Enforcement of Intellectual Property Rights and Population

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Abstract

Non complete enforcement of IPR and non-homogeneous labor from individuals endowed with heterogeneous abilities are introduced in the endogenous growth model developed in Romer (1990). Intermediate goods' monopolies are faced with the probability of their goods being imitated and sold at a lower price (at their marginal cost). This probability is tantamount to the IPR regime. The relative wage between the R&D and the Final sectors is determined by the parameters and the IPR regime.

If the relative wage is equal to one, lower prices for intermediate inputs increase their demand by the final good firms, thus production and consumption. Lower benefits for R&D firms due to the relaxation of IPR decreases the rate of innovation, hence economic growth. A trade-off between consumption today and in the future arises.

When the relative wage is higher than one, neither the rate of growth in the steady state nor the composition of labor across the two sectors depend on the IPR regime. Consumption of R&D workers increases as IPR are tightened. The opposite is true for workers in the Final sector. The trade-off comes no longer from rate of growth and current consumption but from consumptions derived from wages in the two sectors.

By taking account of these trade-offs, the welfare maximizing IPR regime in the equilibrium is computed as a function of total population and population in the higher tail of the ability distribution.

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 Intellectual Property Protection (IPP) arising from this negotiation gave shape to the Agreement on Trade-Related Aspects of Intellectual Property Rights, best known under its abbreviation 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 thus stated that a minimum level of IPP 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 this measures were designed are summed up 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."

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 irrespective 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 add: (i) imperfect enforcement of IPRs as the probability of production inputs protected by patents being imitated by other input firms and then sold at a 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 good) or in R&D (producing innovations); whereas individuals with low ability work exclusively in the Final sector.

The result of this exercise points to the fact that the main determinant of the welfare maximizing degree of enforcement of IPRs is the relationship between total population and that of individuals with high ability. This result is in part explained by the presence of scale effects because it is the size of the total population what 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 individuals with heterogeneous abilities. Two cases regarding wages for workers in the R&D and final good sectors are considered. 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.

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 (final or consumption), intermediate goods (used as inputs in the production of the homogeneous good) and innovations (new varieties of intermediate goods). Growth is driven by research in the R&D sector.

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):

$$Y_{i,t} = AL_{i,t}^{1-\alpha} \sum_{j=1}^{N_t} x_{i,j,t}^{\alpha}, \text{ for all } t \text{ and } i \in [1, M] \text{ with } \alpha \in (0,1) \tag{2.1}$$

$Y_{i,t}$ 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 t the total number of workers in all firms equals the labor force in the final good sector, $L_{Y,t}$:

$$\sum L_{i,t} = L_{Y,t} = L - L_{R,t} \tag{2.2}$$

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 intermediate good sector as number 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 intermediate good j.

There is imperfect competition in this sector due to the particular nature of innovations[1]. Once a new variety is 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. 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).

[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"

For a given monopoly 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:

$$x_{j,t} = \begin{cases} \text{Monopoly status} & ; \quad \text{with probability} \quad \nu \\ \text{Imitated} & ; \quad \text{with probability} \quad 1 - \nu \end{cases} \tag{2.3}$$

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. Knowledge is deterministically produced according to the accumulation function:

$$\frac{\partial N_t}{\partial t} = \dot{N}_t = \frac{N_t L_{R,t}}{\eta} \tag{2.4}$$

Technological progress comes 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 a stock of knowledge.

$$N(0) = N_0 \tag{2.5}$$

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

$$U(c_t) = \ln c_t \tag{2.6}$$

Each household is endowed with the same initial amount of financial assets and one unit of labor which is inelastically supplied. The population with a high level of ability is known as $L(a_h)$, and the one with a low level of 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:

$$L = L(a_l) + L(a_h) \tag{2.7}$$

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

[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.

their possession.

