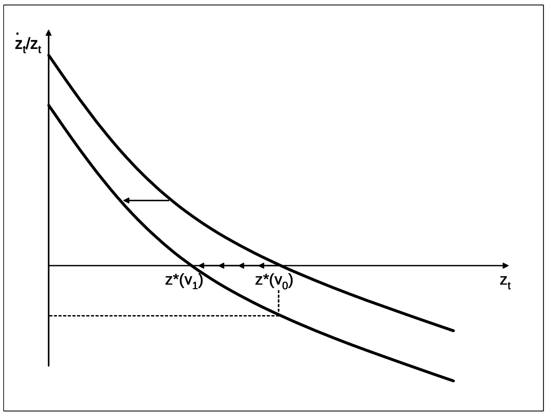
The goal of this section is to recreate what happens to the South as a consequence of an increase in the level of enforcement of IPRs under the case where the relative wage is one. A situation of the kind might be expected under the TRIPS agreement. Indeed, the TRIPS agreement demands all WTO members to ensure a minimum level of patent protection resulting in a partial harmonization of patent lenghts. The harmonization in question is only partial since any country is free to establish more stringent IPRs protection at any time.

Suppose that the South experiences an increase in the enforcement of its IPRs at time t_0 being in the steady path before that date. The change is represented by an increase in the parameter ν from ν_0 to ν_1 in figure (a). A higher ν moves the function describing the evolution of the North-South technological gap, $\dot{z}_t/z_t$, to the left (figure (b)). The transition to the new steady state starts inmediately after the change. There are two stages to be considered: the first one happens at time t_0 (given by the simultaneous effect of the increase in ν and the decrease in the growth of the technological gap from zero to a negative value); the second stage takes place right after the change and is characterized by the decrease in the technological gap from $z^*(\nu_0)$ to its new steady state $z^*(\nu_1)$ at a decreasing rate converging to zero (figure (c)).

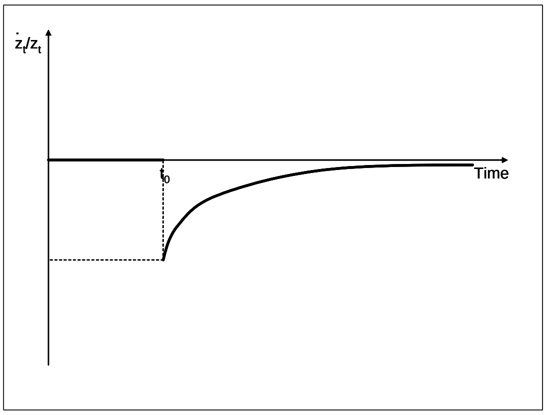
Right after the change, a higher level of IPRs reduces the demand for intermediate goods. This decreases the marginal productivity of workers in the Final sector, and consequently wages for both sectors (skilled labor moves from the Final to the R&D sector in response to the variation in the marginal productivity until wage equality is again obtained, this explains the initial positive jump in $L_{R,t}$ and the respective negative jump in $L_{Y,t}$ in figures (f) and (g) respectively). According to the knowledge accumulation function, more workers enroled in R&D activities increase the rate of technological progress (figure (e)). Lower wages create the prospect of positive profits in the R&D sector, nonetheless the free-entry condition implies that more resources are allocated to R&D drawing the value of patents down and profits back to zero. The combination of less valuable patents along with the prospect of a future increase in the value of patents ($\frac{\dot{V}_t}{V_t}$) raise the returns of R&D investment, i.e. financial assets. The interest rate must increases too in order to avoid arbitrage opportunities (figure (d)). Households react to a higher interest rate by adjusting consumption: present consumption is more expensive relative to future consumption so they increase their accumulation of financial assets. Saving more implies a higher consumption rate in the future (this can be observed in figure (h) by the steeper slope of the function representing the logarithm of per capita consumption).



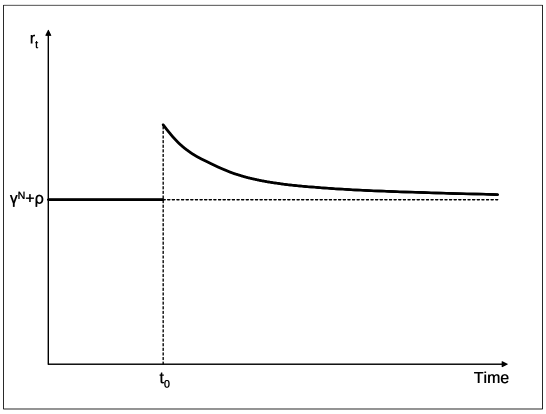
(a) An increase in the enforcement of IPRs at time t_0.



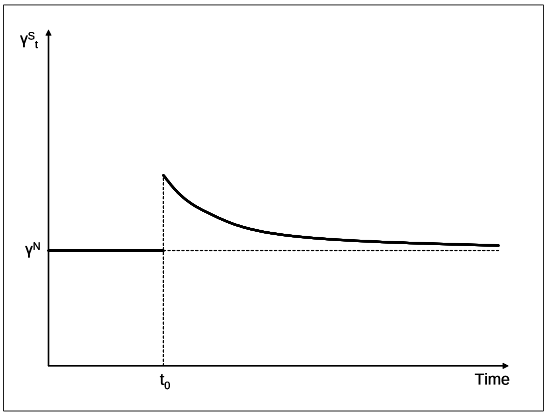
(b) The law of motion of the technological gap $\left(\frac{\dot{z}_t}{z_t}\right)$ moves to the left as a result of the increase in ν.



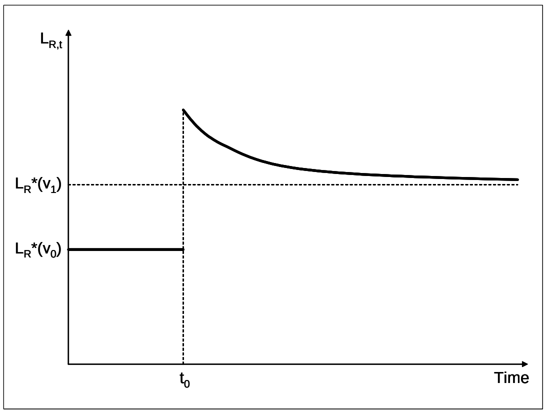
(c) The economy moves to a new steady state with dynamics determined by the evolution of the technological gap.



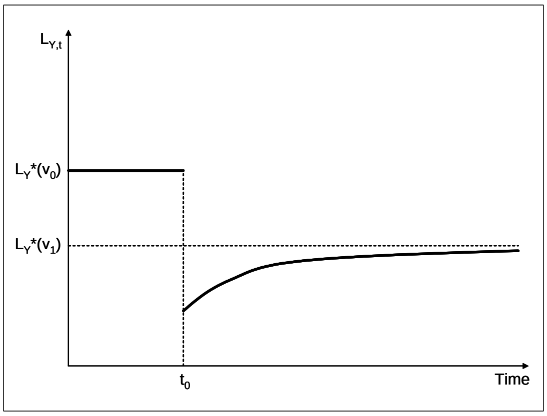
(d) The interest rate jumps into a higher value at time t_0, converging afterwards to the same value it had before the change.



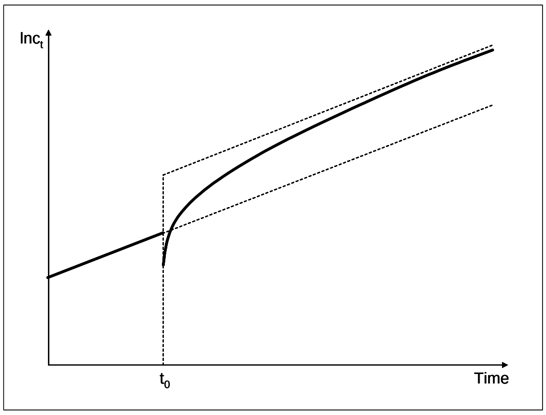
(e) The rate of growth exhibits the same behavior as the interest rate. The difference between the two equals the discount rate ρ.



(f) Skilled labor in the R&D sector exhibits a jump at the moment of the change. It decreases afterwards to its new steady state level (higher than the old one).



(g) Labor in the Final sector is reduced at the moment of the change. It recovers during the transition to a new steady state value lower than the old one.



(h) There is an initial negative impact on consumption followed by a recovery during the transition. In the long term consumption grows at the rate of technological change.

After the initial reaction of the economy to the change in the IPRs regime, a transition process to the new steady state takes place.

Under stronger IPRs the North-South technological gap is reduced. This is shown graphically in figure (b), the technological gap moves from $z^*(\nu_0)$ to the lower value $z^*(\nu_1)$. The reason for this transition can be explained once we consider the sudden increase in R&D labor. The increase in the number of skilled workers producing innovations raises the rate of technological progress in the South. As result of this, the denominator in the ratio $\frac{N_t^N}{N_t^S}$ grows at a faster pace than the numerator, therefore the technological gap decreases.

Whenever the rate of growth in the South is higher than the one in the North, the prospect of negative profits in the R&D sector arises. Indeed, under such a situation the costs of R&D increase at a faster pace than the revenues. The free-entry condition pins down the value of a patent to the cost of the labor required for its production $V_t = w_{R,t}\frac{L_{R,t}}{\dot{N}_t^S} = w_{R,t}\frac{\eta}{N_t^W}$.

Equivalently, the value of a patent is given by the ratio between the cost of one unit of R&D labor and the productivity of R&D labor in the production of blueprints. The numerator of this expression grows at the rate of growth of technology in the South but the denominator grows at the rate of growth of the world's technology (which is strictly lower than the one in the South right after the change in the IPRs regime). The prospect of negative profits reduces the amount of resources invested in R&D, leading to the reallocation of skilled labor from the R&D sector to the Final sector. The combined effect of a lower technological gap and the reallocation of R&D labor implies a rate of growth of technology in the South still higher than the one in the North but closer to it with respect to its level at t_0. This process takes place until the rate of growth in the South coincides with the one in the North and the technological gap is again constant (figures (e) and (c)).

According to the previous explanation, it is possible to conclude that the key variable governning the transition from the original steady state to the new one is the value of the patent and its evolution . As the technological gap decreases, the value of the patent increases with its rate of growth eventually converging to zero. In other words, during the time following t_0 the return of the financial assets decreases, both because of a variation of the dividends ($\frac{\pi_{I,t}}{V_t}$) and a reduction in the value gains of the value of a patent ($\frac{\dot{V}_t}{V_t}$). In order to avoid arbitrage opportunities the interest rate exhibits a similar behaviour (figure 2.3.2), returning to its original steady state value at the end of the transition.

2.3.3 The relative wage is higher than one ($w_{R,t} > w_{Y,t}$)

In this section we will proceed in a similar way than in the previous section. The main difference is that we consider now the case in which the wage in the R&D sector is higher than the one in the Final sector. Whether relative wages are equal or higher than one will be shown to be an exogenous function of the parameters of the economy. The next section fully develops the conditions under which a given situation arises while combining them to state a result about the IPRs parameter that maximizes expected future utilities for workers in the R&D and Final sectors.

We start by proposing a set of preliminary steady state results in which time variation comes exclusively from the dynamic behavior of the North-South technological gap. We establish the long-term value of this variable and use it to fully characterize the steady state value of the relevant variables, i.e. the interest rate and rate of growth of the economy. We use the wages in the R&D and Final sector to construct the consumption functions for workers in the R&D and in the Final sector and we analyze the response of the relative wage to changes in the IPRs parameter.

Preliminary Steady State Results

It is straightforward to show that whenever the wage in the R&D sector is higher than the one in the Final sector all skilled workers are engaged in R&D activities whereas all unskilled labor produces final output. Behind this behavior lies our initial assumption about skilled labor being able to perform both R&D and final output related tasks, while unskilled labor participates exclusively in the production of final good.

It is thus the case that

$$L_{R,t} = L(a_h) \tag{2.3.35}$$

$$L_{Y,t} = L(a_l) \tag{2.3.36}$$

The wage in the Final sector is still determined by the marginal labor productivity in the production of Final output. It is therefore the same expression stated in equation 2.3.8.

The determination of the R&D wage entails an additional complication since it is no longer true that it can be assimilated to the Final wage as in the previous case. The value of the patent being equal to the discounted future flow of monopolistic profits leads to the no arbitrage condition 2.3.11. By replacing the value of the patent in equation 2.3.13 in the no arbitrage condition, and solving for the R&D wage we obtain:

$$w_{R,t}\left(1-\frac{\frac{\dot{V}_t^e}{V_t^e}}{r_t}\right)=\frac{\nu(1-\alpha)\left(A\alpha^2\right)^{\frac{1}{1-\alpha}}L(a_l)\left(N_t^N+N_t^S\right)}{\alpha\eta r_t} \tag{2.3.37}$$

According to this expression, the R&D wage equals the value of the average labor productivity in the R&D sector. In other words, the RHS of equation 2.3.37 is equivalent to the number of innovations produced by one worker, in average, multiplied by the value of a patent (which is equal to the present value of the monopolistic flow of profits).

In the steady state, the rates of growth of consumption and technological progress are equal. The following equality must be verified:

$$\gamma_{C,t}=r_t-\rho=(1+z_t)\frac{L(a_h)}{\eta}=\gamma_{N_t^S}$$

From which it is possible to compute the interest rate as a function of the endowment of skilled workers in the population, the technological productivity parameter and the

North-South technological gap.

$$r_t = (1 + z_t) \frac{L(a_h)}{\eta} + \rho$$

We now proceed to derive the dynamic behavior of the technological gap. As it was the case in the situation in which the relative wage was equal to one, the equilibrium results do not imply the economy being in the steady state (this is true in the original model by Romer where there are no transitional dynamics). The rates of growth of consumption, output, technological progress, the interest rate and per capita consumptions are functions of the technological gap, z_t. It will be shown that, similarly to the case of wage equality, the stock of initial knowledge in the South determines the dynamic path followed by the southern economy, eventually leading to the South's rate of growt converging to the one of the North.

Technological Gap (z_t)

The evolution of the North-South technological gap is given by the difference in the rates of growth of the North and the South

$$\frac{\dot{z}_t}{z_t} = \frac{\dot{N}_t^N}{N_t^N} - \frac{\dot{N}_t^S}{N_t^S} = \gamma^N - \frac{(1 + z_t) L(a_h)}{\eta}$$

This is a decreasing function represented in the $\left(z_t, \frac{\dot{z}_t}{z_t}\right)$ plane in figure 2.3.2. The function has a negative slope which guarantees that the value of z_t resulting from the crossing of the function with the horizontal axis is a stable equilibrium. We define this value as the long term technological gap z^*. It is independent of the South's IPRs regime and is positive given the underlying assumption about the rate of growth of the North being higher than the one in the South in autarky, i.e. setting $z_t = 0$.

$$z^* = \frac{\eta\gamma^N - L(a_h)}{L(a_h)} > 0 \tag{2.3.38}$$

According to equation 2.3.38 the gap between the stock of knowledge in the North compared to the one in the South is constant in the long run. It is smaller the larger the size of the skilled population in the South and the higher the productivity in the R&D sector $\left(\frac{1}{\eta}\right)$, and it increases with a higher rate of growth in the North.

Results

Similarly to what was done in the case of equal R&D and Final wages, the steady state results are given by the equilibrium results discussed before evaluated at the long term technological gap, z^*. The following proposition summarizes the main findings:

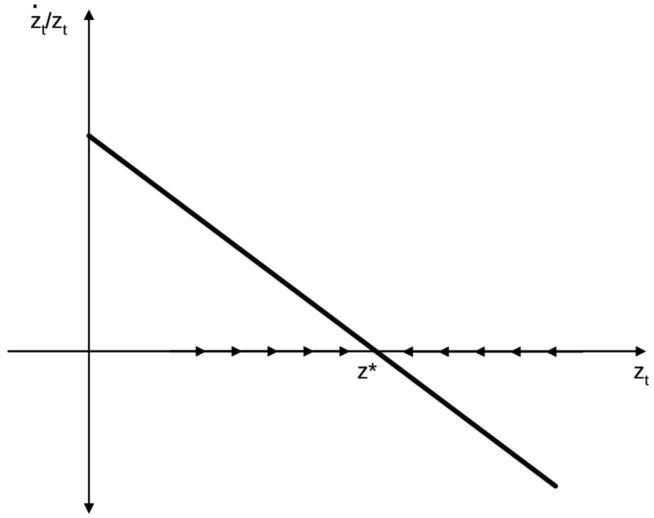


Figure 2.3.2: The function describes the dynamics of the North-South technological gap. The stable equilibrium is given by z^* which is independent from the current IPRs regime in the South.

Proposition 2.3.5 *The following results represent the steady state for the South:*

1. *The value of a patent:*

$$V^*(\nu) = \frac{\nu(1-\alpha) A^{\frac{1}{1-\alpha}} \alpha^{\frac{1+\alpha}{1-\alpha}} L(a_l)}{\gamma^N + \rho} \tag{2.3.39}$$

2. *The number of workers in the R&D and Final sectors:*

$$\begin{aligned} L_R^* &= L(a_h) \\ L_Y^* &= L(a_l) \end{aligned}$$

3. *The interest rate:*

$$r^{S*} = \gamma^N + \rho \tag{2.3.40}$$

4. *The rate of growth of product, consumption and technology:*

$$\gamma^* = \gamma^N \tag{2.3.41}$$

The value of a patent is represented by an increasing function of the degree of IPRs protection. Nonetheless, both R&D and Final labor along with the interest rate and the rate of growth of the economy are independent from the IPRs regime in the South.

