MASTERARBEIT / MASTER'S THESIS

Titel der Masterarbeit / Title of the Master's Thesis

„Intellectual Property Rights: Alternative Theoretical Analysis“

verfasst von / submitted by

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angestrebter akademischer Grad / in partial fulfilment of the requirements for the degree of

Master of Arts (MA)

Wien, 2023 / Vienna, 2023

Studienkennzahl lt. Studienblatt / degree programme code as it appears on the student record sheet:	UA 066 642
Studienrichtung lt. Studienblatt / degree programme as it appears on the student record sheet:	Masterstudium Philosophy and Economics
Betreut von / Supervisor:	Uni. Prof. Alejandro Cuñat, PhD

Acknowledgements

For the realization on this work, I would like to thank my supervisor Alejandro Cuñat for his advises and inspiring courses. Furthermore, I would like to thank Felix Pinkert and Justin Leduc for this amazing program and for all the things they taught me.

Then I would like to thank my girlfriend Beatrice for the hours spent trying to understand what I was doing and the support through all my studies. Her love made the difference in finishing this work. Moreover, I would like to thank my mother Simona that made the possible moving in another country to pursue my goals. She has always supported my choices making me feeling less pressure in following my path. The same counts for my sister Arianna and my grandmother Liliana. They let me be myself no matter what this would mean. Then there are the friends of a lifetime Marco, Davide, Riccardo, Daniele, Linda, Camilla, Giacomo, Simone, Simone, Silvia, Marta, Kevin, Agnese, Roberto, and Paola. They means home to me. I would not be myself without them. I would also like to thank the friends I met in this journey Anna Luise, Bernhard, and Julia. They welcomed me in Austria without letting the language barrier overcome us. Last but not least, I would like to thank my dog Nina. She always welcomes me home like I never left, I will never be enough grateful.

Contents

1 Introduction

In the debate between the instrumental and the natural approach regarding private property, the second one had the most appealing arguments, especially in the Anglo-Saxon world. However, the explanation is given to the conception of intellectual property has more instrumental characteristics than natural ones. While, it can be argued, as in Locke [Locke and Laslett, 2003], that property is a natural right because it is possible to exclude others to use land, it is not the same for ideas. In this, it is evident that inside the categorization of public and private, and rival and excludable goods, the natural representation of property has an impossible case in the non-rivalry and public good sphere. This is also noticeable in the way arguments in favor of intellectual property are formed. [1]

Nowadays, we are used to thinking that intellectual property, both in the form of patents and copyrights, is the only way to deal with such a matter. New ideas are considered public goods that produce good externalities that the innovator is not benefiting from. Hence, to induce her to produce more innovation, we insure her a monopoly rent. The story we told each other is that innovators should receive compensation of some kind for the creation of something new, otherwise, they will not innovate at all. In the last 300 years, this has been the mainstream approach toward the issue of intellectual property. In this work, I would like to bring to the attention another point of view regarding intellectual property, and how what is said to be a necessary evil (QUOTE SOMETHING), is eventually just an unnecessary evil.

This work wants to rethink in a theoretical fashion the perspective surrounding the I.P. (Intellectual property from now on). In particular, I am going to build a model that resembles the Romer 1990 [Romer, 1990] paper which is a milestone in the classical endogenous growth literature. This paper has given the start to a strands in the growth research, although, it also imposed as the main assumption the existence of I.P. rights. In fact, in his analysis, Romer imposes an ad-hoc setting in which any R&D firm receives perpetual I.P. rights over each invention (more on the model structure later). In doing this, he argues that such a setting is needed to create an incentive for the firms to innovate. Fearing to be copied and then entering a Bertrand game, they would not innovate if they expect to make negative profits since to innovate it is needed to pay a fixed cost upfront. I would like to show that this line of thinking is inconsistent in two dimensions:

[1] An important note to make is that in this dissertation, just patents and copyrights are taken into account and only from an economic point of view. Nothing is said and nothing wants to be said about plagiarism. Any policy implication that the theory that this thesis can produce has nothing to do with it.

1. Following the previous reasoning, if without patents the incumbent expects to end up in a zero-profit environment, why would the entrant expect something different? And so, why should it decide to enter a zero-profit market?