2.2 Equilibrium

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

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 labor demand functions.

$$x_{i,j,t} = L_{i,t} \left(\frac{A\alpha}{p_{j,t}} \right)^{\frac{1}{1-\alpha}} \tag{2.8}$$

$$w_{Y,t} = (1-\alpha) A L_{i,t}^{-\alpha} \sum_{j=1}^{N_t} x_{i,j,t}^{\alpha} \tag{2.9}$$

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

Case 2.1 *The status of monopoly is preserved*

With probability ν the owner of the patent chooses the price (p^*) that maximizes profits according to the demand of the good given in equation 2.8.

$$p^* = \frac{1}{\alpha} > 1, \text{ for any } j \text{ and } t \tag{2.10}$$

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,

$$x_{i,t} = L_{i,t} \left(A\alpha^2 \right)^{\frac{1}{1-\alpha}} \tag{2.11}$$

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

$$x_t = \sum_i x_{i,t} = \left(A\alpha^2 \right)^{\frac{1}{1-\alpha}} L_{Y,t} \tag{2.12}$$

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

$$\pi_{I,t} = \left(\frac{1-\alpha}{\alpha}\right)\left(A\alpha^2\right)^{\frac{1}{1-\alpha}} L_{Y,t} \tag{2.13}$$

Case 2.2 *The good is imitated*

With probability $1-\nu$ the owner of the patent is not able to charge the monopolistic price. Other intermediate firms would compete in prices (Bertrand competition) until prices equal marginal costs and monopolistic rents are exhausted.

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

$$x_t = (A\alpha)^{\frac{1}{1-\alpha}} L_{Y,t} \tag{2.14}$$

To sum up, the following table presents the main results for the two cases above:

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

The R&D sector develops innovations and sell patents to the intermediate sector. Because a patent is an asset generating a return at each period, its value at t corresponds to the present value of expected future monopolistic rents discounted by the average interest rate between times t and u, $\bar{r}_{t,u}$[4]

$$V_t = \int_t^{\infty} \nu\left(\frac{1-\alpha}{\alpha}\right)\left(A\alpha^2\right)^{\frac{1}{1-\alpha}} L_{Y,u} \exp - \left[\bar{r}_{t,u}\cdot(u-t)\right] du \tag{2.16}$$

Observe that in the case where $\nu = 0$ the patent is worthless; imitation always occurs and the R&D sector is unable to retrieve its investment.

There is free entry in the R&D sector. The income in this sector as a whole is given by the value of new innovations. The costs are given by the remuneration of the production factor (wage for researchers). The free-entry condition holds, drawing profits down to zero.

$$\pi_{R,t} = V_t \dot{N}_t - w_{R,t} L_{R,t} = 0 \tag{2.17}$$

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

$$\bar{r}_{t,u} = \frac{1}{u-t}\int_t^u r_s ds \tag{2.15}$$

The equilibrium interest rate equals the value of the innovations in equations 2.16 and 2.17.

By computing the time derivative in equation 2.16, the following value equation for the spot interest rate is obtained,

$$r_t = \frac{\pi_t}{V_t} + \frac{\dot{V}_t}{V_t} \tag{2.18}$$

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 percentual gains in its value $\left(\frac{\dot{V}_t}{V_t}\right)$.

2.2.1 Households

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

$$Max \int_0^\infty U\left(c_{k,t}\right) \exp\left(-\rho t\right) dt \text{ for } k = R, Y \tag{2.19}$$

Subject to the budget constraint,

$$\dot{b}_{k,t} = w_{k,t} + r_t b_{k,t} - c_{k,t} \text{ for } k = R, Y \tag{2.20}$$

Where 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 future generations' consumption.

