# Inferior Products, Inequality and Growth

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The Date

**Abstract**

This paper faces the concern of whether the determinants of patent infringement and declaratory judgement suits may affect both the long-term economic performance and income distribution. In doing so, we construct a quality-ladder R&D-based endogenous growth model, in which the institutional setting devoted to patent protection directly impact the long-run private incentive to conduct R&D. By ruling, Courts' interpretation of patent law generates the coexistence of the leader's and follower's product, especially in those patent suits where lagging breadth is at the core of litigation. For the quality-leader, the existence of a positive probability to loss a patent suit against a potentially producer of an inferior product constitutes a threat for its monopoly position affecting its strategic behavior. We find that both the institutional setting and the Court's behavior actively affect both the long-term growth performance and income distribution.

**Keywords:**Innovation, quality improvement, patent litigation

**JEL classification** : L16, O31, O34

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## 1 Introduction

According to Lanjouw and Schankerman (2001), patent litigation have grown dramatically during the period 1978 - 1999. Combining data from the LitAlert database

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with others information collected by the U.S. Patent and Trademark Office, they report that the number of patent rose by almost tenfold, with much of this increase concentrating during the 90s. Lerner (1995) and Lanjouw and Lerner (2002) provide empirical evidences that even if parties can settle their patent disputes without resorting to suits, the effective threat of litigation influences the incentive to undertake R&D by avoiding small firms to enter those R&D areas where the threat of litigation from larger firms is high. Lanjouw and Schankerman (2001) finds that the mean filing rates vary substantially across technology fields and that the plaintiff probability to win the patent suit does not depend on all the sorting among patent disputes[1]. About this concerns, they state that:

> *"From a policy perspective, this is a good new because it means that enforcement of patent rights relies on the effective threat of court actions (suits) more than on extensive post-suit, legal proceedings that consumes court resources."* [Lanjouw and Schankerman (2001), pp.26]

In this paper we are interested in studying the implication for the R&D of the determinants of patent infringement and declaratory judgement suits. In particular, may Court's decisions represent the guidelines to interpreting and applying the patent law? By fixing a bound to the incumbent's power to invalidate more recent claims made by others, do the courts affect both the firm's freedom in setting price and income distribution?

The importance of patent protection for R&D-intensive sectors has been widely highlighted by the R&D-based growth literature. In the "Neo-Schumpeterian" endogenous growth theory (e.g. Romer (1990), Grossman and Helpman (1991), Aghion and Howitt (1992, 1998)), patent protection – or more generically, the intellectual property (IP) rights protection– plays a primary role in the process of economic development. Granting patents, firms establish a product's virtual everlasting monopoly, which allows entrerpreneurs to recoup the enormous amounts of cash spent in the R&D process. When a new pathbreaking invention improves the existing stock of technological knowledge, the discoverer of the new method, good, or production process, must preserve it discovery from any possible attempt of being copied or imitated. In a sense, IP rights are a sort of compromise between preserving the incentive to create knowledge and the desiderability of disseminating knowledge at little or no cost, and constitutes a second best solution to a failure in the markets for knowledge and information[2].

[1] In theoretical studies of patent litigation (e.g. P'ng (1983), Bebchuk (1984), Waldfogel (1998)), the plaintiff win rate at trial considerably differs across models depending on whether information is asymmetric or whether there is divergent expectations among parties.

[2] Although IP rights are important to encourage domestic innovation also through effective mechanisms to disseminate information, many historical works demonstrates that appropriate policy toward IP rights are not independent of the level of development nor of the overall institutional environment (see Maskus, (2000a, b)) . In Europe and US, for instance, a democratic IP system

Whenever a valuable innovation breakthroughs, firms apply for a patent permitting them to obtain claims that directly read on what competitors are doing. In many industries – in particular in the pharmaceutical ones–, firms use its original priority date to obtain several patent applications, each of which protects a different aspects of the same technology. The aim is to build a patent-blocking around the new product or process, and to keep a patent application filing always alive, so that when a competitor enters the innovation marketplace, firms have the opportunity to analyze the competitor's product and file new patent claim language to block its commercialization.

The question of patent infringement refers to different aspects of IP protection of an idea and then of the patented product. A concept often used, but quite vague, as the most basic test for infringement is the issue of the "use of a technology". If a product uses a technology covered by the claims of a patent, then the product infringe the patent. However, as O'Donoghue (1998) maintains

> *"the use of technology' is a vague concept, so the court have a lot of discretion in how to interpret it."*[O'Donoghue (1998, p.657)]

Since the meaning of the "use of a technology" is quite vague, a number of different doctrines have borne in the courts addressing the question of infringement. Our work focus on the doctrines of disclosure and enablement, which address the validity of the patent. The core of such a theory maintains that if a product falls within the claims of a patent, then the product infringes the patent. However, for the claims to be valid, the patent must contain information not in the prior-art that is required to make the product, and then the patent must contain enough information to make the product without significant experimentation.