2. Such a setting is static. The innovator and the entrant will copy their decision almost simultaneously, and when the entrant enters, the Bertrand game is immediate. Although, the facts around us suggest us a different intuition. When an innovator innovates, it has a first mover advantage and, also without patents, as the incumbent, when an entrant enters, they will play a Stackelberg game.

It is worth noticing that the first dimension questions the reasoning as it is usually expressed, making already in the first place the logic behind the reasoning incoherent. On the other hand, the second dimension expresses a more realistic consideration of how industrial games usually work.

These achievements are in line with the work of Boldrin and Levine [Boldrin and Levine, 2002] [Boldrin and Levine, 2008a] and also Quah's work [Quah, 2002]. This paper contributes to the literature by managing to have the same results as the mentioned authors but in a continuous time context. It would give more credibility and mathematical strictness. Moreover, because it will follow step by step the Romer 1990 model, this paper will allow an easier comparison with that model.

The thesis is divided into five chapters in which the goal stated before is achieved. In the first chapter, it is given a short review of the relevant literature regarding the classical endogenous growth model and how the mentioned above authors have tackled the issue of patents. In this chapter, the main contribution of this thesis is clearer. Moreover, it is given a short history of how the patents have been implemented through time. This is meant to make clear to the reader why assuming patents are the "starting kick" for endogenous growth can be detrimental to long-run growth. Then, finally, in the third chapter, comes the model. Afterward, in the fourth chapter, the consequences of possible deregulation of patents are analyzed. In particular, the chapter focuses on alternative policies. In the end, the fifth chapter is the conclusion.

2 Literature review and short history of patents

2.1 Literature review

The literature regarding patents in economics has always been very flourishing, but the extensive use in the economic growth literature arrived after the Romer 1990 paper [Romer, 1990]. However, it can be said that this branch of macroeconomics has been started by Romer with his paper "Increasing returns and long-run growth" romer1986. This paper has been very influential in the literature because it was the first of its kind, demonstrating how to produce endogenous growth, hence, producing innovations that lead to growth. The paper achieves this goal by letting knowledge spillovers be the unintended by-product of capital accumulation.

Moreover, it introduced the concept of learning by doing learning-by-doing. Because of this, innovation in this model has no cost. Differently to the Solow-Swan model[Solow, 1956] [Swan, 1956], we can see growth effects in parameter changes and not just level effects. Another two interesting features of the model are the absence of an R&D sector, but just of households who are also producers, and also the absence of any intellectual property assumption. The last aspect of this paper is for my purposes the most important.

In fact, the assumption of monopoly rights assumption was introduced by Romer in the paper we talked about in the first section [Romer, 1990]. The interesting aspects of this model, other than monopoly rights for innovations, are the introduction of the R&D sector that establishes innovation as an active decision of the firms. In the model, the introduction of infinitely lasting monopoly rights is justified in the following way.

Let's assume innovation has an upfront fixed cost of any kind. Moreover, let's imagine a firm (innovator) that has to decide whether to innovate, and create a new market, or not, and other many incumbent firms that can copy it and enter the market (emulators). If the innovator decides to innovate and does not have any monopoly rights over the innovation, once it innovates, other incumbent firms will copy its innovation leading to a Bertrand game and so to a perfect competition regime. In this case, the final profits of the innovator will be negative because of the upfront cost of innovating. In front of this perspective, the innovator in front of the possibility of having negative profits will not innovate. Hence, to stimulate innovation it is necessary to grant monopoly rights over the innovation to the innovator.

This type of reasoning seems to be corroborated by the Judd [Judd, 1985], and Barro and Sala-i-Martin [Barro and Sala-i Martin, 2004] analyses. They took the Romer (1990) model and allow the possibility of monopoly erosion. They showed that when the probability of losing the monopoly is instantaneous, the firms have no incentive in innovating. Moreover, there is a general worsening of the overall welfare.

Although this has been the dominant vision in the economic growth literature, a new point of view on the problem came out at the beginning of the twenty-first century. Mainly Quah with his book "24/7 Competitive Innovation" [Quah, 2002] and Boldrin and Levin [Boldrin and Levine, 2002] [Boldrin and Levine, 2008b] with a series of articles that tried to argue for different reasoning.