In the constraint, $\dot{b}$ represents the household's asset accumulation. Asset accumulation (wealth) is 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.

$$\gamma_{c,t} = \frac{\dot{c}_{R,t}}{c_{R,t}} = \frac{\dot{c}_{Y,t}}{c_{Y,t}} = r_t - \rho \tag{2.21}$$

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 2.1 and 2.11, total production in the economy is,

$$Y_t = \sum_i Y_{i,t} = A^{\frac{1}{1-\alpha}} \alpha^{\frac{2\alpha}{1-\alpha}} L_{Y,t} N_t \tag{2.22}$$

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,

$$Y_t = C_t + N_t x_t = C_t + (A\alpha)^{\frac{1}{1-\alpha}} L_{Y,t} N_t \left[\nu \alpha^{\frac{1}{1-\alpha}} + (1-\nu) \right] \tag{2.23}$$

Proposition 2.1 *In the equilibrium, aggregate consumption, total production of final good, and technology plus labor in the final sector grow at the same rate.*

$$\frac{\dot{Y}_t}{Y_t} = \frac{\dot{C}_t}{C_t} = \frac{\dot{N}_t}{N_t} \tag{2.24}$$

Proof. The equality between the first and third terms comes straightforward from the equilibrium output in equation 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 is zero. The second equality is obtained by equating the right hand side of equation 2.22 with the right hand side of 2.23, dividing each term by $L_{Y,t} N_t$, taking logarithms and deriving with respect to time. ■

2.3 Steady State

The steady state of this economy is characterised 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) are constant.

2.3.1 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 made about workers endowed with high ability being able to perform in both sectors, the case in which the Final sector pays higher wages than the R&D is not comtemplated as it never arises[5].

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 an answer to 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 is refered to as "endogenous equilibrium".

At the time being I solve the steady state for the two cases mentionned above without explaining the determination of whether a given economy is subject to one or the other results. It will be shown 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 for the economy, the allocation of workers is given by the following set of equalities:

$$L_{R,t} = L(a_h) \tag{2.25}$$

$$L_{Y,t} = L(a_l) \tag{2.26}$$

The equilibrium wage in the Final sector corresponds to the marginal productivity of labor given in equation 2.9 once the expected equilibrium demand for durables is taken into account,

$$w_{Y,t} = (1-\alpha) A^{\frac{1}{1-\alpha}} N_t \alpha^{\frac{\alpha}{1-\alpha}} \left[\nu \alpha^{\frac{\alpha}{1-\alpha}} + (1-\nu)\right] \tag{2.27}$$

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 quantities. Less intermediate inputs reduces labor productivity in the sector, reducing wages.

[5] If this was the case, an endogenous reallocation of high-ability workers into the Final sector would take place, restoring wage equality.

The derivation of the wage in the R&D sector is somehow more compliclated. From the non arbitrage condition in equation 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 future monopolistic profit flow. 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 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 2.17. The following expression for the R&D wage is obtained.

$$w_{R,t} = \frac{\nu (1-\alpha) (A\alpha^2)^{\frac{1}{1-\alpha}} L(a_l) N_t}{\alpha [L(a_h) + \rho\eta]} \tag{2.28}$$

Stronger IPR's protection makes the R&D labor productivity more valuable, 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.

$$w_{k,t} = (1-\alpha) A^{\frac{1}{1-\alpha}} N_t \left[\nu\alpha^{\frac{2\alpha}{1-\alpha}} + (1-\nu)\alpha^{\frac{\alpha}{1-\alpha}}\right] \text{ for } k = R, Y \tag{2.29}$$

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 wages are unchanged, this change 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 2.27 and 2.28 in order to construct the following auxiliary relative wage function,

$$\frac{w_{a_h,t}}{w_{a_l,t}} = \frac{L(a_l)}{L(a_h) + \eta\rho} \Phi(\nu) \tag{2.30}$$

Where,

$$\Phi(\nu) = \frac{\nu\alpha^{\frac{1}{1-\alpha}}}{\nu\alpha^{\frac{\alpha}{1-\alpha}} + (1-\nu)} \tag{2.31}$$

Function $\Phi(\nu)$ increases with ν and verifies $\Phi(0) = 0$ and $\Phi(1) = \alpha$.