The doctrine of disclosure and enablement concerns the so called patent breadth, which specifies a set of products that no other firm can produce without permission from the patentholder, often in the form of license agreement. The doctrine of disclosure and enablement concern in particular the lagging breadth question, that is the set of inferior products (i.e. product that require no further innovation) that would infringe a patent[3]. As O'Donoghue (1998) maintains

> *"the strength of lagging breadth is determined by the interpretation of the doctrines of disclosure and enablement."* [O'Donoghue (1998 p.658)]

had been crucial to ensure that returns to individual investments in creativity accrue to society as a whole. The setup of an efficient IP rights regime had been assessed in a broader policy context including trade and antitrust policies, with a different level of protection which took into account intersectorial differences as a part of a more general industrial policy. Indeed, while the US patent system undoubtedly contributed to economic growth, its effects varied widely between different industries especially from the mid 19th century onwards (Khan (2002)).

[3]Patent breadth also specifies the set of superior products – that is the products that require further innovation – that would infringe the patent. The literature and the law refers to such cases as leading breadth of a patent.

It is interesting to note that the term "breadth" covers both products horizontally and/or vertically removed from the patented product[4].

The standard "Neo-Schumpeterian" endogenous growth theory (e.g. Grossman and Helpman (1991), Aghion and Howitt (1992, 1998) has often used the notion "patent scope", "patent protection", in order to mean leading or lagging breadth[5]. The protection against imitators is granted by a perfectly enforceable patent law by "*assuming that the patent laws protect indefinitely a firm's exclusive right to sell the goods it invents*"[Grossman and Helpman (1991), p.89][6]

Because of intrinsic characteristics, institutional issues are very slippery to handle for economic theory. The standard "Neo-Schumpeterian" endogenous growth theory envisages stationary patent policies - policies under which all generations are treated identically. Moreover it envisages complete lagging breadth, which means that any patentable innovation receives sufficient lagging breadth to protect the entire quality increase facilitated by the innovation.

In this work we address the concern of whether institutional setting may affect both the long-term economic performance and income distribution by relaxing the current literature's assumption of a complete lagging breadth protection. We assume that patent law cannot definitively determine the effective protection of a patented product against imitator, since there exists the possibility to interpret the same patent law by the courts. In U.S., for instance, it has been both the Federal Circuit Judges and the Supreme Court who have decided just how to interpret and apply the patent law, so that several sentences constitute an high burden to deny patents[7]. In an always evolving environment - such that of incremental innovations and cumulative improvements -, Courts adequate the effective patent protection to the changing technology, which increasingly creates always new cases and situations. All these matters, we believe, are important concerns for economic growth.

The paper is organized as follow. In section 2 we construct a modified version of the quality-ladder R&D-based endogenous growth model of Grossman and Helpman (1991, ch.4) by introducing the justice sector. In section 3 we sketch the dynamical properties of the general equilibrium and discuss the main findings of the paper in section 4. Finally, section 5 concludes.

[4] Klemperer (1990) suggests to use breath for horizontal infringement, and height for vertical infringement.

[5] For a more detailed analysis on how the patent policies may impact R&D in the endogenous-growth framework, see O'Donoghue and Zweimuller (2004)

[6] The standard neo-Schumpeterian endogenous growth literature rules out the possibility of multiple producers under Bertrand competition considering costly imitation.

[7] For a deeply discussion on this issue see Merges and Nelson (1990)

# 2 The model

In this section we discuss a modified version of a scale-invariant quality-ladder endogenous growth model. Although we use the general equilibrium framework of Grossman and Helpman (1991, ch.,4) as building block, the model is substantially different from the current literature because it brings to the forefront the roles of institutional setting and patent litigation.

## 2.1 Preferences

Let consider a closed economy with a continuum of $L_t$ identical individuals. Individuals are infinitely lived and are endowed with one unit of labor. The demographic dynamics is such that the population grows over time at a constant rate $n > 0$. As in Grossman and Helpman (1991, ch.4), individuals choose their consumption from a continuum of goods $j \in [0, 1]$, which differs one with another because of their quality level, $m$. Particularly, let denote by $q_m(j) \equiv \lambda^m$ the quality of the $m$th vintage of good in industry $j$. By definition, new vintages are better than old, in the sense that consuming new vintage of good provides more services than consuming goods of the previous vintage. Assuming a quality jump, $\lambda > 1$, exogenous, constant, and common to all industries, all goods start at time $t = 0$ at a quality level $m = 0$, so that the starting quality level turns out to be $q_0(j) = 1$.