The main idea of these authors is that the decision game that a firm faces when it has to decide if innovating or not is not what the previous authors expressed. Their main argument follows this path. Let's take again the assumption we had before regarding the innovation fixed cost and a firm that has to decide whether to innovate or not. When a firm innovates, it will have a comparative advantage in using the new technology that other firms do not have.

Moreover, it will also have a production advantage over the other possible emulators. Because of this, even if the emulators enter the market, there will not be a Bertrand competition regime, but more of a Stackelberg competition. In this case, the innovator will recover its fixed cost and will innovate also without the monopoly rights over its innovation. This should demonstrate that imposing artificial monopoly rights over innovation is inefficient and just creates annuities. Although, they demonstrate this to be true just in discrete time, not in continuous.

2.2 Short History of Patents

The history of patents is interesting and rather long. Hence, to remain in line with the scope of this dissertation, I emphasize the most interesting and relevant aspects.

Although some important scholars claim the first forms of patents have been experienced already during Ancient Greece and the Roman eras; everybody agrees that the first modern reported patent was in the Republic of Florence on June 19, 14211 to Filippo Brunelleschi. This case has been a major influence on the British patent system later on.[Moore and Himma, 2022]

In 1474 in the Venetian Republic, the first comprehensive statute for intellectual property protection appeared. It was quite complex including rights and incentives for the inventors, plus punishments and compensations for infringements. [Moore and Himma, 2022]

Finally, in 1624, the Statute of monopolies was introduced establishing fourteen years of

monopolies to the inventors but also authors of literary works. The system of copyrights was developed and extended in 1710 with the Statute of Anne, which is considered the first modern example of copyright law. The protection granted by the statute was of fourteen years with the possibility of been renew for another fourteen years if the author was still alive.
[Fisher, 2023]
However, what I would like to underline with this small section is the reason for which patents were implemented in the first place. As far as we know, the main reason for which these protection systems have been implemented in England is to protect from royal power. In particular, during the time of Queen Elizabeth I, the Queen was issuing grants for importing goods and establishing new industries. The sentiment to prevent the exploitation of this power, the Statute of Monopolies was written[Fisher, 2023].

If I am allowed for a personal comment, I see a bit of irony in it. Patents and copyrights are born to contrast strong powers but nowadays they are mainly used to consolidate this power. Let us think for example of Microsoft. During the 1990s, it was impossible to put patents on software, and this allowed many different firms to emerge copying each others' innovations and improving them.

3 The model

3.1 Game theoretic analysis

Before moving to the actual model, for clarity reasons, it will be explained beforehand in the game theory part. This is because it is crucial to understand the difference between what the mainstream view arguments and what other minor scholars are proposing, and in the end to understand the main reasoning behind the model.

3.1.1 Mainstream view

When arguing why patents are essential to let innovation happens, many scholars from which Romer here is taken as an example [Romer, 1990] argued in the following way. Let us assume to have a two-period game with two firms, an innovator and an entrant. The innovator in the first period has two possibilities innovating creating a new product and a new market or not innovating. When it decides to innovate, it has to incur a fixed cost eta, otherwise, so not innovating, it does not have any fixed costs. In the second period, the innovator faces a payoff function if it has innovated, otherwise, its profits would be zero.

On the other hand, there is the entrant. It only participates in the model in the second period and it has a two-decision choice. It can either enter the market copying the innovator (usually it is assumed a $eta = 0$ for the entrant) and facing a payoff function, or not entering and having payoff zero.

Both the cases in which either the innovator does not innovate and the enter does not enter are not interesting. The most interesting case is the one when the innovator innovates and the entrant enters. In this case, the mainstream view argues, it starts a Bertrand Game between the innovator and the entrant that brings instantly the profits for both to zero. If this happens, because the innovator pays a fixed cost for innovation, its profits would be smaller than zero; while for the entrant it makes no difference because it does not have fixed costs so its best strategy would be to always enter.

Solving this model with backward induction, the Nash equilibrium will be that the innovator never pays the fixed cost for innovation because the pure strategy of the entrant would be to always enter. So knowing that the Pure Strategy Nash Equilibrium would be the choice set not innovate, not enter.