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

$$\frac{w_{R,t}}{w_{Y,t}} \begin{cases} >1 & \text{if} \quad \frac{w_{a_h,t}}{w_{a_l,t}} > 1 \quad \Leftrightarrow \quad L > \frac{L(a_h)[\Phi(\nu)+1]+\eta\rho}{\Phi(\nu)} \\ =1 & \text{if} \quad \frac{w_{a_h,t}}{w_{a_l,t}} \leq 1 \quad \Leftrightarrow \quad L \leq \frac{L(a_h)[\Phi(\nu)+1]+\eta\rho}{\Phi(\nu)} \end{cases} \tag{2.32}$$

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.

2.3.2 Interest rate, population allocation and rate of 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 2.2 *The level of consumption per worker in the steady state is*

$$c_{k,t} = w_{k,t} + \rho b_t, \text{ where } k = R, Y \tag{2.33}$$

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:

$$c_{k,t} = w_{k,t} + (r^* - \gamma^*)\, b_t$$

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 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 2.3 *In the steady state the level of final good, number of innovations and per capita consumption for workers in the R&D and the final good sector grow at the same rate.*

$$\gamma_y^* = \gamma_N^* = \gamma_{c_R}^* = \gamma_{c_Y}^* = \gamma^* \tag{2.34}$$

Proof. Comes directly from equations 2.33 and 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 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.*

$$r^* = \frac{L(a_h)}{\eta} + \rho \tag{2.35}$$

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

$$L_R^* = L(a_h) \tag{2.36}$$

$$L_Y^* = L(a_l) \tag{2.37}$$

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

$$\gamma^* = \frac{L(a_h)}{\eta} \tag{2.38}$$

Both the equilibrium interest rate and the rate of growth are independent of the IPRs regime. It is labor in the R&D sector given by the exogenous endowment of population with high ability the main determinant of the steady state results.

Since wages differ across sectors, so do per capita consumptions. Two consumptions must be considered: one for those households with a high level of ability working in the R&D sector and another one for the rest of the labor force in the final good sector. According to equations 2.27, 2.28, 2.33 and the total resource constraint ($Y_t = N_t X + C_t$),

$$c_{a_l,t} = (1-\alpha) A^{\frac{1}{1-\alpha}} N_t \left[\nu \alpha^{\frac{2\alpha}{1-\alpha}} + (1-\nu)\alpha^{\frac{\alpha}{1-\alpha}} + \frac{L(a_l)\alpha^{\frac{1+\alpha}{1-\alpha}} \eta\rho\nu}{L[L(a_h)+\eta\rho]} \right] \tag{2.39}$$

And,

$$c_{a_h,t} = \frac{\nu(1-\alpha) A^{\frac{1}{1-\alpha}} \alpha^{\frac{1+\alpha}{1-\alpha}} L(a_l) N_t (L+\eta\rho)}{L[L(a_h)+\eta\rho]} \tag{2.40}$$

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

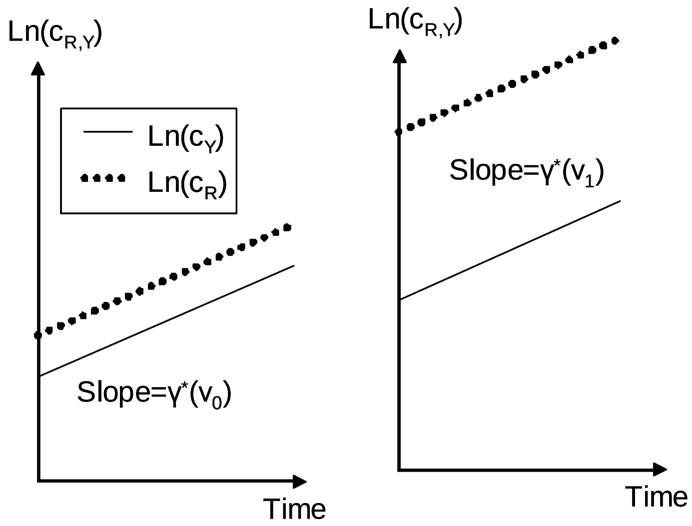


Figure 2.1: The effect of an increase in ν from ν_0 to ν_1 in t_0. There is a decrease in per-capita consumption for workers in the final sector and an increase in the consumption of those in the R&D sector. The steady state rate of growth is unchanged.

the wage in the R&D sector. On the other hand, the level of 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. On the contrary, for R&D labor the two effects move in the same direction increasing per capita consumption. Figure 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 across sectors, $w_{R,t} = w_{Y,t} = w$. The results obtained in the first case no longer hold. The new results are summarized in the following set of propositions.