The representative consumer has additively separable intertemporal preferences of logarithmic type given by the following intertemporal felicity function

$$U = \int_t^{\infty} L_0 e^{-(\rho-n)\tau} \log u_\tau d\tau \tag{1}$$

Its intertemporal optimization problem is to maximize [1] subject to the following constraints:

$$\log u_t = \int_0^1 \log[\sum_m q_m(j) x_{tm}(j)] dj \tag{2}$$

$$E_t = \int_0^1 [\sum_m p_{tm}(j) x_{tm}(j)] dj \tag{3}$$

$$W_t + A_t = \int_t^{\infty} E_\tau \cdot e^{n\tau} e^{-R(t)(\tau-t)} d\tau \tag{4}$$

Equ.[2] is the Dixit-Stiglitz consumption index specification for the extent of the "love of quality" preferences, where $x_{tm}(j)$ denotes the consumption of the vintage $m$ of the $j$th brand at time $t$. Eq. [3] is the static budget constraint where $E_t$ is the per capita consumption expenditure and $p_{tm}(j)$ the price of the vintage $m$ of the brand $j$ at time $t$. Finally, eq. [4] is the intertemporal budget constraint, where $W_t$ is the present value of the aggregate labor income at time $t$, $A_t$ is the aggregate value of wealth at time $t$, and $R_t \equiv \int_0^t r(s)ds$ is the cumulative interest rate from time $t$ to 0.

Because of the separability of eq.[1], the consumers maximization problem can be solved in three steps: $(i)$ solving the within-industry static maximization problem $(ii)$ solving the across-industry static maximization problem is such a way to allocating the instant expenditure across existing brands $j \in (0,1)$ – e.g., choosing the composition of each instantaneous level of spending that maximizes equ.[2] subject to the static budget constraint [3]; $(iii)$ Solving the dynamic optimization problem in such a way as to determine the optimal allocation of the lifetime wealth over time –e.g., determining the optimal time path of spending, $E_t$, that maximizes intertemporal utility [1] subject to the budget constraint [4].

In the first subproblem, consumers choice to only buy the product with the lowest quality-adjusted price $p_{tm}(j)/\lambda^m$. For the sake of simplicity, in the proceeding of the analysis we assume that when two products of the same brand have the same quality-adjusted price, consumers only buy the higher quality product.

In the second subproblem, individuals maximize static utility by allocating expenditure for each product to the quality $\widetilde{m}(j)$ offering the lower quality-adjusted price, where the tilde denotes the top quality of each brand (e.g. the last vintage of each brand). Solving this static optimization problem yields representative consumer's static demand function

$$x_{mt}(j) = \frac{E_t}{p_{mt}(j)} \text{ with } m = \widetilde{m}(j) \tag{5}$$

Individuals demand function [5] features unitary price and expenditure elasticities, and take the following form for the aggregate spending

$$X_{mt}(j) = \frac{E_t L_t}{p_{mt}(j)}$$

In the third subproblem, the solution of the intertemporal maximization problem by maximizing discounted utility [1] given [2], [5] and the intertemporal budget constraint [4]. The solution to this optimal control problem leads to the following well-known intertemporal saving rule or Euler equation of the case of logarithmic preferences

$$\frac{\dot{E}_t}{E_t} = r_t - \rho \tag{6}$$

This condition holds for every individuals and also for the aggregate spending. Following Grossman and Helpman (1991), we impose a normalization of prices that makes nominal spending constant through time and equal to one- i.e. $E_t = 1$. Then, the Euler equation [6] determines the usual condition $r_t = \rho$ which must hold over time.

## 2.2 Production

As usual in the neo-Schumpeterian growth models, we assume that once a new good has been invented in the research lab, the producers with the requisite know-how can manufacture it with a constant returns to scale technology. Labor is the only production factor, so that we can choose units so that one unit of any good requires one unit of labor input. This makes the marginal cost of every brand of consumption good $j \in [0,1]$ equal to the wage rate $w_t$.

We rule out the existence of multiple producers of the same state-of-the-art product, by assuming that the patent law everlastingly protects the firm's exclusive right to sell the good that it invents. In such an environment - and assuming no-drastic innovations - the Bertrand competition between producers in the same industry line implies that the leader will set a limit price equal to the quality jump over the marginal production cost, i.e. $p_t = \lambda w_t$. This limit pricing allows the leader to capture the whole consumption demand of its brand and eventually to exclude the producers of the inferior products (e.g. the producers of the preceding vintage of the same brand)[8].