Because of this result, the mainstream view argues that patents are vital to ensure innovation. Imposing patents, the innovator would always innovate because the patents ensure the recovery of the fixed cost of innovation preventing the entrant to enter the market and copying the innovator.

Sure this argumentation is elegant, yet it presents some logical fallacies. Let us see which one illustrates which is the alternative view.

3.1.2 The alternative view

This view presents the same setting then the mainstream one with a difference in the interpretation of the dynamics of the model. In fact, the first mistake of the model is to assume the game between the innovator and the entrant is static. In the moment in which the entrant enters the profits drop immediately to zero.

Here there is a hidden assumption that the entrant enters with the same supply capacity that the innovator has and the same productivity that the innovator has. These assumptions are practically incorrect and although elegant, they simplify too much the situation losing applicability in reality.

In fact, when a new firm enters a market, it does not have the same experience as the ones already present. The same Romer in a previous model of his [Romer, 1986], learning by doing is a key feature in production and productivity. In the Industrial Organization literature, this is called "the first mover advantage"[**?**]. Already with these counterarguments, it is impossible to conclude that in the instant moment in which the entrant enters, a Bertrand Competition will set off, preventing the innovator to have negative profits.

These alternative arguments make the necessity of patents way weaker. In fact, because the innovator does recover the innovation costs without the need for patents, these are a monopoly rent more than an incentive for innovating. Let us now try to formalize a bit more this idea.

3.1.3 Formalization alternative view

For simplicity let us assume again a two-firm two-stage game with an innovator and an entrant that can copy the innovation. Moreover, to simplify even more the setting, let us assume that the primary advantage that the inventor has is the so-called first mover advantage formalized in better use of the new technology. This has to be intended as a difference between the innovator and the entrant in the production function. Last but not least, it is assumed that the entrant incurs a fixed cost γ for shifting part of its capital to use the new technology. However, the entrant fixed cost is lower than the innovator fixed cost, $\gamma < \eta$

This setting implies that the innovator is more flexible in selecting the quantity it wants to produce; while the entrant has a constraint in this. This suggests that the right way to approach the setting is through Cournot's competition and not Bertrand one. Moreover, because the innovator has one period more to "discover" the technology, it can also pressure to not enter, triggering a Stackelberg game.

Hence, given the price function in the industry be $a - \sigma(q_1 + q_2)$ and the only costs are the fixed costs, respectively η for the innovator and γ for the entrant, it is possible to solve the model by backward induction.

The entrant's profit and the following maximization are:

$$\Pi_2 = (a - \sigma(q_1 + q_2)) \cdot q_2 - \gamma q_2 = \frac{a - \sigma q_1}{2\sigma} \tag{3.1}$$

Moving to the innovator's problem, its profits and the following maximization are:

$$\Pi_1 = (a - \sigma(q1 + q2(q_1)) \cdot q_1 - \eta q_1 * - \frac{a}{2\sigma} \tag{3.2}$$

Hence, plugging back q_1* in q_2, it is obtained the optimal quantity for the entrant that is $q_2* = \frac{a}{4\sigma}$. The response function of the innovator produces higher profits than the entrant's, the price is not given equal to marginal costs, so the innovator is having profits to recover the initial fixed cost.

3.1.4 Final Note

This would hold also in the case of 3 or more firms, and it would also show that the innovator has more power the more firms try to enter. The last important thing to notice is that, if we assume that an infinite number of firms can enter not all of them will enter. There will enter up to the one who does not have negative profits. In mathematical terms, when $\Pi_n < \eta$, the n^{th} firms will not enter. Due to the type of game, the n^th firm will be such that perfect competition in the industry will never set immediately. This will be of crucial importance when solving the general equilibrium.

Although the logic the alternative view shows seems to be more realistic, it still has room for improvement. What it is been trying to model and explain is why is not possible to immediately exclude the innovator from the market by copying its innovation. Hence, the innovator has the time and the market power to recover the initial cost of innovation. This makes the assumption for patents redundant. Although, in the mid/long run, it is given the case, and it happens quite often, that the innovator then disappears from the market because of imitation. How could this be modeled?