Proposition 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 is determined in the labor market.*

$$r^* = \frac{(L - L_R^*)}{\eta}\Phi(\nu) \tag{2.41}$$

2. *The number of workers in the R&D and Final sectors are constant and endogenously determined.*

$$L_R^* = \frac{L\Phi(\nu) - \rho\eta}{\Phi(\nu) + 1} \tag{2.42}$$

$$L_Y^* = \frac{L + \rho\eta}{\Phi(\nu) + 1} \tag{2.43}$$

3. *The rate of growth of product, consumption and technology increases with total population (scale effect).*

$$\gamma^* = \frac{L\Phi(\nu) - \rho\eta}{\eta[\Phi(\nu) + 1]} \tag{2.44}$$

These four variables increase with the level of enforcement of IPRs (they are decreasing with the probability of imitation) and are independent of time.

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 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 2.18 the equilibrium interest rate is obtained.

2. Replacing the value of the equilibrium interest rate in equation 2.41 in equations 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 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.

3. Replacing the expression for the number of workers in the research sector defined by 2.42 in 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 is the scale effect found by Romer.

■

Per capita consumptions are in this case, as wages, equal for households in each sector.

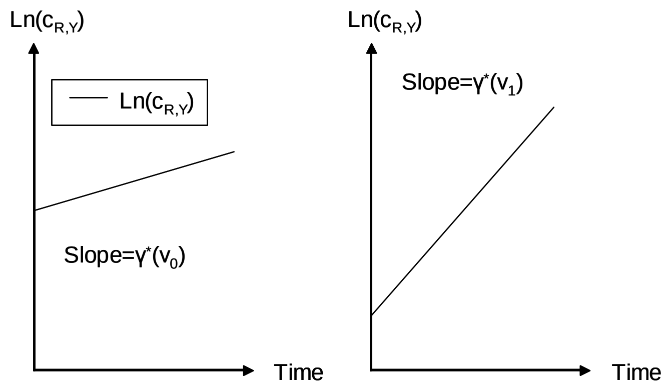


Figure 2.2: An increase in IPR protection (ν) produce a negative inmediate decrease in per capita consumption as well as an increase in the steady state rate of growth.

$$c_{R,Y,t} = \frac{N_t\left(L+\rho\eta\right)A^{\frac{1}{1-\alpha}}\left(\alpha^{\frac{\alpha}{1-\alpha}}-\alpha^{\frac{1}{1-\alpha}}\right)}{L\left[\Phi\left(\nu\right)+1\right]}\left[\nu\left(\alpha^{\frac{\alpha}{1-\alpha}}-\alpha^{\frac{1}{1-\alpha}}\right)+\left(1-\nu\right)\right] \tag{2.45}$$

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 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.

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 as 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[6]. The characteristic feature of these models is the presence of "scale effects", i.e. the per capita growth rate of output, at least in the steady state, is proportional to the amount of resources invested in R&D.

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

Intuitively, the level of imitation of any final or intermediate good is the result of the interaction among both endogenous and exogenous factors. One may think, for instance, that more recent generations of consumption goods are more likely 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, then there is little anti-piracy policies can do 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 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 to 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 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 beyond any reasonable doubt, 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 of deny the ubiquitous agreement with respect to the desirability of full enforcement of IPRs. 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 by an agent working for the R&D or Final sectors to the question: In the context of private 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?