Let now assume that patent law perfectly protects the patentholders against those imitations that perfectly reply the state-of-the-art embodied in the latest vintages. At the same time, let depart from current literature and assume that patents are not perfectly enforceable when a new competitor gets in the market by producing an inferior product with a lower quality than the existing state-of-the-art, but with a quality level higher than the previous incumbent producer. Then, between two given quality-lad - say, $m$ and $m+1$ -, a firm can produce a laggered-quality good but that infringes the claim of a patent based on patent breadth.[9] Patent law is defined by the legislative sector, but since it is also defined and effectively applied by the Courts, we suppose that the Courts can determine the effective degree of protection against inferior products by the application of the doctrine of disclosure and enablement.

The potentially threat that a new competitor may enter the market and sell an "imperfect imitation" of the state-of-the-art without incurring with certainty in a legal infringement, will induce the quality leader to lower the limit price in order to serve the whole market. This is also holds even in the event that the patent infringement could be recognized by the Courts. Indeed, the mere existence for the leader of a positive probability $(1-q) > 0$ of loss the patent suit when it is imperfectly imitated will induce it to lower the limit price. Assuming rational expectations, the leader will adopt the following Bertrand-Nash equilibrium limit pricing

[8] **The markup over the marginal cost exactly equates the quality jump $\lambda$ since with an elasticity of substitution between any two brands equal to one we are automatically treating the case of a model with non-drastic innovation. Li (2003) further generalized this framework by allowing the model for elasticity of substitution between any two brands larger than one. However, our main conclusions do not vary by adding drastic innovation in the model.**

[9] Since as in Grossman and Helpman (1991) there exists perfect intertemporal knowledge spillover in the same industry line, we assume that once it is note how to produce the best quality product, each firm will be able to produce a "worst" product in the same industry line. That is we assume that the imitating firm - which produces a product with a lower quality than the state-of-the-art - only incurs in production labor costs.

$$p_t = \begin{cases} p = \lambda w_t & \text{with prob } q \\ p' = \frac{\lambda}{\varepsilon} w_t & \text{with prob } 1-q \end{cases} \tag{7}$$

where $q > 0$ is the plaintiff probability to win the legal fight against imperfect imitators, $(1-q) > 0$ is the probability to loss the legal fight against imperfect imitator, and $\varepsilon \in (1, \lambda)$ is a parameter that proxy the degree of tolerance with which courts judge about patent suits concerning lagging breadth infringement.

Our interpretation of the parameter $\varepsilon$ stems from the use of the doctrine of disclosure and enablement. The parameter $\varepsilon$ represents a sort of degree of tolerance whereby Courts rule in litigation in which lagging breadth infringement were involved. In the extent in which $\varepsilon = 1$, the inferior product coincides with the state-of-the-art of the preceding vintage, whereas with $\varepsilon = \lambda$, the inferior product consists in a "perfect imitation" that perfectly replies the top quality of each brand. In the proceeding of the paper, we will exclude the extreme of the imitation interval $(1, \lambda)$ and we will concentrate to the extent in which the inferior product constitutes an imperfect imitation (or a bad version) of the top quality.

Denoting the expected price by $p_t^e$, one can write

$$p_t^e = \left[q + \frac{1}{\varepsilon}(1-q)\right] \lambda w_t$$

Since the Arrow's effect is at work even in such an economy, no industry leader undertakes research in the general equilibrium and all the innovations are carried out by outsider firms. Once that the innovations occur, the succeeding firms will find themselves one step ahead of the former leaders that they have displaced. Given the above price limit behavior and the aggregate demand for each product $j \in [0, 1]$, the profit flow for the industry leader at time $t$ will be

$$\pi_t(j) = \begin{cases} \frac{\lambda-1}{\lambda} L_t & \text{with prob } q \\ \frac{\lambda-\varepsilon}{\lambda} L_t & \text{with prob } 1-q \end{cases} \tag{8}$$

with can be solved in terms of the expected profit

$$\begin{aligned} \pi_t^e(j) &= \frac{\lambda-1}{\lambda} L_t q + \frac{\lambda-\varepsilon}{\lambda} L_t \ (1-q) \\ &= L_t(1-\eta) \end{aligned} \tag{9}$$

where, to simplify the formula, we denoted the probability-adjusted share of revenue that goes to workers by $\eta \equiv [(1-\varepsilon) q + \varepsilon] / \lambda$ [10].