The rate of growth of the South, as the technological follower, converges to the rate of growth of the North. There are no transitional dynamics coming from changes in the

IPRs regime because R&D and Final labor are exogenously determined by the population endowments

Per capita consumptions

The R&D wage in equation 2.3.37 converges to its steady state value $\left(w_{R,t}^{*}\right)$ as the interest rate converges to $\gamma^N + \rho$, the change in the value of a patent reaches zero and the stock of knowledge in the South attains N_t^N / z^*.

$$N_t^{S*} = \frac{N_t^N}{z^*} = \frac{L(a_h) N_t^N}{\gamma^N \eta - L(a_h)} \tag{2.3.42}$$

The number of intermediate goods in the South is expressed as a fraction of those in the North. Higher levels of R&D labor and R&D productivity $\left(\frac{1}{\eta}\right)$ imply a larger number of intermediate goods.

The R&D and Final wages can therefore be expressed as functions of the amount of intermediate varieties in the North, skilled and unskilled populations, the rate of growth of the North and the degree of enforcement of IPRs in the South. By solving for the wage in the R&D sector using equations 2.3.37, 2.3.39 and 2.3.42; and replacing equation 2.3.42 into 2.3.8, we obtain:

$$w_{R,t} = \frac{\nu (1-\alpha) A^{\frac{1}{1-\alpha}} \alpha^{\frac{1+\alpha}{1-\alpha}} \gamma^N L(a_l) N_t^N}{(\gamma^N + \rho)\left[\eta \gamma^N - L(a_h)\right]} \tag{2.3.43}$$

$$w_{Y,t} = \frac{(1-\alpha) A^{\frac{1}{1-\alpha}} \alpha^{\frac{\alpha}{1-\alpha}} \left[\nu \alpha^{\frac{\alpha}{1-\alpha}} + (1-\nu)\right] L(a_h) N_t^N}{\eta \gamma^N - L(a_h)} \tag{2.3.44}$$

Stronger patents increase the value of innovations thus the remuneration of skilled labor. A larger endowment of skilled labor, $L(a_h)$, reduces the North-South technological gap. R&D labor is thusly more productive and the wage is consequently higher. A similar effect takes place from a larger endowment of unskilled labor, $L(a_l)$. A higher amount of unskilled labor in the Final sector increases the aggregate demand for intermediate goods and profits for intermediate firms. An increase in the flow of monopolistic profits increases the value of an innovation and the remuneration for R&D labor.

On the other hand, stronger patents decrease wages for unskilled workers. Strenghtening monopolistic pricing for intermediate goods has a negative effect on the equilibrium demand by firms in the Final sector causing a decrease in the marginal productivity of unskilled labor. The effect on $w_{Y,t}$ of an increase in the endowment of skilled workers is once again positive. More skilled workers increase technological progress by reducing the North-South technological gap and increasing the world's stock of knowledge. In turn, this increases the marginal productivity of unskilled labor.

In order to fully characterize consumption it is necessary to consider the level of asset holdings in possession of households endowed with high and low levels of ability along with wages. Equation 2.3.17 establishes the relation linking wages, asset holdings and consumption. According to this equation it is optimal for households to consume their wages in addition to the excess return of financial assets over the rate of growth of the economy (in equilibrium this excess return coincides with the constant utility discounting factor, ρ). It is therefore the case that the initial distribution of financial assets among households holds for every future period independently of the skill level of the household ($b_{a_h,t} = b_{a_l,t} = b_t = b_0 \exp(\gamma^* t)$ in the steady state).

We solve for asset holdings b_t using equations 2.3.17, 2.3.43, 2.3.44 and the resource constraint adapted for the case of a "separating equilibrium" in the following form

$$c_{R,t} L(a_h) + c_{Y,t} L(a_l) = C_t = Y_t - N_t^S x$$

Where x corresponds to the expected equilibrium demand of any intermediate good. The resulting expression for asset holding is:

$$b_t = \frac{\nu A^{\frac{1}{1-\alpha}} (1-\alpha) \alpha^{\frac{1+\alpha}{1-\alpha}} L(a_h) L(a_l) N_t^N}{(\gamma^N + \rho) [\gamma^N \eta - L(a_h)] [L(a_h) + L(a_l)]}$$

Asset holdings increase with stronger patents and with skilled and unskilled labor. The first increases the returns to R&D and the value of innovations. A larger population size, whether it comes from more skilled or unskilled labor, affects asset holdings in opposite ways. There is a negative effect coming from the fact that a larger population implies a lower level of per capita asset holdings to share. On the other hand, having more skilled workers increases the rate of technological progress and the supply of financial assets in the economy. More unskilled workers also increase the level of financial assets by increasing the demand for intermediate inputs and the R&D returns. In both cases the positive effect dominates over the negative effect making b_t increasing with $L(a_h)$ and $L(a_l)$.

We obtain per capita consumptions by using the expression for asset holdings in the consumption profile of skilled and unskilled labor.

The resulting consumption for skilled workers is:

$$c_{R,t}^* = \frac{\nu A^{\frac{1}{1-\alpha}} (1-\alpha) \alpha^{\frac{1+\alpha}{1-\alpha}} L(a_l) N_t^N \left[\gamma^N L(a_l) + \left(\gamma^N + \rho\right) L(a_h)\right]}{(\gamma^N + \rho) [\gamma^N \eta - L(a_h)] [L(a_h) + L(a_l)]} \tag{2.3.45}$$

The wage of R&D labor and the remuneration of financial assets share the same determinants. Consequently it is the case that changes in key variables (i.e. $\nu, \gamma^N, L(a_h)$ and $L(a_l)$) produce mutually reinforcing effects over R&D consumption. For instance, consider the case of the IPRs regime: stronger patents increase the value of innovations which is in turn the main determinant of wages in the R&D sector, but it also increases the return to financial assets owned by households generating an additional positive effect on consumption.

More interesting is the case of consumption for unskilled workers. Both determinants of consumption (i.e. wages and asset holdings) react in opposite ways to a hardening in patent protection. Stronger patents are unambiguously harmful for wages in the Final sector but increase the value of financial assets. The negative effect over wages coming from higher monopolistic static distortion dominates over the positive effect on patent value. Consequently consumption for unskilled labor is not maximal under complete enforcement of patents (as it is the case for skilled labor) but under a weaker regime of IPRs.

$$c^*_{Y,t} = \frac{A^{\frac{1}{1-\alpha}}\left(1-\alpha\right)\alpha^{\frac{\alpha}{1-\alpha}}L\left(a_h\right)N_t^N\left[\left[\nu\alpha^{\frac{\alpha}{1-\alpha}}+\left(1-\nu\right)\right]\left(\gamma^N+\rho\right)L+\nu\alpha^{\frac{1}{1-\alpha}}\rho L\left(a_l\right)\right]}{\left[\gamma^N\eta-L\left(a_h\right)\right]\left(\gamma^N+\rho\right)L} \tag{2.3.46}$$

Per capita consumption in equation 2.3.46 reacts positively to increases in the endowments of skilled and unskilled labor. For reasons mentioned above, a larger amount of the population in the R&D or Final sectors has a positive effect on both wages and asset holdings leading to a positive reinforced effect on consumption.

2.3.4 Determination of the relative wage

Let us define an auxiliary function representing the ratio between the wage in the R&D and Final sector in equations 2.3.43 and 2.3.44, expressing unskilled labor as the difference between total population and skilled labor.

$$\frac{w_{R,t}}{w_{Y,t}} = \frac{\left[L-L\left(a_h\right)\right]\gamma^N}{L\left(a_h\right)\left(\gamma^N+\rho\right)}\Phi\left(\nu\right) \tag{2.3.47}$$

According to the previous equation this function increases with the degree of enforcement of IPRs both because of their positive effect over the R&D wage on the numerator and the negative effect on the Final wage in the denominator.

Whenever the auxiliary relative wage function 2.3.47 is higher than the unity the "Separating equilibrium" results apply. The opposite case stands for the "Endogenous equilibrium". In the following proposition I state conditions over total population, skilled labor and other parameters including the degree of IPRs that must hold in each equilibrium.

Proposition 2.3.6 *The following relations between the size of total population, endowment of skilled labor, the rate of growth of the technological leader, degree of enforcement of IPRs in the South and utility discount rate determine which one of the two possible steady state outcomes is relevant for the South:*

- *If $L \leq \bar{L}\left(\nu\right)$, the "Endogenous Equilibrium" results apply.*

- *If $L > \bar{L}(\nu)$, the "Separating Equilibrium" results apply.*

Where $\bar{L}(\nu) = \frac{L(a_h)\left[\gamma^N[1+\Phi(\nu)]+\rho\right]}{\gamma^N\Phi(\nu)}$.

In the next section we undertake a welfare analysis in order to compute the welfare maximizing IPRs regime both for skilled and unskilled labor. Using the result from the proposition above we present this "optimal" IPRs regime as a function of total population and the number of skilled workers.

2.4 Welfare

Romer (1990) shows that, in general, the equilibrium results from this kind of expanding varieties endogenous growth models are not optimal. Optimality comes from the maximization of intertemporal discounted utility undertaken by the social planner facing resource, technological and population constraints. Not only is the monopolistic distortion resulting from imperfect competition in the intermediate sector the cause of this divergence but also the incomplete appropiation of the full social value of the invention by present inventors whose ideas are freely used in the creation of future inventions. According to Romer, the optimal allocation of workers in the R&D sector (in the case of homogeneous labor) is larger than the one resulting from the decentralized equilibrium. The optimal rate of growth is consequently higher than the rate of growth resulting from the equilibrium.

It turns out that granting subsidies both to R&D activity and to the demand for intermediate goods (financed by lump-sum taxes) may implement the optimal results in a market economy. The patent system is only necessary as long as it succeds to provide enough incentives for technological innovation. However, once the new technology is discovered, monopolistic pricing decreases welfare. R&D subsidies provide higher incentives to the creation of new technologies than the patent system, while intermediate demand subsidies counteract any harmful effect of monopolist pricing distortions.

For the present welfare analysis I use the equilibrium results from the steady state in the previous section. The goal of the present section is to characterize the IPRs regime that maximizes equilibrium intertemporal utilities for each type of labor. Hereafter, the term "optimal" when making reference to the IPRs regime must be seen with some caution since it does not represent the first best allocation in this economy. Optimality in this context comes from the fact that that the said IPRs regime maximizes welfare under "second best" results implemented by the patent system which is characteristic of a decentralized equilibrium.

The maximization program takes the following form:

$$\begin{aligned}\nu^* &= \arg\max{}_\nu \int_t^\infty U\left[c_\tau^*(\nu)\right]\exp\left[-\rho(\tau-t)\right]d\tau \\ &= \arg\max{}_\nu \int_t^\infty \ln\left[c_t^*(\nu)\exp\left[\gamma^*(\tau-t)\right]\right]\exp\left[-\rho(\tau-t)\right]d\tau \qquad (2.4.1)\end{aligned}$$

The way in which we integrate the results from the previous part into welfare analysis is by replacing the relevant consumption functions in equation 2.4.1. If the economy is in the "Endogenous Equilibrium" case, per capita consumption is given by equation 2.3.34. In the case of a "Separating Equilibrium" equations 2.3.45 and 2.3.46 represent the equilibrium consumptions for skilled and unskilled labor. Since in both cases the rate of growth in the South converges to the rate of growth of the North independently of the value of ν, it is straightforward to come to the conclusion that the level of IPRs that maximize consumption is the same that maximizes welfare.

According to our previous steady state results, in the case the economy is characterized by the "Endogenous Equilibrium" results the welfare maximizing IPRs enforcement is given by $\nu^* = 1$, i.e. IPRs attain the highest possible value which corresponds to perfect enforcement. The same is true for the welfare of skilled labor in the "Separating Equilibrium" case.

For unskilled workers however it is necessary to go through a different analysis. A previous result stated that a low degree of patent protection maximizes unskilled labor consumption. Because the relative wage is an increasing function of ν, there is a certain threshold below which the "Separating Equilibrium" case no longer holds. In other words, decreasing intellectual property protection migh enhance welfare for unskilled workers in the Final sector, but there is a certain positive value of ν, denoted as $\bar{\nu}$, under which relative wages in both sectors equalize.

$$\begin{aligned}\bar{\nu} &= \Phi^{-1}\left[\frac{L(a_h)\left(\gamma^N+\rho\right)}{\left[L-L(a_h)\right]\gamma^N}\right] \\ &= \frac{L(a_h)\left(\gamma^N+\rho\right)}{\alpha^{\frac{1}{1-\alpha}}\left[L-L(a_h)\right]\gamma^N+\left(1-\alpha^{\frac{\alpha}{1-\alpha}}\right)L(a_h)\left(\gamma^N+\rho\right)}\end{aligned}$$

Any value of ν below than this threshold makes the economy switch to the "Endogenous Equilibrium" case, in which the welfare maximizing value of ν is given by $\nu^* = 1$. The lowest possible IPRs regime that is consistent with the economy exhibiting a "Separating Equilibrium" is hence given by $\bar{\nu}$.

Function $\bar{\nu}$ is downward sloping with respect to total population attaining zero asymptotically. An increase in $L(a_h)$ implies a movement of the function up and to the right.

The maximiziation program for skilled and unskilled workers in the "Separating Equilibrium" case is therefore given by:

$$\nu^* = \arg\max{}_{\nu} \int_t^{\infty} U\left[c^*_{k,\tau}(\nu)\right] \exp\left[-\rho(\tau - t)\right] d\tau \mid L > \frac{L(a_h)\left[\gamma^N(1+\alpha)+\rho\right]}{\gamma^N \alpha}$$

Where $k = Y, R$.

The next division of the section tackles the problem of integrating the results obtained so far in a continuous (although not differentiable) function relating the welfare maximizing degree of IPRs and total population size.

2.4.1 Graphical representation of the welfare maximizing degree of patent enforcement

We combine the results from equation 2.4.1 evaluated at the levels of consumption for the case in which the wage in the R&D and Final sectors is equal and the case in which the R&D wage is superior than the one in the Final sector.

For population levels between zero and $\bar{L}$ evaluated at the maximum degree of patent enforcement ($\nu = 1$), the welfare maximizing degree of patent protection is given by full patent protection. This is the case both for unskilled workers in the Final sector and skilled workers endogenously distributed between the R&D and Final sectors.

For levels of population higher than $\bar{L}(\nu = 1)$ the values of ν^* for skilled and unskilled labor no longer coincide. Skilled labor still see their welfare maximized at $\nu^*_R = 1$ while unskilled workers maximize welfare under the lowest value of ν, i.e. $\nu^*_Y = \bar{\nu}$.

Figure 2.4.1 represents the welfare maximizing degree of patent protection in the (L, ν) plane. The results for labor in the R&D sector (skilled labor) are represented by the function ν^*_R and those for labor in the Final sector (skilled and unskilled labor depending on the case in which the economy is placed) by the ν^*_Y function.

As it can be seen from the graph, two countries of exactly the same population size might exhibit different welfare maximizing IPRs profiles depending of their endowment of skilled labor (and other parameters such as α and ρ). Consider for instance two countries such as Switzerland and Honduras. Data provided by the U.S. Census Bureau indicate their estimated population for the year 2007 as being close to each other (7,554,661 inhabitants in Switzerland versus 7,516,214 in Honduras). Nevetheless if we assimilate the amount of skilled labor to the population enroled in tertiary education[9] and compute it for each one of those economies we find that skilled labor is almost three times higher in Switzerland than in Honduras (3,550,691 versus 1,289,031 following World Bank data

[9] According to the World Bank "tertiary education broadly refers to all post-secondary education, including but not limited to universities... public and private institutions in every country - colleges, technical training institutes, community colleges, nursing schools, research laboratories, centers of excellence, distant learning centers, etc -..."

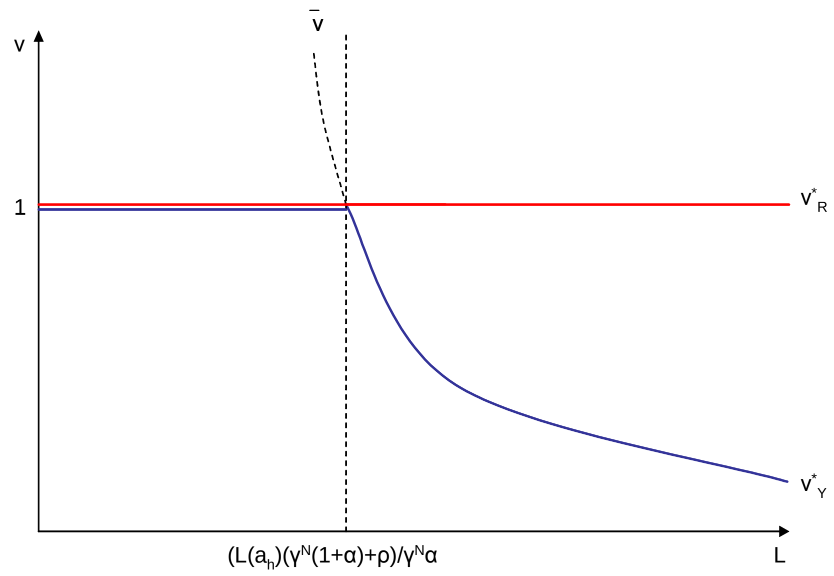


Figure 2.4.1: For a total population L, the welfare maximizing degree of IPRs is given by function ν_Y^* for unskilled labor and ν_R^* for skilled labor.

for 2007). This difference in skilled populations migh be an indication that the relevant results for Switzerland are the ones corresponding to an economy in the "Endogenous Equilibrium" situation whether Honduras corresponds to the "Separating Equilibrium" case. Therefore, unskilled labor in Honduras would be more likely to prefer a weaker degree of protection of IPRs than the one preferred by skilled labor, while there might by a consensus among all Swiss workers regarding the desirability of a strong protecion of IPRs.

2.5 Conclusions

This article presents a theoretical framework for analyzing the role played by Intellectual Property Rights (IPRs) in the context of a North- South endogenous growth model of technological change. The North is a big economy and plays the role of the technological leader while the South is the technological follower assumed to provide incomplete patent protection. There is an exogenous parameter representing the probability of an innovation protected by a patent being imitated and sold at its marginal production cost.