Like the classical model, the alternative model I presented, is missing a bit of dynamic. Again consider perfect, complete information, and the same setting as before. Let us now introduce the possibility for the innovator to become so small to be immediately excluded from the market. If the innovator knows that innovating in a particular sector, will not recover the innovation costs because bigger firms would exclude that after it enters, it will not innovate. However, if it knows it can recover the fixed costs and make a margin, it will enter.

As it is possible to see, this is just a small addendum to the logic before, but it does not change the outcome. Although, it opens interesting consideration regarding when it makes sense to use patent legislation. More on this in section 4. Now let us move to the model.

3.2 The model

Finally moving on to the model, it is worth remembering that this model will take inspiration from the Romer 1990 model [Romer, 1990], and it is in the end a modification of it. The differences between the two models will be highlighted during the discussion.

This model has as its ultimate aim the one of producing endogenous growth without assuming the existence of patents. To achieve such a goal, the model presents 3 sectors in the economy in a closed economy with population L=const.

The first one is the Research and Development sector (from now on R&D) which is the sector responsible for innovation in the economy. The firms in this sector only take into account in their profit maximization function the net present value of their future expected profits that every new innovation produces. The R&D firms sell them to the final output firms. All the innovations are a change of the first original good, so each innovation can be considered as a variation of one another. This is the first difference with the Romer 1990 model. In fact, that model presents just one good, and the R&D Firms through innovation produce different intermediate goods that improve the output.

The second sector is the final output firms are the ones in charge of producing the final good. As said before, in this model, every firm produces different varieties of the same good, where innovation represents the discovery of a new variety. Every firm produces n varieties according to how many innovations it has bought from the R&D firms. The final output firms only care about their profits.

The last sector is the household sector - which is infinitely lived and with constant members - buy from the final output sectors the different varieties of the good. The household agents only care to maximize their utility function which is the same for everybody. Hence, we can think of the sector through the representative agent.

From section 3.1 to section 3.5, it is described the behavior of the single sectors of the economy. From section 3.6 on, it is explained how the different components interact with each other and produce the general equilibrium. [1]

3.3 Final Output Firms

The production function for a single product: $Y_i = AL^{1-\alpha} \cdot X_i^{\alpha}$. So every final good firm has a cumulative production function: $\sum_i^N Y_i = AL^{1-\alpha} \cdot \sum_i^N X_i^{\alpha}$. The final products Y_i are different from each other, so their price would be equal to the monopolistic competition price. The profits for a final good firm for all the products it produces is: $\sum_i^N Y_i - wL_i - \sum_i^N P_i X_i$, where w is the wage rate; P_i is the price of the intermediate good; L_i is the labor input; X_i the intermediate input. These producers face perfectly competitive marginal profits, so taking the derivative w.r.t. X_i: $\frac{\delta Y_i}{\delta X_i} = A\alpha L_i^{1-\alpha} \cdot X_i^{\alpha-1}$ that brings to $X_i = L_i \cdot (\frac{A\alpha}{P_i})^{\frac{1}{1-\alpha}}$. Given this, the wage rate is equal to the marginal product of labor.

$$w = (1-\alpha) \cdot (\frac{Y_i}{L_i}) \tag{3.3}$$

This section follows the same steps as Romer 1990 with some small variations.

3.4 Research Firms

To create new goods, it is assumed that R&D firms produce innovations that can create new intermediate goods that are associated with a new final good. It is assumed that every R&D firm creates a new design different from what others produce.

R&D firms are modeled in a two-stage decision game. The first one regards whether entering or not the market and producing a new design. They do it when the net present value of their future expected profits is bigger or equal to their production costs that have to be paid before the invention. The second stage is the determination of the optimal price at which the R&D firms can sell the invention to the final good firms. To solve this game, let us proceed in a backward induction fashion.

3.5 Final good producers' game

To determine the optimal price of the innovation, it is necessary to solve the final good firms' decision game in buying it or not. Without the assumption of patents, once a final good firm buys a new design, it faces the possibility to be copied by other final output firms. However, this is not the case. First, it is assumed that copying has a cost, smaller than the cost of buying the innovation from the R&D firms, so $\eta > \gamma$, where η is the cost for buying from the R&D firms and γ the cost for copying. That

[1] Important to notice that the notation is mainly taken from the 6^{th} chapter of the Barro and Sala-i-Marin textbook "Economic Growth" [Barro and Sala-i Martin, 2004]

said, although it is less expensive to copy than to buy, the supposed incentive for all the firms to copy and enter the market creating a Bertrand equilibrium does not exist. In fact, supposing a firm decides to enter the market paying the cost, and then to start Bertrand war, the follower would have negative profits. Hence, it would not enter. Because of this reason, it is possible to exclude that any potential entry would start a Bertrand competition. However, it is still possible that the follower starts a Cournot game.