The higher (lower) the probability for the plaintiff to win the litigation against the producer of the inferior product, , $q$, the higher (lower) is the expected profit flow of the leader. These two effects are easily explained. For given $\varepsilon$, an increase

[10]Notice that $\eta$ crucially depends on the probability $q$. In particular, for $q$ approaching one, $\eta$ approaches $1/\lambda$, while for $q$ approaching zero, $\eta$ approaches $\varepsilon/\lambda$.

in the plaintiff probability to win the litigation against the producer of the inferior product reducers the risk of being partially imitation and induces the leader to set a higher limit price. Notice that mere existence of the threat that an inferior product may erose the monopoly rent, on the one side reduces the leader's market power in fixing price, on the other it rises the consumer demand of every existing brand. These two opposite force on profit flows testifies that the negative effects on the profit flows deriving in an increase in the opponent probability to win the patent suit - as measured by an increase of the probability $(1-q)$ and of the parameter $\varepsilon \in (1, \lambda)$ - operates through an increase of the production costs of the leader[11].

## 2.3 R&D sector

Innovation is a risky venture which requires to firms to invest resources in lab activity. The premium consumers are willing to pay for higher quality products is the incentive inducing the agents to invest resources in improving the existing quality levels. As in the bulk of the R&D-based endogenous growth literature, we model the process of innovation as a continuum memoryless Poisson process and assume constant return to scale in research effort. To achieve an R&D intensity of $\iota$ a firm must invest $a\chi_t$ units of labor per unit of time and incur in a cost of $a\chi_t w_t$, where $\chi_t$ denotes the difficulty of conducting R&D[12]. Each firm that invests resources in R&D at intensity $\iota$ for a time interval of length $dt$, will succeed in creating a new generation of a product with probability $\iota dt$, and will fail with probability $(1-\iota dt)$.

However, in this model we relax the perfect enforcement hypothesis of the laggered-quality products, allowing competitors to grant a patent for the extent innovations with a quality jump $\lambda/\varepsilon$, with $\varepsilon \in (1, \lambda)$. This implies that the value of an innovation depends on the probability that a new competitor, with an imperfect copy of an existing branch, has to win the lawsuit for the case the incumbent incurs in a legal reprisal against its decision to get in the market. Such a probability, $(1-q)$, affects the present value of an innovating firm, in the sense that each incumbent has to take into account to competing with an hypothetical producer of a worse copy of its product.

For the sake of simplicity, we assume that $q$ does not vary among industries, so that jurisdictional institutions do not affect the stock market evaluation of any research firm. In other words we are assuming that the Courts' degree of tolerance regards all the existing industry lines in the same manner.

[11] Since we will focus our attention to a symmetric equilibrium, the plaintiff probability rate to win, $q$, does not vary across industries. An interesting extension of our research would be to consider a different industrial setup by allowing the model to generating heterogeneous quality improvements.

[12] The addition of this variable is the direct consequence of the Jones (1995)'s critique of scale effect. We specify the $\chi_t$ in such a way to avoid explosive growth and scale effect. In particular, we adopt the PEG specification (or dilution specification) developed by Dinopoulos and Thompson (1996), which captures the idea that difficulty of conducting R&D is proportional to the size of the total market $\chi_t = \delta L(t)$, with $\delta > 0$.

Free entry into innovation implies that the expected present value of the representative research firm must be no higher than the cost of R&D, and equal to it when R&D actually is taking place

$$v_t^e \leq a\chi_t w_t \qquad \text{with } \iota > 0 \text{ when equality holds} \tag{10}$$

where $v_t^e$ denotes the expected value of an innovation. Free entry condition [11] prevents firms from earning excess returns and also denotes the scale of aggregate research effort that, because of constant return to scale technology, turns out to be indeterminate.

As usual in the R&D-based endogenous growth model, stock-market evaluation of profit-maximizing research firm is such that a no-arbitrage condition relates the expected equity returns to a yield on a riskless bond. Moreover, we assume that capital market is walrasian, so that equity holders expect that gains or losses must match the change in the expected value of the research firm. Because the flow of profit does not vary among industries, the research firms will be indifferent as to the target of their innovation efforts if and only if the expected monopoly duration does not vary among industry. Of course, this is the case when we assume $q$ identical $\forall j \in [0,1]$, so that investors can offset the risk of capital loss just diversifying their asset portfolio. Thus, in a time interval of length $dt$ the total return of the representative firm turns out to be $\pi_t^e dt + \dot{v}_t^e\, dt$, and perfect-foresight equilibrium in capital market requires

$$\frac{\pi^e}{v^e} + \frac{\dot{v}^e}{v^e} = \rho + \iota + n \tag{11}$$

Notice that for the extent of a steady-state equilibrium $\dot{v}^e / v^e = 0$, so that equ.[12] can be solved for the expected present value of the firm

$$\begin{aligned} v^e &= \frac{\pi^e}{\rho + \iota + n} \\ &= \frac{1-\eta}{\rho + \iota + n} L_t \end{aligned} \tag{12}$$

## 2.4 The dynamical equilibrium system

In the remaining of the paper we will focus on a rational-expectations equilibrium where a positive long-run rate of innovation coexists with a market-clearing in all markets. Because any individual firm will perform different flow of sells according to the probability, $q$, the expected employment in manufacturing will be

$$\begin{aligned} x^e &= \frac{L_t}{p} q + \frac{L_t}{p'} (1-q) \\ &= \eta \frac{L_t}{w_t} \end{aligned}$$

where $\eta \leq 1 \Longleftrightarrow q \leq 1$.