The model predicts that knowledge spillover from the technological leader to the follower generates convergence in rates of growth. This convergence is governed by transitional dynamics which are functions of the North-South technological gap.

The labor force is exogenously divided in two groups according to the level of innate ability: skilled labor is allowed to work in the R&D or in the Final sector while unskilled labor is exclusively engaged in the production of Final goods. As a consequence of this heterogeneity two equilibrium results are obtained: one in which skilled workers are endogenously distributed in the R&D and the Final sector, and the other in which all skilled labor is engaged in research and all unskilled labor in production. Whether one case or the other applies to a given economy is shown to be a function of total population size and skilled labor.

In the first case we observe that although there is convergence in terms of the rates of growth of the two regions, there is a steady state technological gap that is in turn a decreasing function of the level of patent enforcement. In other words, higher levels of IPRs increases the number of intermediate inputs in the South relative to the North. For relevant values of the parameters this positive effect over welfare dominates the negative effects of stronger monopolistic distortion so that agents' welfare is enhanced with stronger IPRs. In this setup the positive effect of IPRs over the span of intermediate goods replaces the positive effect over the steady state rate of growth present in the closed economy setup.

The other possible case comtemplates a situation where all production of the homogeneous good is undertaken by unskilled labor and all skilled labor is engaged in R&D. As long as the relative wage is higher than one this case will hold. Variations in the degree of IPRs affect only the equilibrium results now if they make the economy switch from the second to the first case. Welfare for skilled labor is maximized under full enforcement of IPRs. On the contrary, unskilled workers maximize welfare under a weaker IPRs regime.

Future research in this line could be improved by using cross-country data on technological spillovers and diffusion, evolution of the skill premium both in developed and developing economies and recently constructed indexes on the level of enforcement of IPRs from a sample of countries.

Chapter 3

Intellectual Property Rights Induced Trade

3.1 Introduction

The TRIPS agreement might be considered as the most extensive multilateral agreement on Intellectual Propert Rights (IPRs) to date. It covers all areas of IPRs (e.g. patents, copyrights, trademarks) and concerns all WTO member countries. The treaty makes provision for variable implementation periods for countries at different stages of development. Although the TRIPS agreement was fully implemented in developed economies by 1995, and developing economies by 2000, its implementation for Least Developed Countries is still uncertain. At the time being, the expected enforcement date for that group of countries is 2013 for general issues, and 2016 for pharmaceuticals.

As a result of the TRIPS agreement, fellow WTO members should be in the capacity of providing both national and foreign owners of goods protected by IPRs with a set of non discriminatory minimum standards intented to deter the unauthorized use of their proprietary information.

Since international negotiations on IPRs have taken place in the framework of more general trade negotiations (e.g. TRIPS, NAFTA, and various trade bilateral treaties) it is desirable to consider the trade implications of the provisions contained in these type of agreements.

Theorical research on IPRs and trade has been noticeable scarce. Maskus and Penubarty identify two opposite effects by which strengthening of IPRs potentially affect trade flows. On the one hand there is the "market power" effect by which increasing IPRs enhances market power hold by the owners of the Knowledge-Based Asset (KBAs), who in turn are able to increase profits by curbing the production of the good and setting prices higher than the production cost. On the other hand, the "market expansion" effect states that the incentives of foreign producers to export to a given economy increase under stronger

IPRs since the risk of being imitated is expected to fall.

On the empirical side, there is evidence of a positive link between a country's degree of IPRs enforcement and the flow of differentiated goods being exported to that economy. Smith (99) extends Maskus and Penubarti (97) by focusing on the sensitivity of US exports to the IPRs regime of trade partners. Smith creates subsamples of countries by their "threat of imitation" level. This "threat of imitation" results from the interaction between the stringency of patent protection (as measured alternatively by the Ginarte and Park and the Rapp and Rozek indexes[1]) and the country's imitative capabilities (as measured by the number of skilled workers used as a proxy for the number of potential imitators). Smith claims that weak IPRs are a barrier to US exports for countries clasified as posing a high threat of imitation. Most importantly, the chapter shows that US exports to these countries (this is, countries with strong imitative abilities and weak patent rights) increase substantially after the implementation expected under the TRIPS agreement.

Ivus (10) measures the impact of the TRIPS agreement on exports from OECD countries for a sample of developing economies. Her methodology is based on the historical fact that former British and French colonies implemented most of the provisions included in the TRIPS agreement during the 1960-1990 period, while the group of "non-colonies" did so between 1990 and 2005. In order to isolate changes in trade flows accountable to reforms concerning patent rights alone, the author conducts a difference-in-difference analysis on the average rate of growth of exports from OECD countries to a group of developing countries, both in patent-sensitive and patent-insensitive industries. She finds that the value of trade accountable to the increase in patent rights by developing countries can be estimated at US35 billion and that this increase is driven by quantities and not by higher prices.This is equivalent to a 8.6% rise on the value of North-South trade.

The present chapter provides a theoretical formalization of the empirical findings mentioned above. We argue that stronger IPRs generate a reallocation of R&D resources (in the form of skilled labor) out of the imitative activity and into the innovative activity and the production of consumption goods. This diversion of resources reduces the potential risk of imitation faced by foreign innovators were they to export to the domestic economy. In expectations, the time before an innovation is imitated lengthens. Consequently, the flow of profits accruing to foreign patent owners rise. Those foreign innovators that did not export under the old IPRs regime, may be willing to do so under the new regime motivated by a higher flow of profits coming from the domestic market.

We consider a North- South general equilibrium framework with trade in differentiated capital inputs. We follow Melitz (03) in assuming there is a fixed (sunk) cost of exporting per destination market and variety of exported good. As explained by Melitz "...there is mounting evidence that firms wishing to export not only face per-unit costs (such as transportation costs and tariffs), but also - critically - face some fixed costs that do not

[1] See Ginarte and Park (1998), and Rapp and Rozek (1990).

vary with the export volume". Still in the lines of Melitz, we allow skilled labor to be heterogeneous in its productivity. Only firms integrated by the most productive workers are able to obtain enough profits from the foreign market to be willing to pay the fixed costs of exporting.

Skilled workers choose between working for the R&D sector or the Final sector. Skilled workers in the former engage in one of two productive activities: innovation or imitation. Imitation is modelled as a costly activity requiring skilled labor to undertake reverse engineering on blueprints of already existing varieties of capital goods. Imitators can target any existing blueprint in the world independently of the geographical location of its legal producer. In some cases this leads to a situation where imitators and innovators compete for profits in the same market. The outcome of this "rent cannibalization" game calls for imitators avoiding price competition with more productive innovators. In particular, imitators target non exporting foreign innovators and less productive exporting foreign innovators. Under these two cases, the imitator sets his profit maximizing price in the domestic economy while the innovator makes zero profits in that market but keeps maximal profits in the foreign economy.

We based the assumption about costly imitation on empirical research by Mansfield, Schwartz and Wagner (81) estimating the costs related to imitation as corresponding to around 65% of the costs related to innovation.

We focus on a situation in which IPRs are weak in the South and perfectly enforced in the North. Nonexporting units of skilled labor in the South take advantage of the combination between lower costs of imitation relative to innovation and weak IPRs to become imitators; while high IPRs act as a disincentive to imitation in the North.

Each potential exporter in the North observes the productivity of imitators located in the South in order to assess the risk of imitation that they face in the southern market. This risk is idiosyncratic since it increases with the number of imitators of productivities higher than the exporter's. The present value of future profits from the southern market, conditional on the idiosyncratic risk of imitation coming from the South, and the fixed costs of exporting determines the innovator's exporting status.

IPRs are modelled as the hazard rate faced by imitators of being punished and stripped of profits from the sale of imitated varieties of intermediate goods. As IPRs increase, the value of an imitation (defined as the expected value of these profit flows) relative to the value of an innovation falls. Some of the most productive skilled workers, previously engaged in imitation under the lower IPRs regime, decide to switch R&D activities and move out of imitation and into innovation. This reallocation of skilled labor reduces the risk of imitation faced by exporting northern innovators with productivity parameters lower than those of the former imitators. Some of the innovators in the North, that were not willing to pay the fixed cost of exporting under the previous IPRs regime in the South, would now be willing to do so under the stronger IPRs. This mechanism is therefore able to explain the rise in trade flows from developed economies to developing economies after the latter's implementation of measures intending to strengthen IPRs, such as the provisions contained in the TRIPS agreement.

Using the results from the model we construct a numerical representation of the world economy. We then compute the steady states corresponding to two IPRs regimes in the South. We start from a pre-TRIPS world economy where most of the world innovative activity takes place in the North (i.e. 99.99%), the ratio of exporting firms relative to non exporting firms in the North is 13.37%, and the rate of growth of the world is 2%. By less than doubling the parameter representing the IPRs regime in the South (i.e. from a pre-TRIPS value of 0.0145 to a post-TRIPS of 0.0268) the calibrated model predicts an increase in the value of exports from the North to the South of 7%. The exporting/non exporting ratio in the North increases to 14.38%. Even though the number of innovators increases in the South, and the number of those innovators who export increases in the North, the total number of innovators in the world falls. The model reports a fall in the rate of growth of the world of 0.001 percentage points.

The model developed in this chapter differs from previous theoretical modelizations of the role played by IPRs in an open economy. Helpman's seminal paper (Helpman (93)), and a more recent Grossman and Lai (04) also consider a North-South model with imperfect protection of IPRs in the South. Nonetheless, they make specific assumptions on the South's R&D capabilities: Helpman assumes the South is unable to engage in innovative activities; while Grossman and Lai allow the South to engage in innovation, but assume the North has a comparative advantage in that area. Our model manages to explain the preponderance of the North in the world's innovative activities without recurring to differences in production technologies but relying exclusively on differences on endowments of R&D resources and IPRs.

We start by presenting the model in section 2. The first part describes the institutional and technological framework of the economy while the second focuses on the definition of the descentralized equilibrium. We present the "rent cannibalization" games played by imitators and different types of innovators in section 3. Section 4 defines the rules governing the allocation of skilled labor between sectors (R&D and Final sector), activities within the R&D sector (innovative and imitative) and exporting status of the innovators. Section 5 compares two steady states derived from two different specifications of IPRs regimes in the South. Because only so much can be obtained by theoretical results, the second part of this section attempts a calibration of the model to obtain a further representation of the effects of IPRs on the world economy.

3.2 Model

3.2.1 Technologies

We consider a model of endogenous growth in continuous time with two regions where technological progress is explained by the arrival of horizontally differentiated varieties of production inputs.

The world is composed of two regions: the North (n) and the South (s). Each region is endowed with a fixed amount of unskilled labor ($L^k, k = n, s$) and skilled labor (H^k).

There are two productive sectors in each economy: the Final sector (FS) and the R&D/Intermediate sector (R&D/Int.). Unskilled labor is engaged exclusively in the FS while skilled labor is allocated into the FS and the R&D/Int. sector. All workers are equally productive in the FS but not in the R&D/Int. sector.

Firms in the FS produce a rival and excludable homogeneous good by means of a constant returns to scale technology that requires units of unskilled and skilled labor, and units of intermediate inputs. There is a large number of firms in this sector. Aggregate production is defined by the following function,

$$Y_t^k = \left(H_{Y,t}^k\right)^{\alpha} \left(L^k\right)^{\beta} \int_{i \in A_t^k} \left(x_{i,t}\right)^{1-\alpha-\beta} di \text{ with } \alpha, \beta > 0 \text{ and } \alpha + \beta < 1 \tag{3.2.1}$$

Final output is represented by Y_t^k. $H_{Y,t}^k$ stands for the number of units of skilled labor engaged in the production of final goods, and $x_{i,t}$ the number of units of intermediate good of type i. The set of varieties of intermediate inputs effectively used in country k by firms in the FS is A_t^k. The price of the homogenous good is normalized to one.

The R&D/Int. sector is composed of skilled workers. For simplicity we assimilate one skilled worker to be one firm in this sector. They manufacture and sell units of intermediate inputs to firms in the FS. The production technology is linear and requires only homogeneous good. Firms in the R&D/Int. sector are heterogeneous in their productivities. A firm j characterized by cost parameter η_j, employs η_j units of homogeneous good to produce one unit of intermediate input. Cost parameters are distributed across skilled workers according to a pdf $f(\eta)$ with support $\left(0, \phi_l^{-1}\right]$ with $\phi_l > 0$. The lowest the cost parameter the highest the productivity of the firm. Cost parameters are drawn once at the beginning of time and are publicly observable by all domestic and foreign agents in the economy.

The production of variety i by firm j, $x_{i,j,t}$ is therefore given by

$$x_{i,j,t} = \frac{Y_{i,j,t}}{\eta_j}$$

Where $Y_{i,j,t}$ is the amount of homogeneous good used by firm j for the production of variety i.

Firms in the R&D/Int. sector need to own a blueprint for each one of the varieties of intermediate inputs they produce. A blueprint may be thought of as the "recipe" detailing the procedures and ingredients required for the manufacturing of physical units of a given variety of intermediate inputs. There are two ways for firms in the R&D/Int. sector to acquire a new blueprint. It may invest resources in the development of an original intermediate variety that would be represented by a new element of the set of existing intermediate varieties in the world, i.e. $\mathbb{A}_t^k \cup \mathbb{A}_t^{k'}$. Blueprints arising from this type of R&D are denoted "innovations". Conversely, a firm may invest resources in the reproduction of an already existing intermediate variety through a process of reverse or backward engineering. Blueprints arising from this type of R&D are denoted as "imitations". Imitations allow a firm to manufacture an existing variety but do not add an additional element to the set of intermediate varieties in the world.

Following the specification for the arrival of blueprints proposed by Romer (1990) we assume that each skilled worker/intermediate firm is endowed with one unit of human capital that produce blueprints deterministically. In particular, the number of blueprints that arrive at each period is proportional to the number of existing blueprints at the beginning of the period. This formulation allows us to incorporate the fact that the body of knowledge in the world enhance the productivity of researchers whose output itself (i.e. new ideas) will be part of this set from the next period. For simplicity, let's assume that the number of blueprints (whether they are innovations or imitations) per researcher arriving at every period is a linear function of the stock of knowledge in the world. We define the stock of knowledge in the world, i.e. $A_t^w \in \mathbb{R}_+$, as the measure of the set $\mathbb{A}_t^k \cup \mathbb{A}_t^{k'}$, i.e. the number of intermediate varieties produced up to time t either in country k or k'.

Mansfield et al. (1981) perform an empirical study about the costs of imitation relative to the cost of innovation. They found that "On the average, the ratio of the imitation cost to the innovation cost was about 0.65, and the ratio of the imitation time to the innovation time was about 0.70." We make use of this empirical findings and assume that the productivity related to the production of imitations is higher than the corresponding productivity for the production of innovations. An R&D/Int. firm j's (or the corresponding researcher's) per period production of innovations is $\dot{A}_{j,t} = \delta_A A_t^w$[2]. Alternatively, that same firm's production of imitations would be $\dot{I}_{j,t} = \delta_I A_t^w$. Following from the discussion above, we assume throughout this chapter that $\delta_A < \delta_I$ and firms must choose whether to allocate their human capital either to the production of innovations or that of imitations (in the first case we refer to the firm as an "innovator" while in the second case as an "imitator").

Let us denote the number of innovators and imitators (i.e. units of skilled labor in

[2]Dots on top of a time-varying variable represent time derivatives, i.e. $\dot{A}_{j,t}^k = \partial A_{j,t}^k / \partial t$.

the R&D/Int. sector engaged in innovation and imitation) as $H^k_{A,t}$ and $H^k_{I,t}$ respectively. The aggregate number of innovations and imitations developed in region k at time t is:

$$\begin{aligned}\dot{A}^k_t &= \sum_{j=1}^{H^k_{A,t}} \dot{A}^k_{j,t} dj = \delta_A H^k_{A,t} A^w_t \\ \dot{I}^k_t &= \sum_{j=1}^{H^k_{I,t}} \dot{I}^k_{j,t} dj = \delta_I H^k_{I,t} A^w_t\end{aligned}$$

The specification of the production function in (3.2.1) implies that new varieties do not displace existing ones, i.e. old varieties never become obsolete. At any time, a firm in the R&D/Int. sector has developed $A^k_{j,t}$ innovations, or $I^k_{j,t}$ imitations, throughout its productive life. The aggregation of these blueprints across innovative and imitative firms in country k provides the number of innovations and imitations produced in each region up to time t, A^k_t and I^k_t. Therefore, $A^w_t = A^k_t + A^{k'}_t$[3].

There is a fixed number of households, $H^k + L^k$. There is no international labor mobility. All unskilled labor is allocated to the FS, while the endowment of skilled labor is endogenously allocated to the FS and the R&D/Int. sector (where they are either innovators or imitators).

$$H^k = H^k_{Y,t} + H^k_{A,t} + H^k_{I,t}$$

Household h maximize the discounted value of future utilities:

$$\int_t^{\infty} \exp -\rho(\tau - t) u(c^k_{h,\tau}) d\tau$$

Where $\rho > 0$ represents the subjective utility discount factor. Instantaneous utility is assumed to be logarithmic on household's consumption $c^k_{h,t}$, $u(c^k_{h,t}) = \ln c^k_{h,t}$. Households can trade financial assets, $b^k_{h,t}$, and borrow/lend at rate r^k_t.

3.2.2 IPRs Institutions

Innovators are legally granted a costless and infinitely lived patent for each blueprint they develop.

Intellectual Property Rights (IPRs) are modelled as the hazard rate of punishment per variety imitated. Punished imitators are charged with a fine equivalent to the value of all future profits coming from the punished variety. This hazard rate is represented by $\mu^k \in [0, \infty)$, being $\mu^k = 0$ the case where no IPRs exist and imitators are never punished and $\mu^k \to \infty$ the opposite case where IPRs are fully enforced and imitators are punished

[3]It is important to notice that this formulation makes the implicit assumption that there is no simultaneous redundancy in R&D efforts. In other words, the intersection of the set of innovations discovered by different R&D/Intermediate firms is always empty.

at the time the blueprint is created[4].