However, in this case, the follower would face a Stackelber equilibrium where the profits for the follower are $\pi_f = \frac{1}{8}(a-c)^2$. For the first mover advantege, the profits would be $\pi_i = \frac{1}{8}(a-c)^2$. When the followers are more than one, the profits of the follower tend to zero when the number of firms to infinity. Because $\gamma > 0$, again also in this case, the possibility of ending up in a perfect competition setup.

3.6 Optimal price for Research firms

Now the PV of the returns from the discovery of a new quality is: $V(t) = \int_t^{\infty} \phi_i(v) \cdot e^{-\bar{r}(t,v)\cdot(v-t)} dv$. Where $\pi_i(v)$ is the profit flow at date v and $\bar{r}(t,v)$ is the average interest rate between periods; *sigma* is a measure of the degree of the Cournot profits when $\sigma = 1$ is the monopoly case if $\sigma = \infty$ it would be the competitive case. Although, as argued before, the competitive case cannot verify, σ can take just oligopoly values. Assuming that both marginal and average costs are constant and normalize to one. So the profit flow is $\pi_i(v) = \frac{1}{\sigma}[P_i - 1] \cdot X_i(v)$, where $X_i(v)$ is the one found before. Therefore, maximising the profit function w.r.t. the price, it is obtained: $P_i(v) = \frac{1}{\sigma\alpha} > 1$. Hence, following the logic stated before, ω and α can only take values for which the reciprocal of their product is bigger than zero.

3.7 Free entry condition

The free entry condition does not change compared to the Romer model. Assuming entering the R&D market is free, the net present value of the innovation shown previously cannot be different from $V(t) = \eta$. If $V(t) \neq \eta$, it would either be no innovation, or there would be no holding equilibrium. The first case happens when $V(t) < \eta$ because if the net present value is lower than the cost of producing innovation, no one would incur the cost and innovate. On the other hand, when $V(t) > \eta$, there would be the case in which an infinite amount of agents would enter the R&D, making an equilibrium to hold impossible. Therefore, in the last instance, the only possible result is when the net PV is equal to the cost of creating an innovation.

Now, differentiating this condition with respect to time with this equation $V(t) = \int_t^{\infty} \phi_i(v) \cdot e^{-\bar{r}(t,v)\cdot(v-t)} dv$ stated in the previous section and considering the condition

$\bar{r}(t,\upsilon) \equiv [\frac{1}{\upsilon - t} \cdot \int_t^{\upsilon} r(\omega)d\omega$, it is obtained:

$$r(t) = \frac{\pi}{V(t)} + \frac{\dot{V}(t)}{V(t)} \tag{3.4}$$

This equation states the fact that investing in bonds is equivalent to inventing in R&D. Meaning that R&D innovation represents an asset in this economy. Moreover, because $\eta = const$, it is implied that $\dot{V}(t) = 0$, the previous equation can be rewritten as $r(t) = r = \frac{\pi}{\eta}$. So, substituting this into the profit maximization, the interest rate is equal to $r = \frac{L}{\eta} \cdot A^{\frac{1}{1-\alpha}} \cdot (\frac{1-\sigma\alpha}{\sigma\alpha} \cdot (\sigma\alpha)^{\frac{2}{1-\alpha}})$.

3.8 Households

Households maximize the following utility function:

$$U_i(t) = \int_0^{\infty} \frac{c_i^{1-\theta} - 1}{1-\theta} \cdot e^{-\rho t} dt \tag{3.5}$$

The households constraint is given by £=$d(asset)/dt = wL + r \cdot (asset) - C$, this gives the Euler Equation:

$$\frac{\dot{C}}{C} = \frac{1}{\theta} \cdot (r - \rho) \tag{3.6}$$

The biggest novelties in the model are the ones introduced in these sections. What will follow are the consequences of the different values of the innovation and hence their prices. However, it is worth continuing the exposition of the model to let the readers the feeling on how comparable are the models. Hence, in one last analysis, how endogenous growth without patents is possible.