With a symmetrical R&D intensity $\iota$, a unit measure of industries, and a labor productivity parameter $a$, the R&D sector labor demand equals $a\iota\chi_t$. In that light, labor market-clearing condition implies

$$a\iota\chi_t + \eta\frac{L_t}{w_t} = L_t \tag{13}$$

Before moving head, it is easy to check that our model predict an interior solution – i.e., an equilibrium where labor market-clearing condition turns out to be compatible with a non-zero rate of innovation– if and only if the equilibrium wage is such that the following inequality holds[13]

$$w_t \geq \frac{1}{\eta} \tag{14}$$

Thus, since free entry in R&D sector states that $\iota > 0$ implies $v_t^e = aw_t$ and full employment in labor imposes $w = 1/\eta$, an internal solution with a positive long-run rate of innovation compatible, implies the expected flow of profit to respect the inequality $v_t > a/\eta$.

Accordingly, plugging free entry condition [11] into [12] yields

$$\iota\chi_t + \eta\frac{L_t}{v_t^e}\chi_t = \frac{L_t}{a} \tag{15}$$

Equ.[LL] the side condition of the model which implicitly relates the long-run rate of innovation, $\iota$, to the equilibrium expected value of an innovation. To close the model, we plug the profit function [9] into the no-arbitrage equation [13] yielding

$$\frac{\dot{v}_t^e}{v_t^e} = \rho + \iota + n - (1-\eta)\frac{L_t}{v_t^e} \tag{16}$$

Equ.[LL] and [VV] form the equilibrium system of the model. For the sake of simplicity, in the reminder of the paper we define $V_t^e \equiv 1/v_t^e$ as the inverse of the expected aggregate value of the stock market, so that the equilibrium system can be reduced to the following two-dimensional system

$$\frac{\dot{V}_t^e}{V_t^e} = \rho + \iota + n - (1-\eta) L_t \cdot V_t^e \tag{17}$$

$$\frac{1}{a\delta} = \iota + \eta L_t \cdot V_t^e \tag{18}$$

where in calculating the [19] we considered the extent in which the difficulty index takes the form of $\chi_t = \delta L_t$

[13] Notice that whenever $w = 1/\eta$, all labor force is employed into the manufacturing sector by leaving no resource to R&D. In such and extent, R&D does not take place and long-run rational-expectations equilibrium characterize for rate of innovation equals to zero.

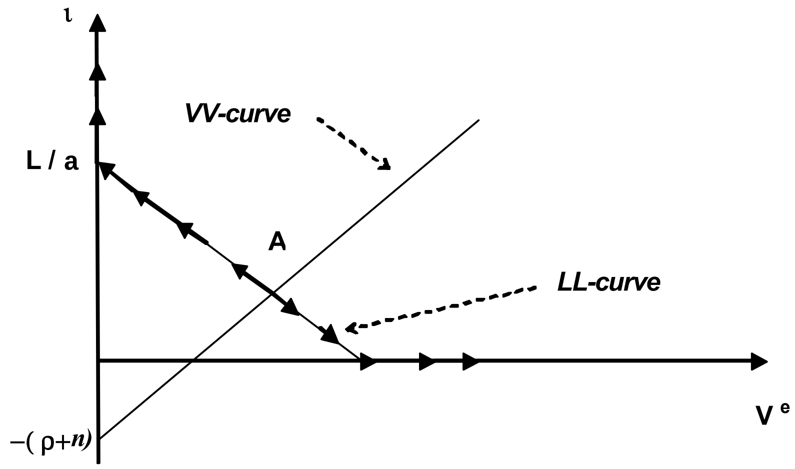


Figure 1: Phase diagram

## 2.5 The steady-state solution

Let now focus to the case of a steady-state equilibrium. A steady-state consists in all those couples of $(\iota, V_t^e)$ such that the long-run rate of innovation, $\iota$, and the inverse of the expected aggregate value of the stock market, $V_t^e$, are constant, and where labor market clears at any moment in time. Because we reduced the model in a system of one differential equation (equ.[18]) and a side condition (equ.[19]), imposing the steady-state condition $\dot{V_t^e} / V_t^e = 0$, we can solve equ.[18] for the steady-state rate of product development $\iota$