This chapter focuses in one specific configuration of IPRs in the world. We assume IPRs to be perfectly enforced in the North and weakly enforced in the South. In terms of the preceding notation, we have $\mu^n \rightarrow \infty$ and μ^s is finite and "low enough". The range of values for the IPRs regime in the South considered as "low enough" will be specified on the chapter in a subsequent section.

3.2.3 Exporting

R&D/Int. firms in country k may export physical units of intermediate inputs to foreign firms in the FS in country k'. Recent research in international trade stresses the role played by fixed costs of exporting. We assume that before shipping the first unit of intermediate good, the producer must pay F units of homogeneous good per variety exported.

We also assume that parallel imports are allowed in both regions. A parallel import is defined as a non-counterfeited product imported without the consent of the patent owner. Parallel imports limit the rights of the patent owner after the good has been sold for the first time.

3.2.4 Decentralized Equilibrium

Definition 3.2.1 *A decentralized equilibrium at time t in this economy is given by a sequence of prices and quantities of intermediate inputs, $\left\{p^k_{i,\tau}, x^k_{i,\tau}\right\}^{\infty}_{\tau=t}$, for $i \in A^k_{\tau}$; wages for unskilled and skilled labor engaged in the FS, $\left\{w^k_{L,\tau}, w^k_{Y,\tau}\right\}^{\infty}_{\tau=t}$; remunerations for skilled workers in the R&D/Int. sector (innovators and imitators), $\left\{w^k_{A,\tau}, w^k_{I,\tau}\right\}^{\infty}_{\tau=t}$; interest rates, $\left\{r^k_{\tau}\right\}^{\infty}_{\tau=t}$; and allocations of skilled labor by productive sector (FS and R&D/Int. sector), research activity (innovation and imitation) and exporting status (exporter and non exporters), $\left\{H^k_{Y,\tau}, \left\{H^k_{EA,\tau}, H^k_{NEA,\tau}\right\}, \left\{H^k_{EI,\tau}, H^k_{NEI,\tau}\right\}\right\}^{\infty}_{\tau=t}$ such that:*

1. *Firms in the R&D/Int. sector set prices of intermediate inputs facing the market demand for each intermediate variety such that expected profits per variety are maximized.*

2. *Firms in the FS demand unskilled and skilled labor, and varieties of intermediate inputs such that they maximize profits taking goods and input prices as given.*

3. *Blueprints of intermediate varieties are priced such that there are no arbritrage opportunities.*

4. *Households maximize intertemporal utility subject to their intertemporal profile of budget constraints.*

[4] An alternative way of thinking about the hazard rate is by considering the expected life lenght of an imitation as the inverse of the parameter μ^k.

5. *Firms in the R&D/Int. sector choose their research activity given the probabilities of imitation they face in each market and conditional on the IPRs regime in place.*

6. *Firms in the R&D/Int. sector decide their export status given the probabilities of imitation they face in each market and conditional on the fixed cost of exporting.*

7. *Trade is balanced.*

8. *All markets (labor market, markets for homogeneous and differentiated goods, and financial markets) clear.*

Firms in the FS maximize profits at every period taking prices as given. The price of the homogeneous good is normalized to one. Let $w^k_{Y,t}$ be the wage perceived by skilled labor in the FS; $p^{kk}_{i,j,t}$ the domestic price of capital good i manufactured by a domestic R&D/Intermediate firm of productivity parameter η^k_j, and $p^{kk'}_{i,j,t}$ the foreign price of the same good[5]. Perfect competition in the final good market and competition between firms for production factors imply factors being demanded at the point where prices equal marginal productivities. Aggregate demand for $H^k_{Y,t}$ is therefore defined by $w^k_{Y,t} = \partial Y^k_t / \partial H^k_{Y,t}$; for L^k by $w^k_{L,t} = \partial Y^k_t / \partial L^k$; and demand for domestic (foreign) variety i, by $p^{kk}_{i,t} = \partial Y^k_t / \partial x^{kk}_{i,t}$ ($p^{k'k}_{i,t} = \partial Y^k_t / \partial x^{k'k}_{i,t}$)[6].

R&D/Intermediate producer of capital good i with productivity parameter η^k_j set price $p^{kk}_{i,j,t}$ in order to maximize domestic profits $\left(p^{kk}_{i,j,t} - \eta^k_j\right) x^{kk}_{i,t}\left(p^{kk}_{i,j,t}\right)$. Those exporting firms also set the profit maximizing price $p^{kk'}_{i,j,t}$ for the foreign market, i.e.

$$\arg\max_{p^{kk'}_{i,j,t}} \left(p^{kk'}_{i,j,t} - \eta^k_j\right) x^{kk'}_{i,t}\left(p^{kk'}_{i,j,t}\right)$$

Profit maximizing prices are given by a markup over the marginal production cost, $p^{kk}_{i,t} = p^{kk'}_{i,t} = p_i\left(\eta^k_j\right) = \frac{\eta^k_j}{1-\alpha-\beta}$, which is independent of the destination market and time. By plugging the profit maximizing price in the expression for profits we obtain domestic profits from variety i manufactured by a type-η^k_j R&D/Intermediate firm, $\pi^{kk}_{i,t}\left[p_i\left(\eta^k_j\right)\right] = (\alpha+\beta)\, p_i\left(\eta^k_j\right) x^{kk}_{i,t}\left[p_i\left(\eta^k_j\right)\right]$. For exporting firms, profits coming from the foreign market are given by $\pi^{kk\prime}_{i,t}\left[p_i\left(\eta^k_j\right)\right] = (\alpha+\beta)\, p_i\left(\eta^k_j\right) x^{kk'}_{i,t}\left[p_i\left(\eta^k_j\right)\right]$.

Lemma 3.2.1 *Per period profits on variety i produced by R&D/Intermediate firm j on the domestic and foreign markets are decreasing functions of the cost parameter, η^k_j.*

[5] The first superscript stands for the region where the good is manufactured and the second for the one where the good is sold.

[6] The equilibrium demand for varitey i from firms in the final sector in country k is:

$$x^{kk}_{i,t}\left(p^{kk}_{i,j,t}\right) = \left[\frac{(1-\alpha-\beta)\left(H^k_{Y,t}\right)^{\alpha}\left(L^k\right)^{\beta}}{p^{kk}_{i,j,t}}\right]^{\frac{1}{\alpha+\beta}}$$

Proof. Functions $\pi_{i,t}^{kk}\left[p_i\left(\eta_j^k\right)\right]$ and $\pi_{i,t}^{kk'}\left[p_i\left(\eta_j^k\right)\right]$ are homogeneous of degree $-\frac{1-\alpha-\beta}{\alpha+\beta}<0$, implying $\frac{\partial\pi_{i,t}^{kk}\left[p_i\left(\eta_j^k\right)\right]}{\partial\eta_j^k}<0$ and $\frac{\partial\pi_{i,t}^{kk'}\left[p_i\left(\eta_j^k\right)\right]}{\partial\eta_j^k}<0$. ■

To summarize, more productive firms in the R&D/Int. sector (i.e. indexed with a lower cost parameter η_j^k) set lower prices, sell larger quantities and make higher profits than less productive firms.

The world economy considered in this chapter is characterized by complete enforcement of IPRs in the North and a weak protection in the South. A direct consequence from the specification of $\mu^n \rightarrow \infty$ is that there are no imitators located in the North and no imitated goods are exported from the South to the North (imitators who export to the North are immediately punished). All skilled labor in the North is allocated into innovative R&D (whether they export or they sell exclusively in the domestic market) and production of the homogeneous good in the FS. Furthermore, I assume IPRs in the South are such that skilled workers are either exporting innovators, non exporting imitators, or they work for the production of the homogeneous good in the FS. I show that for low values of μ^s the remuneration of non exporting imitators is strictly higher than the remuneration of non exporting innovators. Heuristically, when the probability of being punished faced by imitators is zero it is clear that the higher productivity in the imitative activity over the innovative one (recall $\delta_I > \delta_A$) is translated as a higher remuneration for imitators. As μ^s increases, the remuneration of innovators relative to imitators increase until they are eventually equalized. This equalization arrives at the point where relative productivity in favor of the imitator $(\frac{\delta_I}{\delta_A})$ is compensated by an equally higher relative discount factor of future profits that benefits innovators, $(\frac{r_t^s+\mu^s}{r_t^s})$. In other words, even though imitators produce more blueprints per period than innovators, these blueprints are, in expectation, shorter lived.

We denote $P_{A,i,j,t}^{kk}$ the value of innovative blueprint i, manufactured by firm j of type-η_j^k, coming from the domestic market. It corresponds to the expected present value of all future domestic monopolistic profits. Similarly, the price of imitative blueprint i, produced and manufactured by firm j in the South, is $P_{I,i,j,t}^{ss}$. Let us call the hazard rate of imitation in the South faced by southern (northern) innovation i produced by firm j as $\iota_{i,t}^{ss}$ $(\iota_{i,t}^{ns})$ (since there are no imitators in the North, $\iota_{i,t}^{nn}=\iota_{i,t}^{sn}=0$). In the next section, the determination of these hazard rates of imitation will be shown to be endogenously defined by the number of imitators targeting variety i in the equilibrium.

In order to finance R&D investments, R&D/Intermediate firms sell shares to households, yielding dividends proportional to the firm's stream of profits.

In the absence of arbitrage opportunities households must be indifferent between holding shares of R&D/Intermediate innovative firms and obtaining a riskless return (the interest rate) r_t^k. The following equation relates the price of one variety and the interest rate, the hazard rate of imitation and the value of profits[7].

$$P^{nn}_{A,i,j,t} r^n_t = \pi^{nn}_{i,t}\left[p^n_i\left(\eta_j\right)\right] + \dot{P}^{nn}_{A,i,j,t} \quad (3.2.2)$$
$$P^{ss}_{A,i,j,t} r^s_t = \pi^{ss}_{i,t}\left[p^s_i\left(\eta_j\right)\right] + \dot{P}^{ss}_{A,i,j,t} - \iota^{ss}_{i,t} P^{ss}_{A,i,j,t} \quad (3.2.3)$$

When exported, the present value of monopolistic profits coming from the foreign market k', $P^{kk'}_{A,i,j,t}$, must satisfy a similar condition with the addition of the fixed cost of exporting, F.

$$\left(P^{sn}_{A,i,j,t} + F\right) r^s_t = \pi^{sn}_{i,t}\left[p^s_i\left(\eta_j\right)\right] + \dot{P}^{sn}_{A,i,j,t} \quad (3.2.4)$$
$$\left(P^{ns}_{A,i,j,t} + F\right) r^n_t = \pi^{ns}_{i,t}\left[p^n_i\left(\eta_j\right)\right] + \dot{P}^{ns}_{A,i,j,t} - \iota^{ns}_{i,t}\left(P^{ns}_{A,i,j,t} + F\right) \quad (3.2.5)$$

Imitators face an instantaneous probability of being "punished", μ^s. This parameter is tantamount to the IPRs regime.

$$P^{ss}_{I,i,j,t} r^s_t = \pi^{ss}_{i,t}\left[p^s_i\left(\eta_j\right)\right] + \dot{P}^{ss}_{I,i,j,t} - \mu^s P^{ss}_{I,i,j,t} \quad (3.2.6)$$

Households maximize intertemporal utility subject to a profile of budget constraints. Namely, that at every period the accumulation of financial assets, $\dot{b}^k_t$, is given by the non consumed part of total income (i.e. total income is defined as labor revenues and the return of financial assets, b^k_t).

The solution to the intertemporal utility maximization problem yields the usual Euler equation linking the rate of growth of consumption to the interest rate and the discount parameter, ρ.

$$r^k_t = g^k_{c,t} + \rho$$

Where $g^k_{c,t}$ is the rate of growth of consumption at time t in country k.

3.3 Rent cannibalization game

Costly imitation implies that imitators, as well as innovators, require rents to finance R&D expenditures. Nonetheless, imitators have discretion over which innovations to target. Potentially targeted innovations can be separated in four groups by the geographical location and exporting status of the producer: exported domestic and foreign innovations

[7] A household with an amount $P^{kk}_{i,t}$ to invest face two choices: obtaining the riskless interest rate or purchasing shares on the R&D/Intermediate firm. For a period of length dt, the first option yields $P^{kk}_{i,t} r^k_t dt$, while the second option yields $\pi^{kk}_{i,t}\left[p^k_i\left(\eta_j\right)\right] dt + \left(1 - \iota^k dt\right) dP^{kk}_{i,t} - \iota^k dt P^{kk}_{i,t}$. Shares of value $P^{kk}_{i,t}$ give a dividend equivalent to the monopolistic profits. With instantaneous probability $\iota^k dt$ the variety is imitated and the flow of profits stops, and with complementary probability $\left(1 - \iota^k dt\right)$ imitation does not arrive and the owner of the shares obtains value gains of $dP^{kk}_{i,t}$.

The result is obtained when equating the return of the two options, dividing by dt and then evaluating the limit of the expression when dt goes to zero.

and nonexported domestic and foreign innovations.

In order to characterize the set of innovations targeted by each imitator, it is necessary to provide an analysis of the strategic behaviour of these agents.

This analysis is derived from a game, known as the "predation game", in which an Entrant (imitator) and an Incumbent (innovator) move sequentially. The entrant moves first: "In" if it targets the incumbent, "Out" otherwise. If the entrant plays "In", the incumbent can play "Fight" and compete in prices with the entrant *à la Bertrand*; or "Accomodate" and keep the price unchanged.

Payoffs are given by the value of variety i at each node of the game. Depending on whether price competition takes place the value of the variety may be expected to change. For instance let us define the value in the South of variety i for a type-η_I incumbent setting a price equal to its profit maximizing price, $p(\eta_I)$, as $P^{ss}_{\eta_I}[p(\eta_I)]$. It may be the case that, following price competition, the same incumbent sets a price equal to his own (or the entrant's) marginal cost, η_I (η_E). The value of variety i corresponding to this strategy is noted as $P^{ss}_{\eta_I}(\eta_I)$ $(P^{ss}_{\eta_I}(\eta_E))$.

It is a finite game of perfect information. The appropriate concept of equilibrium for this sort of games is a Subgame Perfect Nash Equilibrium (SPNE).

I consider four different games depending on the type of innovator considered to be the incumbent. When necessary, two cases are considered: one where the incumbent is more productive than the entrant ($\eta_I < \eta_E$), and another one where the contrary is true (i.e. $\eta_I > \eta_E$).

3.3.1 Game One: Incumbent is a non exporting innovator in the North

The entrant is located in the South and the incumbent in the North. Since neither the incumbent nor the entrant exports to the other region, they do not share a common market.

The SPNE is trivial. Let us define as σ_E and σ_I the equilibrium strategies played respectively by the entrant and the incumbent. For this game we obtain the following result.

Lemma 3.3.1 *The SPNE of the rent cannibalization game played by an imitator located in the South and a non exporting innovator located in the North is:*

$$(\sigma_E, \sigma_I) = (\textit{In}, \textit{Accomodate if Entrant plays "In"})$$

Proof. By targeting a non exporting foreign innovator, imitators are able to maximize profits by charging the monopolistic price $p(\eta_E)$. Since innovators (located in the North) and imitators (located in the South) do not share markets, profits made by one are independent of the price strategy adopted by the other. ■

This is a somewhat special case since the strategy of this game is going to be defined as the outside option for entrants in the other games. In other words, when targeting other type of innovators, imitators bear in mind that targeting non exporting foreign innovators yields the highest profit they could obtain from any variety. We refer to this case as the outside option for the remaining cases.

3.3.2 Game Two: Incumbent is a non exporting innovator in the South

Both players are located in the same geographical location and they serve only that region's market (i.e. the South).

Case $\eta_I < \eta_E$: Incumbent is more productive than the entrant

Lemma 3.3.2 *The SPNE of the rent cannibalization game played by an imitator and a more productive non exporting innovator both located in the South is:*

$$(\sigma_E, \sigma_I) = (\textit{Out}, \textit{Fight if Entrant plays "In"})$$

Proof. If the entrant plays "In" and targets the variety produced by the incumbent, this one would compete in prices. By doing so the incumbent can expect a value of $P^{ss}_{\eta_I}(\eta_E)$, i.e. by charging a price corresponding to the marginal cost of the entrant. Profits are strictly positive for the incumbent. If instead the incumbent plays "Accomodate", keeping the price $p(\eta_I)$ unchanged, the entrant can enjoy positive profits by setting a price slightly lower than this price and serving the whole market, making the incumbent earn zero profits. In both cases the payoff of the game for the entrant is strictly lower than the outside option $P^{ss}_{\eta_E}[p(\eta_E)]$. ■

Case $\eta_I > \eta_E$: Incumbent is less productive than the entrant

Lemma 3.3.3 *The SPNE of the rent cannibalization game played by an imitator and a less productive non exporting innovator both located in the South is:*

$$\begin{aligned}
(\sigma_E, \sigma_I)_1 &= (\textit{Out}, \textit{Fight if Entrant plays "In"}) \;\; \textit{if}\; \eta_E < \eta_I < p(\eta_E) \\
(\sigma_E, \sigma_I)_2 &= (\textit{In}, \textit{Fight or Accomodate if Entrant plays "In"}) \;\; \textit{if}\; p(\eta_E) \leq \eta_I
\end{aligned}$$

Proof. For $(\sigma_E, \sigma_I)_1$. If the entrant plays "In" the payoff for the incumbent is zero in all cases. If the incumbent plays "Fight", price competition takes place until the equilibrium price would be the marginal cost η_I, which is higher than the one of the entrant. If the incumbent plays "Accomodate", it would set its own monopolistic price which is, again, higher than the one of the incumbent. Profits for the incumbent under the two cases are zero. Nonetheless, under "Fight" the payoff for the entrant is $P^{ss}_{\eta_E}(\eta_I)$ which is strictly lower than the payoff the entrant would get under "Accomodate", i.e. $P^{ss}_{\eta_E}[p(\eta_E)]$. Which, in turn, is equal to the payoff of the outside option. Therefore, by playing "Fight" the incumbent is able to effectively deter imitation by making the entrant strictly choose the outside option.