3.1 Derivation

Case 1 $w_{R,t}/w_{Y,t} > 1. \Leftrightarrow L > \frac{L(a_h)[\Phi(\nu)+1]+\eta\rho}{\Phi(\nu)}$

When a "separating equilibrium" is observed, it is straightforward from equations 2.40 and 2.39 that perfect protection of IPRs maximizes welfare for workers in the R&D sector ($\nu_R^* = 1$) whereas workers in the final sector prefer an IPRs regime as low as possible.

Welfare maximization is written as follows:

$$Max_v \int_0^\infty U\left[c_{a_i,0}\left(\gamma^*, r^*, \nu\right)\exp\left(\gamma^* t\right)\right]\exp\left(-\rho t\right) \text{ for } i = l, h \tag{3.1}$$

The steady state rate of growth and interest rate are both independent of ν. It is then only through consumption (equations 2.39 and 2.40) that IPRs protection affects welfare. Since percapita consumption in the R&D (final) sector is a positive (negative) function of ν, workers in this sector maximize welfare by choosing the highest (lowest) possible IPRs regime. There is thus a conflict of interests in the choice of the IPRs standard for workers in different sectors.

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 2.30 with equality[7]. This value corresponds to:

$$\bar{\nu} = \frac{L(a_h) + \eta\rho}{\alpha^{\frac{1}{1-\alpha}} L + \left(1 - \alpha^{\frac{\alpha}{1-\alpha}} - \alpha^{\frac{1}{1-\alpha}}\right) L(a_h) + \left(1 - \alpha^{\frac{\alpha}{1-\alpha}}\right)\eta\rho} \tag{3.2}$$

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 $\quad w_{R,t}/w_{Y,t} = 1. \Leftrightarrow L \leq \frac{L(a_h)[\Phi(\nu)+1]+\eta\rho}{\Phi(\nu)}$

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 agent whose welfare characterizes the preferences of workers both in the R&D and final sector.

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

$$Max_{\nu} \int_0^{\infty} \ln\left[c(0,\nu)\exp\left(t\gamma^*(\nu)\right)\right]\exp(-\rho t)\,dt \tag{3.3}$$

Where per capita consumption is given by 2.45 and the steady state rate of growth γ^* by 2.44.

Equation 3.3 summarizes the 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 in the final sector. On the other hand, welfare is affected positively by IPRs protection via the higher rate of growth induced by more workers in the R&D sector, thus higher rate of growth for consumption.

Solving the maximization program in 3.3 yields the optimal level of IPRs (v^*) implicitly as the solution of the following quadratic equation:

$$A\nu^{*2} + B\nu^* + C = 0 \tag{3.4}$$

[7] $\bar{\nu}$ 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,

$$A = \rho\eta\left(\alpha^{\frac{1}{1-\alpha}} + \alpha^{\frac{\alpha}{1-\alpha}} - 1\right)^2\left(\alpha^{\frac{\alpha}{1-\alpha}} - 1\right) \quad (3.5)$$

$$B = \alpha^{\frac{1}{1-\alpha}}\left[L\left(\alpha^{\frac{1}{1-\alpha}} - 1\right) - \rho\eta\alpha^{\frac{1}{1-\alpha}}\right] \quad (3.6)$$

$$+\rho\eta\left(\alpha^{\frac{1}{1-\alpha}} + 2\alpha^{\frac{\alpha}{1-\alpha}} - 2\right)\left(\alpha^{\frac{\alpha}{1-\alpha}} + \alpha^{\frac{1}{1-\alpha}} - 1\right) \quad (3.7)$$

$$C = \alpha^{\frac{1}{1-\alpha}}L + \rho\eta\left(\alpha^{\frac{\alpha}{1-\alpha}} + \alpha^{\frac{1}{1-\alpha}} - 1\right) \quad (3.8)$$

According to the optimality condition given by 3.4 the 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:

$$L_0 = \frac{\rho\eta\left(1 - \alpha^{\frac{\alpha}{1-\alpha}} - \alpha^{\frac{1}{1-\alpha}}\right)}{\alpha^{\frac{1}{1-\alpha}}} > 0 \quad (3.9)$$

Applying the Implicit Function Theorem to the quadratic function determining ν^* in 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 individuals 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 level of 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.