3.9 General Equilibrium

This section, it is showed how the different sectors in the model interact with each other and how the general equilibrium takes place. For simplicity and math clarity, it is modeled in a way that at the moment in which the innovators start a new sector, there is already an oligopoly because of imitators. Moreover, it is just considered one entry cost, again for simplicity, there is no loss of generality in doing this.

Firstly, because the setting is a closed economy, the households' total assets are the same as the market value of the firms and because the cost of producing new innovation is constant, we can represent the change in assent in this way: $asset = \eta N$ and the change through time: $\frac{d(asset)}{dt} = \eta\dot{N}$. The wage rate is equation (3.1), and the interest rate, after some manipulation is $r = \frac{1}{\eta} \cdot (1 - \sigma\alpha) \cdot \alpha \cdot \frac{Y}{N}$.

Because the population L is constant, $\dot{C} = \frac{\dot{C}}{L}$. It follows that $Y = wL + r \cdot asset = \alpha^2 Y$. Now it is possible to rewrite the household budget constraint as:

$$\eta \dot{N} = Y - C - X \tag{3.7}$$

where the condition specified in section 3.1 are used. Substituting the interest rate in this last equation, it is possible to obtain the growth rate:

$$\zeta = \frac{1}{\phi} \cdot \left[\frac{L}{\eta} \cdot A^{\frac{1}{1-\alpha}} \cdot (\frac{1-\sigma\alpha}{\sigma\alpha}) \cdot \sigma\alpha^{\frac{2}{1-\alpha}} - \rho \right] \tag{3.8}$$

Through equation 3.5, $Y = A^{\frac{1}{1-\alpha}} \sigma\alpha^{\frac{2\alpha}{1-\alpha}} L\dot{N}$ and $X = A^{\frac{1}{1-\alpha}} \sigma\alpha \frac{2}{1-\alpha} L$, it is possible to write $C = Y - \eta\zeta\dot{N} - \dot{N}Z$ in this way:

$$C = \frac{\dot{N}}{\phi} [LA^{\frac{1}{1-\alpha}} (1-\sigma\alpha)\sigma\alpha^{\frac{2\alpha}{1-\alpha}} [\phi - \alpha(1-\phi) + \eta\rho] \tag{3.9}$$

And this, for L=cons, N, and C have the same growth rate. Hence, the model does not present any transitional dynamics.

3.10 Pareto Optimality

In this section, the Romer model [Romer, 1990] would demonstrate that the decentralized equilibrium brings a non-Pareto-optimal equilibrium which can be improved by the intervention of the social planner. Unfortunately, the variation I presented on Romer's model does not provide any further insides into the Social Planner's problem. Moreover, it does not solve the scale effect that the previous model has. However, this can be done by introducing increasing costs in the innovation, as suggested by Barro and Sala-i-Martin [Barro and Sala-i Martin, 2004]

Quickly summarizing Romer's paper, it is found that the decentralized equilibrium is not a Pareto optimal equilibrium. To assess this issue, it is possible to introduce the Social Planner figure, whose goal is to maximize the representative agent's utility. Proceeding with this, using the Social Planner budget constraint and the Hamiltonian expression to reformulate its problem, it is found that the decentralized equilibrium allocates fewer resources in the variety of goods compared to the social planner. Because of this, the Social Planner's interest rate is also higher than the decentralized one. To make the latter equilibrium look like the better one, it is possible to implement different policies, all three are subsidies. It is possible to do a subsidy to purchase a variety of goods, a subsidy for the Final products, or a subsidy to research.

3.11 Final Remarks

As previously said, in the model presented in this paper this issue is not tackled, so, it does not provide any further adding to the problem. To the final goal of the thesis, this can seem like a big problem. If the goal is to show that patents are unnecessary, why is not a problem having the need of subsiding the demand a problem?

The answer to this legitimate question has to be found in the form of the utility function of the representative agent. The particular utility function used in this model makes no difference between different goods. As reported in the beginning, the original Romer's model presented one final good that could be produced by different intermediate goods. Hence, the representative agent cares only about the total consumption. In this discussion, the different intermediate goods have been changed with different varieties of the same good. In this case, a different type of utility function for the representative agent could have been introduced to make her willing to differentiate between different products.