For $(\sigma_E, \sigma_I)_2$. Under this parameter configuration, even if the incumbent plays "Fight", the payoff for the entrant is equal to the outside option when the entrant plays "In", i.e. $P^{ss}_{\eta_E}[p(\eta_E)]$. This corresponds to a case in which the productivity advantage of the entrant over the incumbent is sufficiently large that the price the entrant charges as a monopolist is lower than the marginal cost of the incumbent. ∎

3.3.3 Game Three: Incumbent is an exporting innovator in the South

Although the entrant and the incumbent are both located in the South, the incumbent sells to the South and the North at the same price. Price equalization across regions is a direct consequence of the existence of parallel imports. Under parallel imports, any geographical market segmentation is offset by the arrival of units of intermediate goods from the market where the price is lower. For instance, northern producers that would want to charge a lower price for a given variety of intermediate good in the South relative to the North would face the arrival of non-counterfeited units of that variety from the South to the northern market. In other words, under parallel imports (and assuming zero variable costs such as transportation costs or tariffs) the producer competes in prices against himself leading to the lowest price among different geographical locations to prevail.

Case $\eta_I < \eta_E$: Incumbent is more productive than the entrant

There are two possible equilibria for the incumbent's strategy.

Lemma 3.3.4 *The SPNE of the rent cannibalization game played by an imitator and a more productive exporting innovator both located in the South is:*

$$
\begin{aligned}
(\sigma_E, \sigma_I)_1 &= (\textit{Out, Fight if Entrant plays "In"}) \;\; \textit{if } P^{ss}_{\eta_I}(\eta_E) + P^{sn}_{\eta_I}(\eta_E) > P^{sn}_{\eta_I}[p(\eta_I)] \\
(\sigma_E, \sigma_I)_2 &= (\textit{Out, Accomodate if Entrant plays "In"}) \;\; \textit{if } P^{ss}_{\eta_I}(\eta_E) + P^{sn}_{\eta_I}(\eta_E) < P^{sn}_{\eta_I}[p(\eta_I)]
\end{aligned}
$$

Proof. For $(\sigma_E, \sigma_I)_1$. Because of parallel imports, price competition between the incumbent and the entrant not only affects the incumbent's profits in the South but also those in the North. The payoff for the incumbent under price competition with the entrant is equal to domestic and foreign profits evaluated at the entrant's marginal cost,

$P^{ss}_{\eta_I}(\eta_E) + P^{sn}_{\eta_I}(\eta_E)$. On the other hand, by playing "Accomodate", the incumbent looses domestic profits to the entrant but can set his profit maximizing price in the foreign economy, earning a total of $P^{sn}_{\eta_I}[p(\eta_I)]$. Profits are then zero for the entrant when he plays "In". His optimal choice is to play "Out" and target the outside opportunity instead.

For $(\sigma_E, \sigma_I)_2$. The incumbent plays "Accomodate" losing profits from the South but maximizing those from the North. Nonetheless, in order to make positive sells the entrant must undercut the incumbent's monopolistic price, $p(\eta_I)$. Under this price, the entrant obtains a payoff of of $P^{ss}_{\eta_E}[p(\eta_I)]$, strictly lower than the outside opportunity, i.e. the payoff under the entrant's own monopolistic price, $P^{ss}_{\eta_E}[p(\eta_E)]$. The entrant therefore plays "Out". ■

There would be another equilibrium when $p(\eta_I) < \eta_E$. It corresponds to a situation where the incumbent's productivity superiority is such that its monopolistic price is lower than the entrant's marginal cost. The two possible actions for the incumbent (i.e. "Fight" or "Accomodate") yield exactly the same equilibrium prices. This SPNE could be described as $(\sigma_E, \sigma_I) =$ (Out,Accomodate or Fight if E plays "In").

Case $\eta_I > \eta_E$: Incumbent is less productive than the entrant

Lemma 3.3.5 *The SPNE of the rent cannibalization game played by an imitator and a less productive exporting innovator both located in the South is:*

$$(\sigma_E, \sigma_I) = (In, \textit{Accomodate if Entrant plays "In"})$$

Proof. The consequence of price competition is the exhaustion of the rents going to the incumbent. Parallel imports imply that the same price in both geographical locations must prevail. The incumbent would be selling at marginal costs in the South and the North simultaneously making zero profits in both locations.

By playing "Accomodate", the incumbent enjoys maximum monopolistic rents in the North, although all rents from the South would be lost to the entrant. The entrant would charge the monopolistic price $p(\eta_I)$ in the South and enjoy the same payoff given by the outside option, i.e. $P^{ss}_{\eta_E}[p(\eta_E)]$. ■

3.3.4 Game Four: Incumbent is an exporting innovator in the North

Case $\eta_I < \eta_E$: Incumbent is more productive than the entrant

There are two possible equilibria for the incumbent's strategy.

Lemma 3.3.6 *The SPNE of the rent cannibalization game played by an imitator located* *in the South and a more productive exporting innovator located in the North is:*

$$\begin{aligned}(\sigma_E, \sigma_I)_1 &= (\textit{Out, Fight if Entrant plays "In"}) \;\; \textit{if } P^{nn}_{\eta_I}(\eta_E) + P^{ns}_{\eta_I}(\eta_E) > P^{nn}_{\eta_I}[p(\eta_I)] \\ (\sigma_E, \sigma_I)_2 &= (\textit{Out, Accomodate if Entrant plays "In"}) \;\; \textit{if } P^{nn}_{\eta_I}(\eta_E) + P^{ns}_{\eta_I}(\eta_E) < P^{nn}_{\eta_I}[p(\eta_I)]\end{aligned}$$

Proof. The incumbent compares the value of an innovation under price competition coming from the North and the South against the value obtained in the North alone under monopolistic pricing. If the former is higher than the latter, the incumbent plays "Fight" and the entrant makes zero profits (first equilibrium strategy). If the latter is higher than the former (second equilibrium strategy) the incumbent plays "Accomodate" and the entrant must sell at the incumbents monopolistic price, $p(\eta_I)$, which yields a payoff of $P^{ss}_{\eta_E}[p(\eta_I)]$, stricly lower than the outside option, $P^{ss}_{\eta_E}[p(\eta_E)]$. In both cases the entrant's optimal action is to play "Out". ■

Case $\eta_I > \eta_E$: Incumbent is less productive than entrant

Competition between a foreign exporting innovator and a more productive imitator.

Lemma 3.3.7 *The SPNE of the rent cannibalization game played by an imitator located in the South and a less productive exporting innovator located in the North is:*

$$(\sigma_E, \sigma_I) = (\textit{In, Accomodate if Entrant plays "In"})$$

Proof. If the incumbent plays "Fight", price competition stops when the price attains the incumbent's marginal cost, η_I, and makes no profits either in the North or the South. However, by playing "Accomodate" the incumbent obtains the maximum value in the North, $P^{nn}_{\eta_I}[p(\eta_I)]$.

The payoff for the entrant in this case is equal to the outside opportunity because the monopolistic price of the entrant is lower than the monopolistic price of the incumbent. ■

The study of the four possible rent cannibalization games considered above allows us to identify imitation patterns linking the geographical location and exporting status of the innovator, and the relative productivities betweent innovators and imitators.

These findings can be summarized in the following proposition.

Proposition 3.3.1 *The set of blueprints targeted by an imitator of productivity η_j located in the South is composed by all blueprints developed by:*

1. *All northern non exporting innovators (from the result of Game 1).*
2. *Those southern non exporting innovators with cost parameters higher than $\frac{\eta_j}{1-\alpha-\beta}$ (from the result of Game 2).*

3. *Those southern exporting innovators with cost parameters higher than η_j (from the result of Game 3).*

4. *Those northern exporting innovators with cost parameters higher than η_j (from the result of Game 4).*

To sum up, the set of blueprints that would yield the highest payoff to an imitator is larger for imitators of lower cost parameters. Out of the elements of this set, imitators randomly pick the blueprints that will be effectively imitated. The number of these blueprints at every point in time is given by the technological constraint of the imitator, i.e. $\dot{I}^s_{j,t}$.

For all categories of innovators considered above (according to geographical location and exporting status), the risk of their blueprints being imitated in the South is determined by the number of imitators targeting those blueprints. As a consequence of this, more productive innovators face a lower risk of imitation coming from the South. For instance, a northern innovator with a given cost parameter would be able to compute de probability of being imitated in the South if he exported into that market by considering the number of imitators in that location characterized by cost parameters lower that his own.

3.4 Allocation of Skilled Labor

The equilibrium remunerations of skilled labor in different productive activities along with the results of the rent cannibalization game allow us to describe the allocation of skilled labor in productive activities as a function of the cost parameter of each unit of skilled labor, η_j.

Lemma 3.2.1 establishes that domestic and foreign profits are decreasing in η_j. The value of discounted future monopolistic profits on each variety of intermediate goods is consequently also decreasing in individual cost parameters. Since exporting requires the payment of a fixed cost F, only workers for which the value of discounted profits coming from the foreign market is at least equal to F become exporters, i.e. for southern exporting innovators characterized by cost parameter η_j the following inequality must be verified $P^{sn}_{A,i,t}\left[\eta_j, \iota^{sn}_{i,t}\left(\eta_j\right) = 0\right] \geq 0$ (similarly for northern exporting innovators, $P^{ns}_{A,i,t}\left[\eta_j, \iota^{ns}_{i,t}\left(\eta_j\right) \geq 0\right] \geq 0$). In other words, future profits must, at least, compensate for the payment of F, and the value of the foreign market from the perspective of individual innovators must be nonnegative. These values are determined by the absence of arbitrage opportunities in equations 3.2.2 to 3.2.6, and depend negatively on the individual cost parameters and on the risk of imitation coming from each market. Since there are no imitators in the North, the risk of imitation faced by innovators selling to this market is zero, $\iota^{nn}_{i,t} = \iota^{sn}_{i,t} = 0$ for all values of η_j in the support of $f(\eta)$. Conversely, the presence of imitators in the South implies that some innovators selling in this market may face a positive risk of imitation that is particular to the cost parameter, $\iota_{i,t}^{ss}\left(\eta_j\right) \geq 0$ and $\iota_{i,t}^{ns}\left(\eta_j\right) \geq 0$.

Exporters are therefore skilled workers with high productivities (corresponding to the lower tail of the cost parameter distribution $f(\eta)$). In other words, exporting innovators represent the top of the productivity distribution and non exporting innovators and imitators are systematically less productive than them. In the equilibrium, "Case $\eta_I > \eta_E$" in Game Three of the Rent Cannibalization Game should never arise.

The remuneration of a skilled worker in the R&D/Inter. sector comes from the interaction of two margins. The "extensive" margin is given by the number of blueprints of intermediate varieties developed at every period, while the "intensive" margin is the expected value of each one of these varieties.

At every period, one innovator produces $\delta_A A_t^w$ blueprints of intermediate varieties. Each intermediate variety produced by southern exporters is sold in the South and the North. The remuneration of a type-η_j southern exporting innovator is:

$$w_{A,t}^s\left(\eta_j\right) = \delta_A A_t^w\left(P_{A,i,t}^{ss}\left[\eta_j, \iota_{i,t}^{ss}\left(\eta_j\right) = 0\right] + P_{A,i,t}^{sn}\left[\eta_j, \iota_{i,t}^{sn}\left(\eta_j\right) = 0\right]\right)$$

The extensive margin in imitation is larger that in innovation (i.e. $\delta_I > \delta_A$); however, imitators face the risk of being punished given by the hazard rate μ^s, and sell exclusively to the southern market. The remuneration of a type-η_j imitator is $w_{I,t}^s\left(\eta_j, \mu^s\right) = \delta_I A_t^w P_{I,i,t}^{ss}\left(\eta_j, \mu^s\right)$.

In the North, skilled labor is allocated either to the R&D sector (as innovators) or to the FS. The remuneration of type-η_j units of skilled labor in the R&D sector is $w_{A,t}^n\left(\eta_j\right) = \delta_A A_t^w\left[P_{A,i,t}^{nn}\left(\eta_j\right) + \max\left\{0, P_{A,i,t}^{ns}\left[\eta_j, \iota_{i,t}^{ns}\left(\eta_j\right)\right]\right\}\right]$. Exporting innovators in the North are those workers for which the second term in square brackets is positive.

The following couple of conditions are needed to guarantee a positive share of skilled labor in the exporting innovative activity in the South and in the North.

Condition 3.4.1 *The remuneration of the most productive units of skilled labor in the South (i.e. $\eta_j \to 0$)is higher in the innovative (exporting) activity than in the imitative activity for all values of the IPRs parameter in the South, μ^s.*

$$\lim_{\eta_j \to 0} \delta_A\left(P_{A,i,t}^{ss}\left[\eta_j, \iota_{i,t}^{ss}\left(\eta_j\right)\right] + P_{A,i,t}^{sn}\left[\eta_j, \iota_{i,t}^{sn}\left(\eta_j\right)\right]\right) > \delta_I P_{I,i,t}^{ss}\left[\eta_j, \mu^s\right] \text{ for all } \mu^s \in (0, \infty)$$

This condition implies that the value from exporting to the northern market (profits minus fixed cost of exporting) must make up for the income loss suffered by southern innovators from being innovators instead of imitators for all possible IPRs regimes in the South. At the end of the day, the northern market should be large enough so that the most productive skilled workers in the South become exporting innovators despite the larger extensive margin in the imitative activity and the fixed cost of exporting.

Condition 3.4.2 *The remuneration of the most productive units of skilled labor in the North (i.e.* $\eta_j \to 0$*) is higher for exporting innovators than for non exporting innovators.*

$$\lim_{\eta_j \to 0} P^{ns}_{A,i,t}\left[\eta_j, \iota^{ns}_{i,t}\left(\eta_j\right)\right] \geq 0$$

Similarly, this condition implies that the value from exporting to the Southern market must be sufficient to incur the fixed cost of exporting without making losses.

It has been discussed that, in the South, for low enough values of the IPRs regime, the relative productivity advantage in the production of imitations dominates over the lower discount factor of being a non exporting innovator. The specification of the remuneration for each sector and activity allows us to provide a proposition containing a formal prove of this heuristic argument.

Proposition 3.4.1 *In the South, under IPRs regimes characterized by hazard rates belonging to the interval* $[0, \bar{\mu}^s)$*, the remuneration of imitators is strictly higher than the remuneration of non exporting innovators. The parameter* $\bar{\mu}^s$ *is unique and is the solution to the equality:*

$$\delta_A P^{ss}_{A,i,t}\left[\eta_j, \iota^{ss}_{i,t}\left(\eta_j\right)\right] = \delta_I P^{ss}_{I,i,t}\left[\eta_j, \bar{\mu}^s\right] \text{ for all possible values of } \eta_j \tag{3.4.1}$$

Proof. We define the wage differential between imitation and non exporting innovation in the South as $w^s_{I,t}\left(\eta_j, \mu^s\right) - w^s_{NEA,t}\left(\eta_j\right)$, where $w^s_{NEA,t}\left(\eta_j\right) = \delta_A A^w_t P^{ss}_{A,i,t}\left(\eta_j\right)$ and $w^s_{I,t}\left(\eta_j\right)$ as above. The values $P^{ss}_{A,i,t}\left(\eta_j\right)$ and $P^{ss}_{I,i,t}\left(\eta_j, \mu^s\right)$ are determined in equations 3.2.3 and 3.2.6 respectively. Under the extreme case $\mu^s = 0$, we obtain $P^{ss}_{A,i,t}\left(\eta_j\right) = P^{ss}_{I,i,t}\left(\eta_j, 0\right)$ and the wage differential takes the positive value $\left(\delta_I - \delta_A\right) A^w_t P^{ss}_{I,i,t}\left(\eta_j, 0\right) > 0$. Under the opposite extreme case $\mu^s \to \infty$, we obtain $\lim_{\mu^s \to \infty} P^{ss}_{I,i,t}\left(\eta_j, \mu^s\right) = 0$ and the wage differential is the negative value $-\delta_A\left(A^s_t + A^n_t\right) P^{ss}_{A,i,t}\left(\eta_j\right) < 0$. It remains to check that the wage differential is a decreasing function of μ^s between these two extreme values (which it is since the IPRs regime has a negative first order effect on the remuneration of imitators) to see that there exists a unique value of $\mu^s = \bar{\mu}^s$ under which the wage differential is zero and is determined by equation 3.4.1. ■

3.4.1 Productivity Cutoffs in the South

Skilled workers in both regions decide on their sector, activity and exporting status provided the institutional framework in place.

Under the specific case considered in this chapter (i.e. perfect enforcement of IPRs in the North and an IPRs regime in the South such as the one presented in Proposition 3.4.1), skilled workers choose to allocate themselves either to the R&D/Int. sector (as exporting innovators or non exporting imitators) or to the FS. A worker is allocated in the sector and activity that provides the highest expected remuneration. According to Condition 1 and Lemma 3.2.1, skilled workers with the lowest cost parameters (i.e. the most productive units of skilled labor) obtain the highest remuneration by becoming exporting innovators in the R&D/Int. sector. Skilled workers with high cost parameters obtain the highest remuneration in the FS while the remaining share of skilled labor become non exporting imitators in the R&D/Int. sector.