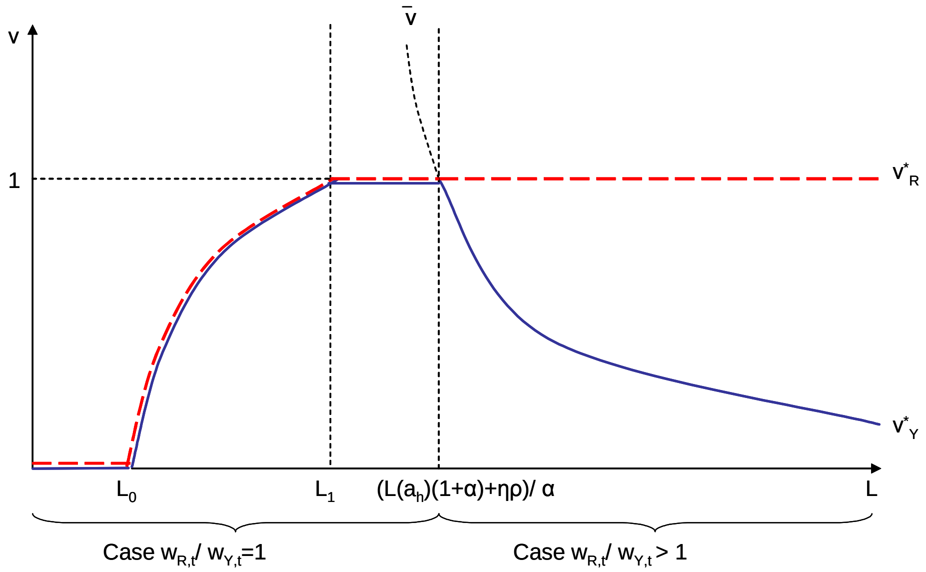
Following the same procedure it is possible to find the level of population for which perfect enforcement of IPRs (i.e. $\nu^* = 1$)is desirable. Hereafter designed as L_1 it is defined by:

$$L_1 = \eta\rho\left[\left(1 - \alpha^{\frac{\alpha}{1-\alpha}} - \alpha^{\frac{1}{1-\alpha}}\right)\left(\frac{1+\alpha}{\alpha}\right) + 1\right] \quad (3.10)$$

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

3.2 Graphical representation of the optimal IPRs protection

Figure **??** relates the optimal degree of IPRs protection and the size of the economy. The thicker line represents the IPRs protection that maximizes intertemporal utility for workers in the R&D sector (ν_R^*) and 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 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 example, 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 becomes in this environment a policy variable aimed to eliminate income 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 3.1 *Given the total population in one 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) 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) the optimal IPRs protection is the highest possible for workers in the R&D sector. It is a decreasing function of the total population reaching the complete absence of IPRs asymptotically.*

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 (innovations), intermediate goods (production inputs) and final good (homogeneous consumption good). Economic growth is driven by technology understood as increases in the variety of intermediate goods. New innovations 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 high and low skill individuals (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 level of enforcement of 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 have a positive effect on the rate of growth of the product, technology and, most important, consumption. Nonetheless this measure has a negative effect over society's welfare by increasing the prices of intermediate goods and, consequently, reducing its demand. This reduction on the demand causes a reduction in the amount of final good produced and consumed by the labor force. The decision between increasing actual consumption and consuming more in the future must be made, and the result of this decision process depends on the degree of impatience and altruism of present generations.

The other possible situation in the economy is when the relative wage is higher than one, with labor force being distributed into the R&D and the final sector depending on their levels of innate ability. The results from the previous section imply that only consumption is affected by changes in the parameter ν representing the probability of holding the monopoly status. 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.

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