$$\iota = -(\rho + n) + (1 - \eta) L_t V_t^e \tag{19}$$

Because $1-\eta > 0$, equ.[20] figures upward-sloping in $V_t^e$, due to the fact that higher rates of product development, $\iota$, must be matched with lower expected aggregate values of the stock market, $v_t^e$. The Intersection of equ.[19] and [20] – see point A in the fig.1– gives us the steady-state couple $(\iota, V_t^e)$ in which market-clearing conditions hold in each market and where the economy grows at a growth rate proportional to the constant rate of innovation $\iota$. Because the [20] slopes upward and the [19] slopes downward, an internal solution for the steady-state system always exists if and only if $1/\delta a > -(\rho + n)$.

As we will demonstrate in the proceeding of the paper, the dynamics of the model is such that the economy jumps immediately to a steady-state with long-run rate of innovation given by

$$\iota = (1-\eta)\frac{1}{a\eta} - (\rho + n)\,\eta \tag{20}$$

Notice that for both $\chi_t$ and $q$ approaching one, $\eta$ approaches $1/\lambda$ and the rate of innovation, $\iota$, is the same as in Grossman and Helpman (1991, ch.4).

With a population growing at a constant rate $n$ and the dilution specification of the R&D-complexity index, eq. [21] is the scale-invariant long-run rate of innovation of the economy. Because of the presence of $\eta$ into eq.[21], the expected rate of innovation will depend on the probability $q$ and on the Courts' degree of tolerance $\varepsilon$.

# 3 The dynamics of the model

In describing the dynamical property of the model we keep in track with Grossman and Helpman (1991) and follow a diagrammatical approach. In carry out the analysis we will suppose in case of patent litigation an invariant probability of success for the leader, $q$, by addressing the comparative statics analysis in the next section.

Fig.1 lay out the phase diagram where the LL-curve represents the resources constraint of the economy and the VV-curve represents the steady-state solution of the no-arbitrage condition [18]. Rational-expectations equilibrium implies that labor market clears at every moment in time. Along the LL, an higher rate of innovation, $\iota \uparrow$, implies bath a larger share of labor force employed in the R&D sector, $a\chi\iota \uparrow$, and a smaller amount of labor for manufacturing activity; this means, in turn, that the supply of goods must be lower, $X \downarrow$, and prices must be higher; in spite of a decline in sells, higher prices imply an higher expected aggregate value of the stock market, $v_t^e \uparrow$ (or, alternatively, a lower value of the inverse of the expected aggregate value of the stock market, $V_t^e \downarrow$).

As aforementioned, from the steady-state solution of the no-arbitrage equation [18] we know that a smaller expected aggregate value of the stock market, $v_t^e$ (a lower value of the inverse of the expected aggregate value of the stock market, $V_t^e \downarrow$) must be matched with a faster rate of innovation. Equ.[20] is the only possible equilibrium trajectory because any other trajectory violates rational-expectations because of an inconsistency in the stock market evaluation of the firms.

To see this more deeply, let suppose that the initial expectations about future aggregate value of the stock market, $v_t^e$ (an inverse of the aggregate value of the stock market, $V_t^e$) smaller (greater) than that associated with point A. In the long-run the dynamics of the model is such that investors would expect ever less research and ever smaller (greater ) aggregate value of the stock market ( inverse of the aggregate value of the stock market).This means that investors would expect the long-run rate of innovation and the expected aggregate value of the stock market (inverse of the expected aggregate value of the stock market) approaching zero (infinity). But even in the extent of totally absence of leapfrogging –i.e., $\iota = 0-$, each incumbent must have a value of $\pi^{e}/(\rho+n) = (1-\eta) L_t/(\rho+n) > 0$, which contradicts investors expectations.

Similarly, for the extent of trajectories lying below the VV-curve, along which the initial expectations about future aggregate value of the stock market, $v_t^e$ (an inverse of the aggregate value of the stock market, $V_t^e$) is greater (smaller) than that associated with point A, in the long-run investors would expect ever more research so that the aggregate value of the stock market (inverse of the aggregate value of the stock market) would be ever smaller (greater) over time until the rate of innovation, $\iota$, would reach its maximum $1/\delta a$. Then, in the long-run investors would expect aggregate value of the stock market (inverse of the expected aggregate value of the stock market) attains to infinity (to zero) so that, again, rational expectations must be violated.