Exporting innovators are units of skilled labor with cost parameters between 0 and a cutoff value $\eta^s_{NE,t}$. This cutoff is defined as the cost parameter that leaves skilled workers indifferent between being exporting innovators and imitators. Skilled labor in the innovative (exporting) activity in the South is defined as $H^s_{EA,t} = H^s \int_0^{\eta^s_{NE,t}} f(\eta)\, d\eta$.

Imitators are units of skilled labor with cost parameters between $\eta^s_{NE,t}$ and $\eta^s_{FS,t}$. The number of imitators is defined as $H^s_{I,t} = H^s \int_{\eta^s_{NE,t}}^{\eta^s_{FS,t}} f(\eta)\, d\eta$.

Finally, skilled labor in the FS is represented by individuals with cost parameters between $\eta^s_{FS,t}$ and the upper boundary of the support of the cost distribution, ϕ_l^{-1}. The number of units of skilled labor in the FS is given by $H^s_{Y,t} = H^s \int_{\eta^s_{FS,t}}^{\phi_l^{-1}} f(\eta)\, d\eta$.

The determination of the two cutoffs is provided in the following proposition.

Proposition 3.4.2 *The cutoff values determining the cost parameter separating skilled workers in the South from the innovative (exporting) activity ($\eta^s_{NE,t}$) and imitative activity ($\eta^s_{FS,t}$) are implicitly determined by the following indifference conditions:*

- $\delta_A \left(P^{ss}_{A,i,t} \left[\eta^s_{NE,t}, \iota^{ss}_{i,t} \left(\eta^s_{NE,t} \right) = 0 \right] + P^{sn}_{A,i,t} \left[\eta^s_{NE,t}, \iota^{sn}_{i,t} \left(\eta^s_{NE,t} \right) = 0 \right] \right) = \delta_I P^{ss}_{I,i,t} \left[\eta^s_{NE,t}, \mu^s \right]$
- $\delta_I A^w_t P^{ss}_{I,i,t} \left[\eta^s_{FS,t}, \mu^s \right] = w^s_{Y,t}$

The first equation states that for the marginal exporting innovator in the South the value of the northern market exactly compensates the loss in revenue from being an innovator instead of an imitator. Similarly, the second condition implies that the labor income for the marginal imitator must make him indifferent between the imitative activity and working for the FS.

3.4.2 Productivity Cutoffs in the North

Under perfect enforcement of IPRs in the North, i.e. $\mu^n \to \infty$, the value of one imitation in the North is zero (from equation 3.2.6), consequently the remuneration that northern skilled workers expect to obtain were they to become imitators is also zero. There is no northern skilled labor engaged in the imitative activity but instead all R&D workers are either exporting or non exporting innovators.

The number of exporting innovators, non exporting innovators and units of skilled labor in the FS in the North are defined respectively as $H^n_{EA,t} = H^n \int_0^{\eta^n_{NE,t}} f(\eta)\, d\eta$, $H^n_{NE,t} = H^n \int_{\eta^n_{NE,t}}^{\eta^n_{FS,t}} f(\eta)\, d\eta$, and $H^n_{Y,t} = H^n \int_{\eta^n_{FS,t}}^{\phi_l^{-1}} f(\eta)\, d\eta$.

Where the corresponding cutoffs are provided in the system of equations in the following proposition.

Proposition 3.4.3 *The cutoff values determining the cost parameter separating skilled workers in the North from the innovative exporting ($\eta^n_{NE,t}$) and non exporting ($\eta^n_{FS,t}$) activity are implicitly determined by the following indifference conditions:*

- $P^{ns}_{A,i,t}\left[\eta^n_{NE,t}, \iota^{ns}_{i,t}\left(\eta^n_{NE,t}\right)\right] = 0$
- $\delta_A A^w_t P^{nn}_{A,i,t}\left[\eta^n_{FS,t}, \iota^{nn}_{i,t}\left(\eta^n_{FS,t}\right) = 0\right] = w^n_{Y,t}$

The first condition states that the marginal exporting innovator (i.e. with cost parameter $\eta^n_{NE,t}$) must be indifferent between exporting and selling exclusively to the North. In other words, the discounted value of the flow of profits coming from the South, conditional on the risk of imitation faced by the marginal exporting innovator, must exactly compensate the fixed cost of exporting to the South.

According to the second condition, the least productive skilled worker in the non exporting innovative activity in the North must obtain the same remuneration were he employed by the FS.

3.4.3 The Steady State

The only long term rate of growth of $H^s_{EA,t}, H^s_{I,t}, H^s_{Y,t}, H^n_{EA,t}, H^n_{NEA,t}$ and $H^n_{Y,t}$, that is compatible with the constancy of H^n and H^s is zero.

South

Capital goods used by southern firms in the FS are manufactured and sold by suthern innovators and imitators, and by northern exporting innovators that have not been imitated. Innovators of type-η_j in the South produce a total of $\frac{A^s_t}{H^s_{EA}} H^s f\left(\eta_j\right)$ intermediate varieties up to time t. Each one of these varieties is demanded in quantity $x^{ss}\left[p\left(\eta_j\right)\right]$ by firms in the southern FS; and $x^{sn}\left[p\left(\eta_j\right)\right]$ by firms in the northern FS..

Southern innovators manufacture a total of $\frac{A^s_t}{H^s_{EA}} H^s \int_0^{\eta^s_{NE}} x^{ss}\left[p\left(\eta\right)\right] f\left(\eta\right) d\eta$ units of intermediate goods that are sold to the aggregate of firms in the South's FS.

Southern imitators manufacture a total of $\frac{I^s_t}{H^s_I} H^s \int_{\eta^s_{NE}}^{\eta^s_{FS}} x^{ss}\left[p\left(\eta\right)\right] f\left(\eta\right) d\eta$ units of imitated intermediate goods that are sold to firms in the South's FS.

According to the results in Game Four, northern exporters that are more productive than the most productive southern imitator (i.e. imitators characterized by cost parameter η^s_{NE}) face no risk of imitation. On the other hand, those northern exporting innovators less productive than some southern imitators face a positive risk of imitation. This risk of imitation is proportional to the number of southern imitators with productivities above that of the northern innovator. The total amount of units sold by foreign innovators to firms in the southern FS is:

$$\frac{A^n}{H^n_{EA} + H^n_{NEA}} H^n \int_0^{\eta^n_{NE}} [1 - \max\{0, i^s_t(\eta)\}] \, x^{ns}(\eta) \, d\eta$$

Where $i^s_t(\eta_j)$ stands for the fraction of goods produced by type-η_j manufacturers, relative to all goods of the same type, that have been imitated in the South at time t.

Using the previous expressions, aggregate output in the South can be rewritten as:

$$\begin{aligned} Y^s_t &= (H^s_Y)^\alpha (L^s)^\beta \left[\frac{A^s_t}{H^s_{EA}} H^s \int_0^{\eta^s_{NE}} x^{ss} [p(\eta)]^{1-\alpha-\beta} f(\eta) \, d\eta \right. \\ &\quad + \frac{I^s_t}{H^s_I} H^s \int_{\eta^s_{NE}}^{\eta^s_{FS}} x^{ss} [p(\eta)]^{1-\alpha-\beta} f(\eta) \, d\eta \\ &\quad \left. + \frac{A^n_t}{H^n_{EA} + H^n_{NEA}} H^n \int_0^{\eta^n_{NE}} [1 - \max\{0, i^s_t(\eta)\}] \, x^{ns}(\eta)^{1-\alpha-\beta} \, d\eta \right] \end{aligned}$$

And the fraction of imitated type-η_j goods.

$$i^s(\eta_j) = \begin{cases} 0 & \text{for } \eta_j \in [0, \eta^s_{NE}] \\ \frac{I_t}{A^n_t} \left(\frac{H^n_{EA} + H^n_{NEA}}{H^s_I} \right) \frac{H^s}{H^n} \int_{\eta^s_{NE}}^{\eta_j} \frac{f(\eta)}{\int_\eta^{\eta^n_{FS}} f(\tilde{\eta}) d\tilde{\eta}} d\eta & \text{for } \eta_j \in (\eta^s_{NE}, \eta^n_{NE}] \end{cases} \tag{3.4.2}$$

North

Firms in the northern FS demand capital goods from northern and southern innovators. There are $H^n \int_0^{\eta^n_{FS}} f(\eta) \, d\eta$ northern firms in the R&D/Inter. sector, each one manufacturing $\frac{A^n_t}{H^n_{EA} + H^n_{NE}}$ varieties of intermediate goods. There is a total of $H^s \int_0^{\eta^s_{NE}} f(\eta) \, d\eta$ exporting innovators in the South, each one selling $\frac{A^s_t}{H^s_{EA}}$ varieties of intermediate goods to the North's FS.

Aggregate output in the North.

$$\begin{aligned} Y^n_t &= (H^n_Y)^\alpha (L^\beta) \left[\frac{A^n_t}{H^n_{EA} + H^n_{NEA}} H^n \int_0^{\eta^n_{FS}} x^{nn} [p(\eta)]^{1-\alpha-\beta} f(\eta) \, d\eta \right. \\ &\quad \left. + \frac{A^s_t}{H^s_{EA}} H^s \int_0^{\eta^s_{NE}} x^{sn} [p(\eta)]^{1-\alpha-\beta} f(\eta) \, d\eta \right] \end{aligned}$$

Imitation Rate, Technological Gap and World Growth

The first term in the second line of equation 3.4.2 corresponds to the ratio between the number of imitated innovations and the stock of innovations from the North. Since in the equilibrium imitators target only northern varieties, this term can be interpreted as the fraction of northern varieties that have been imitated up to time t. We denote this ratio as $m^n_t \equiv \frac{I_t}{A^n_t}$. I also define the North-South technological gap, $z^{ns}_t \equiv \frac{A^n_t}{A^s_t}$, as the ratio between the number of innovations discovered in the North relative to the innovations discovered in the South.

Proposition 3.4.4 *The steady state value of the the North-South technological gap, fraction of northern innovations that have been imitated in the South, and the rate of technological growth of the two regions, g^*, are:*

$$
\begin{aligned}
(m^n)^* &= \frac{\delta_I H_I^s}{\delta_A \left(H_{EA}^n + H_{NEA}^n\right)} \\
(z^{ns})^* &= \frac{H_{EA}^n + H_{NEA}^n}{H_{EA}^s} \\
g^* &= \delta_A \left(H_{EA}^s + H_{EA}^n + H_{NEA}^n\right)
\end{aligned}
$$

Proof. Appendix 2 ■

Since the partitions of intra and intersectoral labor are constant in the steady state, the constancy of the technological gap implies convergence in rates of growth for the two regions in the long term to g^*.

From the value of the fraction of imitated type-η_j goods it is possible to compute the hazard rate of imitation faced by a northern producer of type-η_j exporting to the South:

$$
\iota^{ns}\left(\eta_j\right) = \left(\frac{i^s\left(\eta_j\right)}{1 - i^s\left(\eta_j\right)}\right) g^*
$$

The steady state solution of the model is given by the vector of cutoff values $\{\eta_{NE}^s, \eta_{FS}^s, \eta_{NE}^n, \eta_{FS}^n\}$ solving the system of equations defined by the set of productivity cutoffs for the South and the North in Propositions 3.4.2 and 3.4.3 along with the steady state results in Proposition 3.4.4.

Graphical Representation

The steady state allocation of skilled labor can be represented graphically. Figure 4.1 provides the graphical representation of the steady state allocation of skilled labor in the South. The horizontal axis represents skilled labor ordered increasingly by cost parameters η. The vertical axis represents detrended remunerations for the R&D/Int. sector (exporting and non exporting innovators and imitators), and the FS.

The thick line in Figure 3.4.1 is the maximum detrended remuneration for skilled labor at any point of the cost parameter distribution, i.e. $\max\left[\frac{w_{EA,t}^s(\eta)}{A_t^w}, \frac{w_{I,t}^s(\eta)}{A_t^w}, \frac{w_{Y,t}^s}{A_t^w}\right]$ for all $\eta \in \left[0, \phi_l^{-1}\right]$. Under an IPRs regime represented by μ_0^s, the innovative (exporting) activity provides the highest possible remuneration for skilled labor with cost parameters between 0 and η_{NE}^s; the imitative activity for skilled labor with cost parameters between η_{NE}^s and η_{FS}^s; and the FS for the remaining of skilled labor.

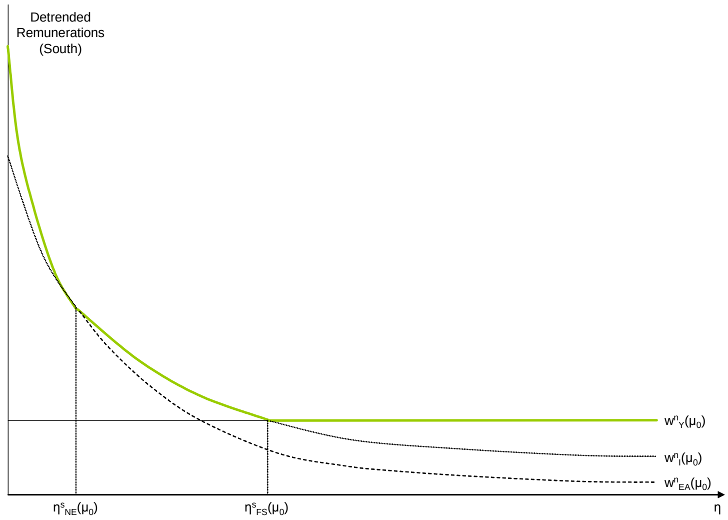


Figure 3.4.1: Detrended remunerations in the South. The thick line represents the maximum remuneration for skilled labor in the pre-TRIPS scenario.

Ceteris paribus, detrended remunerations for units of skilled labor in the R&D sector are decreasing with individual cost parameters. These remunerations take the shape of hyperbolas crossing at a single point, i.e. the one corresponding to the cutoff value η^s_{NE}. Note that the wage in the FS is independent of individual heterogeneity in the manufacturing activity, thusly the horizontal function representing $\frac{w^s_Y}{A^w_t}$.

For the North, we represent the mapping from cost parameters into productive sectors and activities using a similar graphical representation (Figure 3.4.2).

The exporting innovative activity provides the highest remuneration to the most productive units of skilled labor (i.e. those with productivity parameters between 0 and η^n_{NE}), while those skilled workers with productivity parameters between η^n_{NE} and η^n_{FS} obtain the highest remuneration in the non exporting innovative activity. Less productive units in the manufacturing activity are allocated into the FS.

The function representing the remuneration of skilled labor in the innovative (exporting) activity shows a kink at $\eta = \eta^s_{NE}$. Exporting innovators with cost parameters between η^s_{NE} and η^n_{NE} face a strictly positive risk of being imitated in the South while exporting innovators with lower cost parameters are never targeted by southern imitators, i.e. $\iota^{ns}\left(\eta_j\right) > 0$ for $\eta_j \in (\eta^s_{NE}, \eta^n_{NE}]$ and $\iota^{ns}\left(\eta_j\right) = 0$ for $\eta_j \in [0, \eta^s_{NE}]$. Again, the thick line represents the maximum remuneration for workers at every point of the cost parameter distribution, i.e. $\max\left[\frac{w^n_{EA,t}(\eta)}{A^w_t}, \frac{w^n_{NEA,t}(\eta)}{A^w_t}, \frac{w^n_{FS,t}}{A^w_t}\right]$ for all $\eta \in \left[0, \phi_l^{-1}\right]$.

3.5 Comparative Statics: Stronger IPRs in the South

Let us consider the effects of an increase in the IPRs regime in the South from μ^s_0 to μ^s_1. The comparison undertaken in this section considers steady states exclusively.

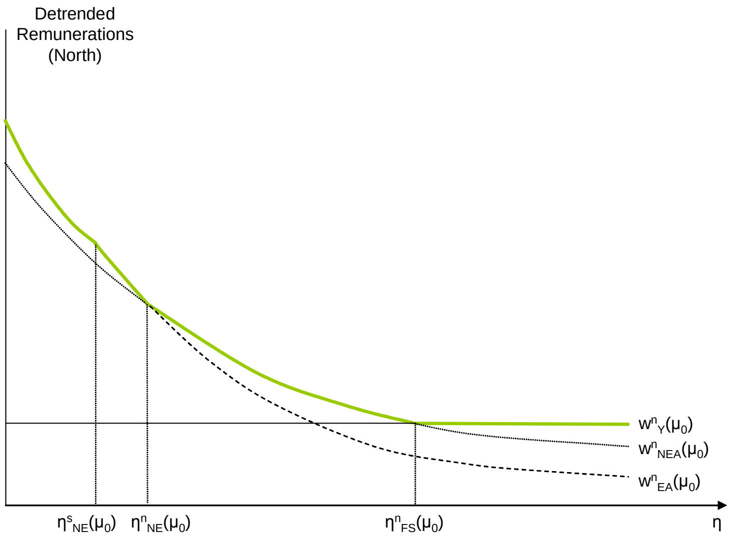


Figure 3.4.2: Detrended remunerations in the North. The thick line represents the maximum remuneration for skilled labor in the pre-TRIPS scenario.

I start by considering the implications of an increase in IPRs in the South obtained from the theoretical model developed in the previous sections. It is possible to find the theoretical predictions of that model regarding the direction of the reallocation of skilled labor following the institutional change in IPRs. Nonetheless, a calibrated model is necessary to assess further predictions relating changes in IPRs to the world rate of growth, the remuneration of skilled and unskilled labor (i.e. total remunerations) and, most importantly, numerical results concerning the impact of IPRs on trade flows.

3.5.1 Theoretical Results

I define direct effects as being the "partial equilibrium" effects. These are independent of the inter and intrasectoral reallocation of skilled labor following the change in IPRs in the South. On the other hand, the indirect or "general equilibrium" effects arise as a consequence of changes in the steady state cutoff vector $\{\eta^s_{NE}, \eta^s_{FS}, \eta^n_{NE}, \eta^n_{FS}\}$.

An increase in the IPRs regime in the South increases the probability faced by southern imitators of being punished and divested of future monopolistic profits. The remuneration for imitators, $w^s_{I,t}$, falls for every possible cost parameter. As a consequence of this fall, those imitators with cost parameters in the vecinity of the cutoff values η^s_{NE} and η^s_{FS} are reallocated into the innovative (exporting) activity and the FS respectively. The cutoff η^s_{NE} rises and η^s_{FS} falls. There would be a reallocation of skilled labor out of the imitative activity and into both the innovative activity and the FS.

The thick line in Figure 3.5.1 corresponds to the maximum remuneration for all types of units of skilled labor under the higher IPRs regime μ^s_1, i.e. $\max\left\{\frac{w^s_{EA,t}(\eta)}{A^w_t}, \frac{w^s_{I,t}(\eta)}{A^w_t}, \frac{w^s_{Y,t}}{A^w_t}\right\}\Big|_{\mu^s_1}$.

Although there are no direct effects on the North from an increase in IPRs in the South,

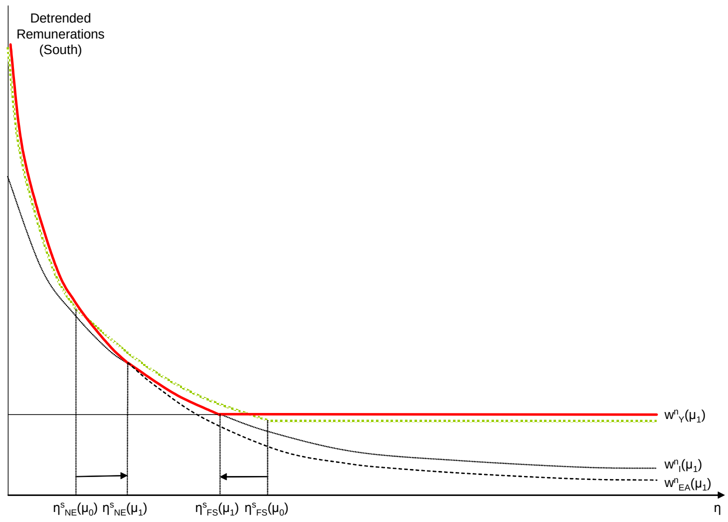


Figure 3.5.1: Detrended remunerations in the South. The thick line represents the maximum remuneration for skilled labor in the post-TRIPS scenario.

the reallocation of skilled labor in the South affects the remuneration of northern skilled labor. The increase in the number of exporting innovators in the South is translated as an increase in the arrival of new varieties of capital goods from the South to the North. This in turn increases the marginal productivity of existing units of skilled labor in the FS. Thusly, the wage function $w^n_{Y,t}$ increases for all cost parameters and induces a fall in the cutoff value η^n_{FS}. A larger amount of workers in the North's FS increases the demand for intermediate capital varieties, and increases profits for R&D firms selling in the northern market. Exporting firms also benefit from larger profits coming from the South.

The key mechanism underlined in this chapter comes from the analysis of the variation on the cutoff value η^n_{NE}. After the change in IPRs taking place in the South, some of the most productive units of skilled labor in the South switch R&D activities, from the imitative to the innovative one. It follows that northern innovators with cost parameters above η^s_{NE} face a lower risk of imitation were they to export to the South. On average, the decrease in the imitation risk, $\iota^{ns}\left(\eta_j\right)$, for those workers characterized by cost parameters higher than η^s_{NE}, implies that they enjoy the flow of monopolistic profits for a longer period before imitation is expected to occur. In turn, this increases the value of the southern market to northern innovators and the number of skilled workers willing to export to the South.

The cutoff value η^n_{NE} increases, while the cutoff η^n_{FS} falls. The number of exporting innovators and of skilled labor in the northern FS increases, while the number of non exporting innovators decreases.

The thick line in Figure 3.5.2 stands for the maximum remuneration available to workers of any type under the higher IPRs regime in the South μ^s_1, i.e. $\max\left\{\frac{w^n_{EA,t}(\eta)}{A^w_t}, \frac{w^n_{NEA,t}(\eta)}{A^w_t}, \frac{w^n_{Y,t}}{A^w_t}\right\}\Big|_{\mu^s_1}$.

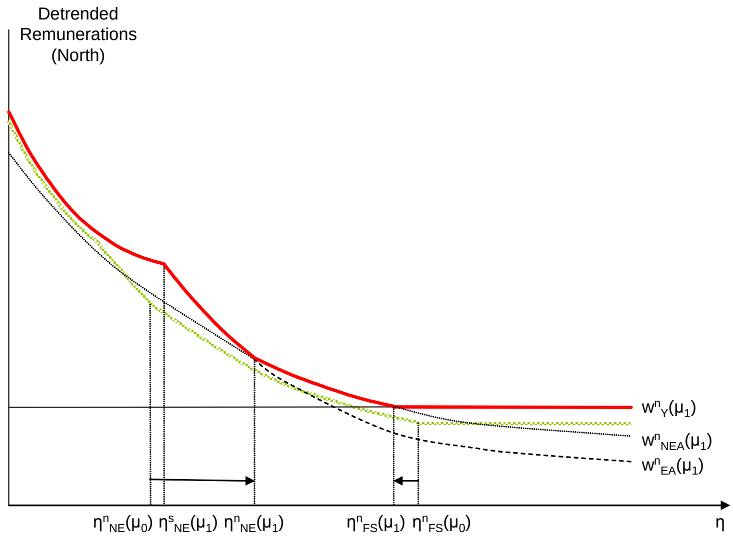


Figure 3.5.2: Detrended remunerations in the North. The thick line represents the maximum remuneration for skilled labor in the post-TRIPS scenario.

3.5.2 Numerical Results

For the numerical calibration I define population endowments based on United Nations data for world population. Since the Uruguay Round took place in 1988 I consider population values for the year 1990 as the pre-TRIPS case. I preserve the partition of the world population between "More developed" and "Less developed" countries as defined by the UN. For 1990, 21,69% of world population came from the "More developed" region (i.e. the North); while the remaining 78.31% came from the "Less developed" region (i.e. the South). These figures imply the North-South relative total population is 3.611 (i.e. $\frac{L^s+H^s}{L^n+H^n}$).

For the human capital endowments I turn to data from the same period collected by Bloom and Rivera-Batiz (99). Human capital is defined as the group of individuals having attained one or more of the following educational levels: post-secondary vocational preparation, follow upper secondary education[8], and educational attainment at or above the university level. For 1995, the attainment rate for tertiary education in low and middle income economies is 6%, relative to 26% in high income countries[9].

I consider population values relative to the amount of skilled labor in the North, i.e. I normalize this endowment to be one, $H^n = 1$. The resulting labor endowments (expressed

[8]This category includes: technical schools, community colleges/junior colleges as well as university enrolment that does not culminate in an university degree.

[9]The World Bank reports estimates of attainment at the tertiary level (for population over 25 years old) only for 1965, 1975, 1985 and 1995. Since the 1995 estimate is closer to the one provided for 1988 regarding the OECD countries I take it as the fraction of human capital in the North relative to the total of the population.

in relative terms with respect to H^n) in both regions are summarized in the following table:

H^s	L^s	H^n	L^n
0.89	12.585	1	2.85

Parameters related to the productivity of skilled labor in the innovative and imitative activities (δ_A and δ_I), fixed cost of exporting (F), and the initial IPRs protection regime in the South (μ_0); are such that: (i) the productivity on innovation relative to imitation is 65%; (ii) the pre-TRIPS rate of growth of the world is 2%; and (iii) the ratio of exporting and non exporting firms is the closest to the value reported by Bernard and Jensen (99) of 14.56% for 1988.

δ_A	δ_I	F	μ_0
0.11	0.17	8.1	0.0145

Other parameters take values standard in macroeconomic literature.

α	β	ϕ_l	θ	ρ
$\frac{1}{3}$	$\frac{1}{3}$	1	3	0.03

We consider an increase in the IPRs regime in the South from the pre-TRIPS level of 0.0145 to 0.0268. We could interpret the change simultaneously as a 1.13 percentage points increase in the discount factor faced by imitators in the South, or as a reduction in the expected life of an imitation in the South from 70 periods to 37.3 periods. By increasing the IPRs parameter this way, the model is able to come close to reproducing the change in exports from the North to the South reported in Ivus (10). The author provides an estimation of the increase in the exporting activity from member countries of the OECD to developing economies of US35 billion (equivalent to a 8.6% increase in the annual value of patent-sensitive imports). We find an increase in the value of North-South exports equivalent to 7%. As in Ivus (10) the change in the value of exports is driven mainly by changes in quantities and not in prices. When computing the effects of IPRs on quantities and prices separately, the change in the value of exports that is explained by quantities alone is 5 percentage points, while the remaining 2 points come from higher prices in the newly arriving varieties to the domestic economy.

The model produces a 1.02 percentage point rise in the fraction of northern exporting innovators relative to non exporting northern innovators from the considered change in southern IPRs (from 13.37% in the pre-TRIPS case, to 14.38% in the post-TRIPS scenario).

Wages and remunerations. As a consequence of the change in the IPRs regime in the South, the wage of skilled labor in the FS falls in the South and rises in the North. The remunerations accruing to exporting innovators in both regions increase, as does the remuneration of non exporting innovators in the North. Conversely, the remuneration of imitators decreases.

The marginal productivity of skilled labor in the production of the homogeneous good increases with the number of varieties of intermediate goods available in the domestic economy. Two opposing effects arise as a result of strengthening IPRs in the South. On the one hand, there is an increase in the number of intermediate varieties exported from the North. On the other hand, the reallocation of skilled labor out of imitation and into innovation depresses the number of varieties of locally produced intermediated goods. This arrives because imitators are more productive at the R&D activity (at the extensive margin) than innovators. The model predicts a negative net effect of increasing IPRs in the South on the marginal productivity of skilled labor in the production of final goods in the South (equivalent to -12.11%).

Wage of skilled labor in the FS in the North increases. The arrival of new varieties of intermediate goods from the South dominates the negative effect of the reduction in the amount of skilled labor in the innovative activity. The net effect is estimated to be 0.62%.

The reallocation of skilled labor points to an increase in the number of skilled workers in the FS in both regions. Profits for R&D firms, thusly remunerations, are positively affected by the quantity of skilled labor in the FS. The remuneration of exporting innovators in the South and both exporting and non exporting innovators in the North increase. The size of the increase is proportional to the productivity parameter of each innovator (see Appendix 1 for the corresponding figures).

While the behaviour of the remuneration of southern exporting innovators is explained by second order effects of H_Y on profits; the remuneration of northern exporting innovators shows an additional interesting component which is key to this chapter. In the case of northern exporting innovators, the main force driving the increase in the remuneration comes from the reduction in the risk of imitation represented by imitators in the South. Under the new, stronger, IPRs regime in the post-TRIPS scenario, the number of imitators in the upper tail of the productivity distribution falls. Therefore, for northern exporters of any productivity parameter, the mass of more productive southern imitators is smaller. The risk of imitation is lower in the post-TRIPS case than it was under the pre-TRIPS case for all northern innovators.

The first order effect of an increase in IPRs is a reduction in the remuneration of imitators. For any productivity parameter, the expected live of an imitation (i.e. the number of periods between the moment when the imitative blueprint is developed and the period when the imitator is punished) is shorter in the post-TRIPS case compared to the pre-TRIPS case. The reduction in the remuneration accruing to imitators is stronger for the more productive workers (see Appendix 1 for a graphical representation).

The effect of IPRs in the remuneration of unskilled labor in the South is twofold. On

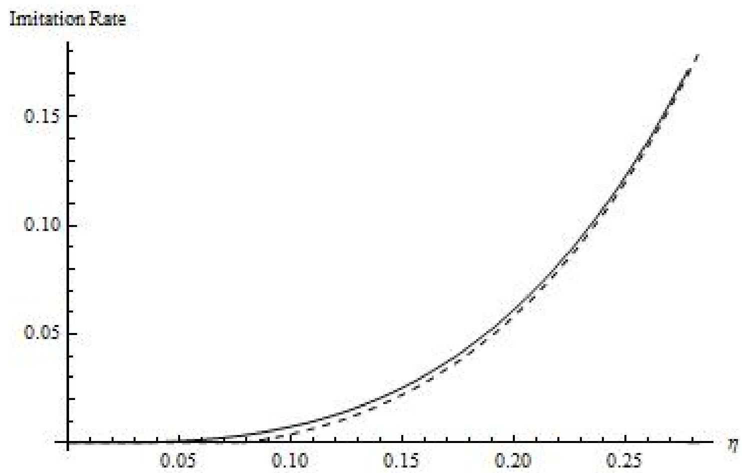


Figure 3.5.3: Imitation rates faced by northern innovators in the South. The pre-TRIPS and post-TRIPS scenarios are represented by the continuous and dashed lines respectively.

the one hand, the increase in the amount of skilled labor working for the FS increases the marginal productivity of all units of unskilled labor. On the other hand, the reduction in the number of differentiated goods in the production of final good has a negative effect on the productivity of unskilled labor. Numerical calculations seem to indicate the negative effect dominates over the positive effect and the resulting remuneration of unskilled labor is lower in the post-TRIPS case.

The opposite situation arrives in the North. The marginal productivity of northern unskilled labor is enhanced both by the increase in the number of varieties of intermediate goods coming from the South after the change in IPRs and by the increase in the number of skilled labor in the FS.

The intrarregional allocation of skilled population. The number of exporting innovators and workers in the southern FS increase, while the number of imitators falls. Exporting innovators also increase in the North, while the number of non exporting innovators falls. Even though the number of innovators in the South increases, the decrease in the number of non exporting innovators in the North is larger in absolute value. As a consequence, the total number of skilled labor in the innovative sector (in the world) falls.

For all productivity parameters in the South, the remuneration of imitators relative to innovators and workers in the FS decreases. As a consequence there is a reallocation of skilled labor out of imitation ($\Delta H_I^s = -16.7\%$) and into innovation (19.2 times higher relative to the pre-TRIPS case in the number of exporting innovators) and final production ($\Delta H_Y^s = 2.45\%$).

The remunerations for all northern skilled workers is higher in the post-TRIPS case than in the pre-TRIPS case. Nonetheless, the change in the remuneration of skilled labor

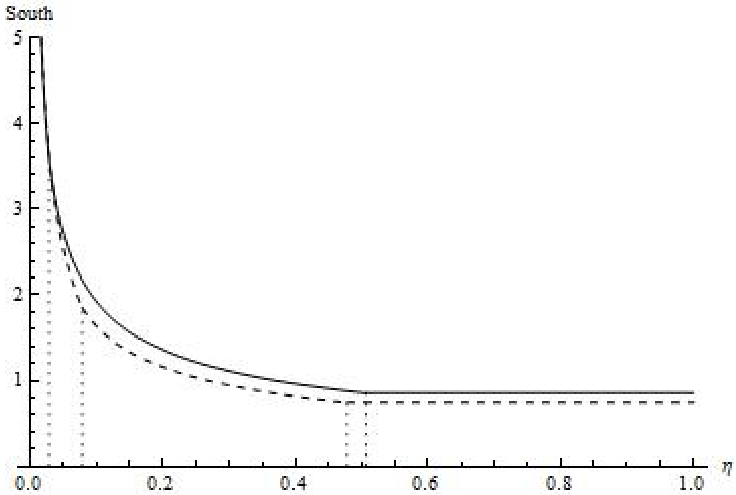


Figure 3.5.4: Remunerations in the South. The pre-TRIPS and post-TRIPS scenarios are represented by the continuous and dashed lines. Cutoff values are represented by dotted vertical lines.

is relatively higher for exporting innovators and workers in the Final sector than the corresponding change in the remuneration of non exporting innovators. As a consequence, we observe skilled labor being reallocated out of the non exporting innovative activity ($\Delta H^n_{NEA} = -1.6\%$) and into the two other productive sectors ($\Delta H^n_{EA} = 5.89\%$ and $\Delta H^n_Y = 0.16\%$).

Non exporting innovators in the North experience an increase in their remuneration because of the higher demand of intermediate goods by firms in the FS. Nonetheless, the increase in their remuneration is lower than the one experienced by exporting innovators. This explains why the cutoff cost value separating exporters and non exporters moves to the right and a higher allocation of skilled labor undertaking exporting is observed.

As a consequence of the changes in relative remunerations we observe an increase in the number of innovators in the South but a decrease in the North. Even though the number of exporters in the North increases, the reduction in the number of non exporting innovators dominates. As a result of this, the total number of innovators in the world decreases.

Technological progress and aggregate productivities. The steady state rate of growth of the world depends on the total number of innovators in the world. The decrease in the number of innovators in the world is therefore translated as a reduction in the rate of technological progress in the North and the South. This result is important since it goes in the same direction of Helpman (93) who predicts a negative effect on world growth following an increase in the degree of protection of IPRs in the developing region. The reduction in the rate of growth predicted by the model is of 0.01 percentual points.

Detrended final output increases in the North but falls in the South. There are no world

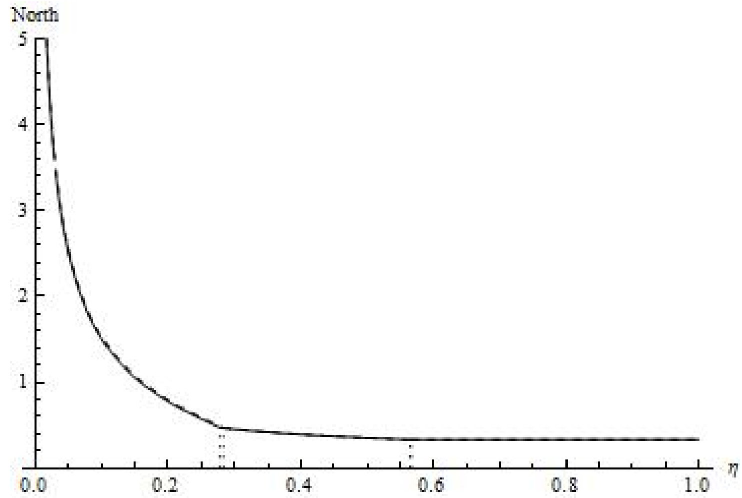


Figure 3.5.5: Remunerations in the North. The pre-TRIPS and post-TRIPS scenarios are represented by the continuous and dashed lines. Cutoff values are represented by dotted vertical lines.