Thus, expectations can be fulfilled only if the economy jumps immediately to the steady-state point A and remain there until an exogenous shock, for instance a change in $q$, makes the rest point A to change and make the adjustment dynamics in motion.

# 4 Discussion of the model

In the preceding sections we studied a scale-invariant model of R&D-based endogenous growth and its dynamical properties. The long-run rate of innovation we obtained, negatively depends on the parameter $\eta$, represents the probability-adjusted share of revenue that goes to workers. Because of the existence of a negative relationship between the parameter $\eta$ and the expected profit flow of the monopolist, eq.[21] is a downward-sloping curve that can be taken as a sort of policy function (see fig.2). According to eq.[21], the long-term economic performance of the economy is affected by the plaintiff probability to win, $q$, and the degree of Court's tolerance, $\varepsilon$, in the event of patent litigation.

Indeed, by having defined $\eta \equiv [(1-\varepsilon) q + \varepsilon] / \lambda$, it is easy to check that the long-run rate of innovation of the economy depends on the institutional setting represented by the parameters $\varepsilon$ and $q$. In particular, any increase of the incumbent's probability to win the lawsuit against the imperfect imitator - as represented by an increase of the parameter $q$ -, positively affects both the patentholder's expected flow of profit and the long-run rate of innovation of the economy.

In fact, eq. [9] shows the existence of a negative relationship between the probability-adjusted share of revenue that goes to workers, $\eta$, and the monopolistic firm's expected profit flow. For a given $\varepsilon$, any increase of the probability to win a patent dispute against an inventor of an inferior product raises the expected markup and spurs the long-run innovation process.

For $\iota$ converging its steady-state value [21], it easy to check that the steady-state wage rate asymptotically converges to

$$w = \eta \tag{21}$$

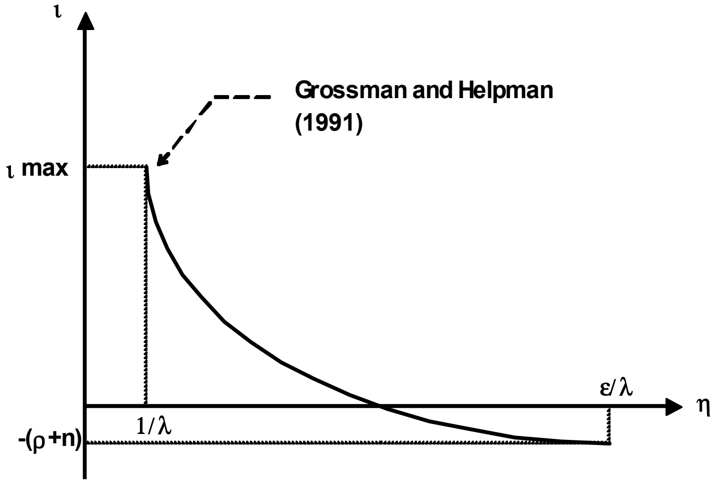


Figure 2: The Policy Function

Eq.[22] also depends on the institutional setting represented by the couple $(\varepsilon, q)$. Any increase in the Court's degree of tolerance, $\varepsilon$, or in the plaintiff probability to win the suit, $q$, raises the steady-state wage rate, $w_t$. Therefore, whenever an inferior product is involved in patent litigation, there exists a trade-off between inequality and growth, and the use of the enablement and disclosure doctrine and then the interpretation of the claims of the patent with respect to the inferior products, can then contribute to determine both the long-run perspectives of economic growth and income inequality of a country.

# 5 Conclusions

In this paper we address the concern of the long-run implication of institutional setting on both the rate of innovation and income inequality. To this goal, a scale-invariant quality-ladder endogenous growth model in the spirit of Grossman and Helpman (1991) has been constructed.

There exists different routes for intellectual protection. By following the seminal work by O'Donoghue (1998), one route consists to protect the patentholder against inferior products. In our paper, this happens through the use of the doctrine of disclosure and enablement interpretation whereby infringement of the lagging breadth are at the core of the disputes. Empirical evidence shows that there exists the possibility for outsiders to create and to market a "imperfect imitation" of the state-of-the-art. We show that the mere existence of such a threat forces the patentholder to reduce the monopolistic limit price by lowering both the mark-up and the expected value of a patent. Courts' interpretation of patent law also affects the long run innovation rate of the economy and income distribution. We show that when Courts' decisions tend to favor the patentholder against potentially new comers, the model generates a positive effect on the expected markup such to increase the expected profit flow. This in turn will spur the research effort and then the long-run rate of innovation of the economy. At the same time, higher protection of patentholder reduces the long-run wage rate. This means that there actually exists a positive relationship between inequality and growth and that Court's behavior may be revisit from a policy perspective.

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