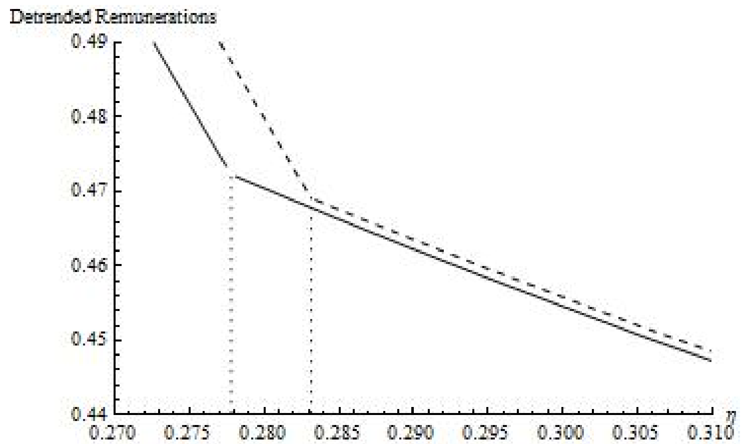


Figure 3.5.6: Remunerations in the North. The pre-TRIPS and post-TRIPS scenarios are represented by the continuous and dashed lines. Cutoff values are represented by dotted vertical lines.

productivity gains because the negative effect of the fall in the South's output dominates the increase in the North's one. Increasing IPRs in the South generates a productivity loss in the world economy since it transfers production of intermediate goods from more productive imitators in the South (both at the R&D and the manufacturing level) to less productive innovators in the North.

3.6 Final Remarks

The main objective of this chapter is to propose a theoretical mechanism capable of explaining the empirical positive link between a country's strength of intellectual property protection and the trade inflow of patent-sensitive capital goods. In this direction, we developed a model that goes one step forward than the previous theoretical research on IPRs in general equilibrium models: not only did we consider the response of northern innovators to stronger IPRs in the South, but also the resulting reallocation of R&D resources out of imitation and into other R&D activities and other productive sector in the South. This mechanism puts in evidence the inconsistency of direct assumptions on the innovative technologies of developing economies, and rather stresses the pattern of a northern-based world innovative industry as an equilibrium output resulting from the interaction between skilled labor endowments and asymmetric institutions related to IPRs in developed and developing countries.

A clear statement on the goodness of such enforcements of IPRs in developing countries would require a proper welfare analysis taking into account not only the role of trade on the determination of the steady state, but also on the transition between the two steady states. This welfare analysis is out of the scope of the present chapter. However, elements of the mechanism presented in this chapter should contribute to the traditional discussion on the field of IPRs that has been somewhat concentrated on the opposite effects of stronger market power to patent owner versus dynamic incentives to innovation.

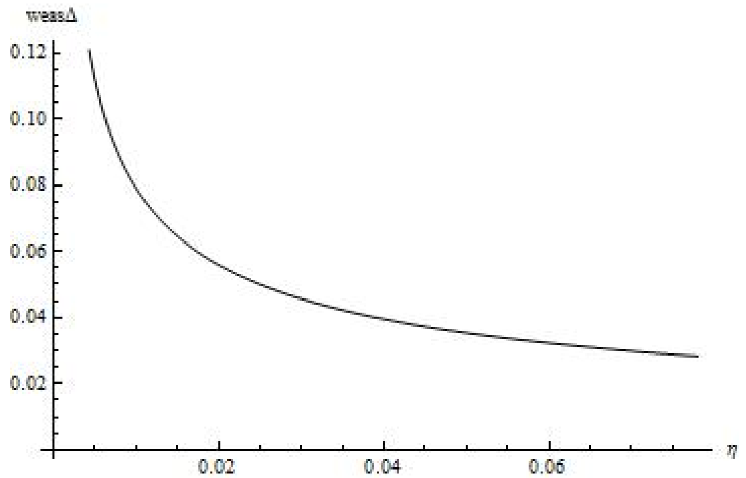
Indeed, we consider that the effects of IPRs on trade and other types of technological diffusion, as well as on mobility of skilled labor, deserve to be part of the future agenda on research on the subject of IPRs.

Appendix A

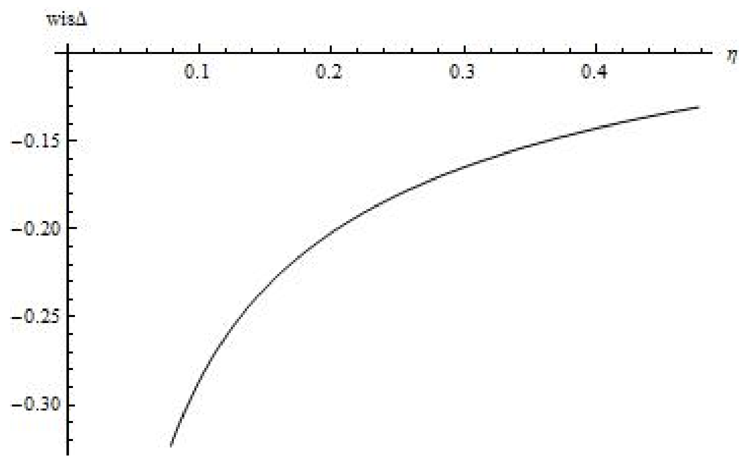
Appendix 1

Variations in the remunerations for units of skilled labor in all productive activities from an increase in the IPRs regime from $\mu_0 = 0.0145$ to $\mu_1 = 0.268$..

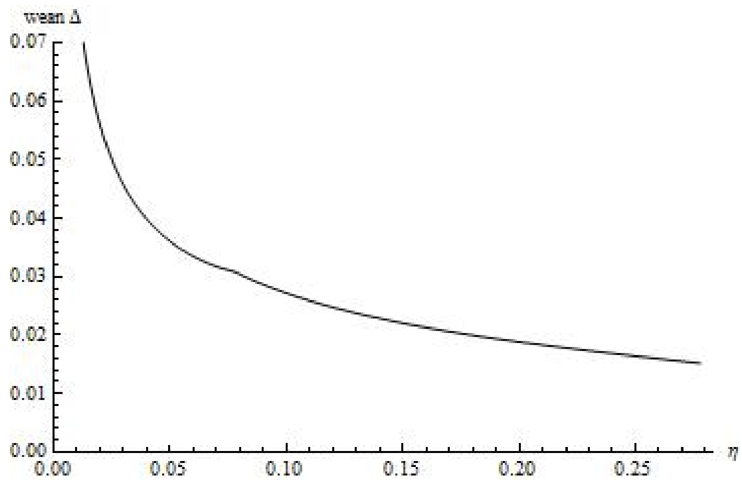
In the South. For exporting innovators.



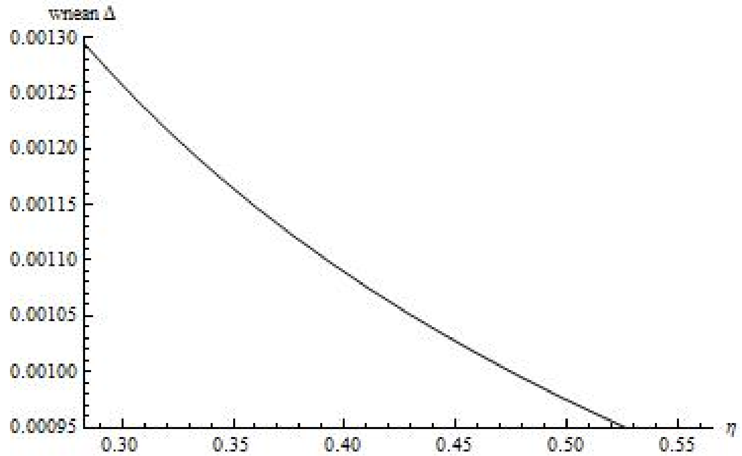
For imitators.



In the North. For exporting innovators.



For non exporting innovators.



Appendix B

Appendix 2

For $(z^{ns})^*$. We define $z_t^{ns} \equiv \frac{A_t^n}{A_t^s}$.

The rate of growth of z_t^{ns} is:

$$\frac{\dot{z}_t^{ns}}{z_t^{ns}}\left(z_t^{ns}\right) = \frac{\dot{A}_t^n}{A_t^n} - \frac{\dot{A}_t^s}{A_t^s} = \delta_A\left[H_A^n + \left(H_A^n - H_A^s\right) z_t^{ns} - H_A^s \left(z_t^{ns}\right)^2\right]$$

In the $\left(z_t^{ns}, \frac{\dot{z}_t^{ns}}{z_t^{ns}}\right)$ plane, this function is represented by a decreasing function of z_t^{ns} that crosses the horizontal axis once at the positive value $(z^{ns})^*$, that is the solution of $\frac{\dot{z}_t^{ns}}{z_t^{ns}}\left[(z^{ns})^*\right] = 0$.

The long term value of the North-South technological gap is therefore given by $(z^{ns})^*$:

$$(z^{ns})^* = \frac{H_A^n}{H_A^s}$$

For the fraction of northern innovations imitated by the South. We define $\mu_t^n \equiv \frac{A_t^n}{I_t}$, so our variable of interest m_t^n becomes $m_t^n = (\mu_t^n)^{-1}$. Similarly we define $\mu_t^s \equiv \frac{A_t^s}{I_t}$

The rate of growth of $\mu_t^n = \mu_t^n$ is:

$$\frac{\dot{\mu}_t^n}{\mu_t^n} = \frac{\dot{A}_t^n}{A_t^n} - \frac{\dot{I}_t}{I_t} = \delta_A\left[1 + \left(z_t^{ns}\right)^{-1}\right] H_A^n - \delta_I\left(\mu_t^s + \mu_t^n\right) H_I^s$$

We must rewrite μ_t^s in a convenient way:

$$\mu_t^s = \frac{A_t^s}{I_t} = \frac{A_t^s}{A_t^n}\frac{A_t^n}{I_t} = \frac{\mu_t^n}{z_t^{ns}}$$

Therefore, in the long term as z_t^{ns} converges to $(z^{ns})^*$, μ_t^s converges to $\frac{H_A^s}{H_A^n}\mu_t^n$. Replacing this expression in the equation representing the rate of growth of μ_t^n we obtain:

$$\frac{\dot{\mu}_t^n}{\mu_t^n}\left(\mu_t^n\right) = \delta_A\left(H_A^n + H_A^s\right) - \delta_I\left(\frac{H_A^n + H_A^s}{H_A^n}\right) H_I^s \mu_t^n$$

In the $\left(\mu_t^n, \frac{\dot{\mu}_t^n}{\mu_t^n}\right)$ plane, this function is represented by a decreasing linear function of μ_t^n that crosses the horizontal axis once at the positive value $(\mu^n)^*$, that is the solution of $\frac{\dot{\mu}_t^n}{\mu_t^n}[(\mu^n)^*] = 0$.

The long term value of the fraction of northern innovations imitated by the South is therefore given by $(\mu^n)^*$:

$$(m^n)^* = [(\mu^n)^*]^{-1} = \frac{\delta_I H_I^s}{\delta_A H_A^n}$$

For the steady state rate of technological change. From the law of motion of innovations in the North, i.e. function $\dot{A}_t^n$ we compute the rate of growth of A_t^n:

$$\frac{\dot{A}_t^n}{A_t^n} = \delta_A \left(1 + \frac{1}{z_t^{ns}}\right) H_A^n$$

In the long term, the value of the technological gap z_t^{ns} attains its steady state value $(z^{ns})^*$. The rate of growth of the North converges to $\delta_A \left(H_A^s + H_A^n\right)$. The constancy of $(z^{ns})^*$ implies technological progress in the South must grow at the same rate that the one in the North. World technology, which is defined as the sum of innovations in the South and the North ($A_t^w = A_t^s + A_t^n$), must therefore also grow at the same rate as each one of its component.

Bibliography

[1] Aghion, P. and Hewitt, P. (1992). "A Model of Growth Through Creative Destruction". Econometrica, 60, March, 323-351.

[2] Arrow, K. (1962). "Economic welfare and the allocation of resources for invention. In "The rate and Direction of Inventive Activity (ed. R. Nelson). National Bureau of Economic Research. Princeton University Press.

[3] Bauer, T. and Zimmermann, K. (1999). Assessment of Possible Migration Pressure and its Labor Market Impact Following EU Enlargement to Central and Eastern Europe, IZA Research Report No. 3, Bonn.

[4] Beine, M., Docquier, F., and Rapoport, H. (2001). "Brain drain and economic growth: theory and evidence". Journal of Development Economics, 64, 275-289.

[5] Bernard, Andrew B. and Jensen, J. Bradford, 2004. Why Some Firms Export. The Review of Economics and Statistics 86(2), 561-539.

[6] Bloom, D. and Rivera-Batiz, F., 1999. "Global Trends in the Financing of Higher Education: Prospects and Challenges for the Next Decade. Statistical Appendix. Unpublished.

[7] Borjas, G. (1990). "The economic benefits from immigration". Journal of Economic Perspectives, 9(2), 3-22.

[8] Borjas, G. (1999). "The economic analysis of immigration". In O. Ashenfelter and D. Card (eds) The handbook of Labour Economics Vol 3E, North Holland, pages 69-133.

[9] Coase, R. (1960). "The problem of social cost". Journal of Law and Economics, 3, 1-44.

[10] Deardorff, Alan V, 1992. "Welfare Effects of Global Patent Protection," Economica, London School of Economics and Political Science, vol. 59(233), pages 35-51, February

[11] Diwan, Ishac & Rodrik, Dani, 1991. "Patents, appropriate technology, and North-South trade," Journal of International Economics, Elsevier, vol. 30(1-2), pages 27-47, February.

[12] Richard Gilbert & Carl Shapiro, 1990. "Optimal Patent Length and Breadth," RAND Journal of Economics, The RAND Corporation, vol. 21(1), pages 106-112, Spring.

[13] Ginarte, J. C., Park, W. G., 1997. Determinants of patent rights: a cross-national study. Research Policy 26, 283-301.

[14] Grossman, G. and Helpman, E. (1991). Innovation and Growth in the Global Economy. MIT Press, Cambridge, Massachusetts.

[15] Grossman, G. M., Lai, E. L.-C., 2004. International Protection of intellectual property. The American Economic Review 94 (5), 1635-1653.

[16] Hamermesh, D. (1993). Labor Demand. Princeton University Press, Princeton.

[17] Helpman, E., 1993. Innovation, Imitation, and intellectual propert rights. Econometrica 61 (6), 1247-1280.

[18] Ivus, O., 2010. Do stronger patent rights raise high-tech exports to the developing world? Journal of International Economics 81, 38-47.

[19] Judd, Kenneth L, 1985. "On the Performance of Patents," Econometrica, Econometric Society, vol. 53(3), pages 567-85, May.

[20] Levine, P., Lotti, E., and Pearlman, J. (2002). "The immigration surplus revisited in general equilibrium model with en dogenous growth". Mimeo., University of Surrey.

[21] Lundborg, P. and Segerstrom, P. (2002). "The growth and welfare effects of international mass migration". Journal of International Economics, 56, 177-204.

[22] Mansfield, E., Schwartz, M., Wagner, S., 1981. Imitation Costs and Patents: An Empirical Study. The Economic Journal 91, 907-918.

[23] Maskus, K. E., Penubarti, M., 1995. How trade related are intellectual property rights? Journal of International Economics 39, 227-248.

[24] Maskus, K. E., Penubarti, M., 1997. Patents and international trade: an empirical study. In: Maskus, K. E., et al. (Ed.), Quiet Pioneering: Robert M. Stern and His International Economic Legacy. University of Michigan Press, Ann Arbor, MI, pp. 95-118.

[25] Melitz, M. J., 2003. The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity. Econometrica 71 (6), 1695-1725.

[26] Miyagiwa, K. (1991). "Scale economies in education and the brain drain problem". International Economic Review, 32(3), 743-759.

[27] Mondal, D., and Ranjan Gupta, M. (2006). "Innovation, imitation and Intellectual Property Rights: Introducing migration on Helpman's model". Economic Research Unit, Indian Statistical Institute, West Bengal.

[28] Rapp, R. T., Rozek, R. P., 1990. Benefits and Costs of Intellectual Property Protection in Developing Countries. Working Paper No. 3. National Economic Research Associates, Inc, Washington, D. C.

[29] Romer, Paul M, 1990. "Endogenous Technological Change," Journal of Political Economy, University of Chicago Press, vol. 98(5), pages S71-102, October.

[30] Smith, P. J., 1999. Are weak patent rights a barrier to U.S. exports? Journal of International Economics 48, 151-177.

[31] Stark, O., Helmensyein, C., and Prskawetz, A. (1997). "A brain gain with a brain drain". Economics Letters, 55, 227-234.

[32] Stark, O., Helmensyein, C., and Prskawetz, A. (1998). "Human capital depletion, human capital formation and migration, a blessing or a "course"?". Economic Letters, 60, 363-367.

[33] Steineck, A. (1996). "The factor market effects of immigration". In S. Gazioglu (ed), Migrantes in the European Labour Market, pages 1-30.

[34] Taylor, M Scott, 1994. "TRIPs, Trade, and Growth," International Economic Review, Department of Economics, University of Pennsylvania and Osaka University Institute of Social and Economic Research Association, vol. 35(2), pages 361-81, May.

[35] World Bank, 2000. Higher Education in Developing Countries: Peril and Promise. The Task Force on Higher Education and Society. Washington, D. C..