However, this would have made this discussion more difficult to follow and it would have missed the primary point. Secondly, it is just a matter of a different utility function. The primary goal of the discussion on the patents has been achieved, the presented model produces the same results as Romer's one. This has been done with a more accurate game theoretical analysis of the same situation that demonstrated how patents are not essential to ensure the incentive for firms to innovate.

4 Consequences of the model

In the previous section, it has been shown that patents are not crucial for economic growth. This is not the first time that this type of argument has been made in the history of economic thought. At the beginning of the millennium, Boldrin and Levin [Boldrin and Levine, 2002] wrote extensively about it. Moreover, also before them, many economic considerations have been made, let us think for example about Stigler already in 1956 was preaching against the necessity of patents as instruments to ensure innovators to innovate[Stigler, 1956].

The debate is driven by the simple fact that ideas are common goods, therefore is no way to exclude people from enjoying them. Due to their nature, "stealing" an idea would be possible as stealing air or stealing the use of sewer systems. Until now, the logic used assumed that innovation would have only happened if and only if the innovator knew she could recover the cost of innovation. Hence, showing patents are not a must for innovation does not solve the problem of creating incentives for innovation. What this work wants to let emerge is the redundancy of patents, especially for long periods of time like the ones that are now in place.

Although this was already clear [Nordhaus, 1969], the main questions remain. Is the patent system the best way to ensure a good incentive to produce innovation? As economists, when thinking about how to regulate public goods, the main objective should be the consumer and increasing consumer welfare. Theoretically, patents increase consumer welfare just as incentives for innovation but when they are proven to not do so they remain just monopoly rents. Regardless of ideology and political views, this should be considered and new alternatives to patents should be found. Even if this would add the degree of difficulty to decide on a sector-by-sector basis when patents are the best tool and when not.

The legislator has a difficult task to face, that is, a trade-off between a legal efficiency and the economic one. On one hand, having one legislation which takes in to account all the possibilities; on the other, the reduction of sunk costs and the maximization of total welfare. Of course, there is no clear cut, however, the debate around it is missing. One example that I think is emblematic is the legislation on copyrights. It implements a monopoly for artistic productions until 70 years after the dead of the author. Here, the incentives are disproportionate and they create distortions into the market.

The reader could maybe think that another example would be the pharmaceutical industries. Patents that can last for 16 to 20 years on drugs that save lives can be considered to much. However, here the discussion becomes trickier. In fact, the innovation costs that a pharmaceutical firm has are enormous. The main problem is not the creation of the drug per se but the trails that follows after. Here maybe, such a legislation could make sense. However, other forms of legislation can be thought to reduce the costs the firm has to pay. For example, the state or other institution could cover totally or partially. This would brings us to briefly mention which are the patents alternatives.

4.1 Alternatives to patents

4.1.1 Rewards system

One of the most discussed alternatives to the patent system is the rewards system, also called the prize system. The idea around this system is that the state, or any other institution, puts a price on the implementation of a certain idea. A simple example could be that the W.H.O. puts a price on the discovery of a cure for cancer. Once the price is awarded, whoever got it cannot patent the idea.

This system allows knowledge to flow more easily but it recognizes a premium to the innovators. In this sense, this premium should match the innovation costs. And with this, comes the negative side of this approach: which is the correct award for every innovation? On which basis it is possible to decide?

No institution can know beforehand with extreme precision how much will be the welfare impact of an innovation. Moreover, there is also a problem of asymmetry information. The institution that fixes the reward does not know which is which will be the cost to produce that innovation. Hence, the reward could be too high or too low. In this regard, patents are a market solution to the internalization of the public good problem. [sha, 2001]

4.1.2 Public production

Another possibility is to let the state be in charge of producing the innovation. An easy example is when the state finances university research. Indirectly, it is contributing to innovation. Using this method, the community contributes through taxes, so the public good problem is solved in the same way that sewer system[Wright, 1983]. In this sense, innovation would be implemented through research contracts.

However, the drawbacks of the model are somewhat similar to the ones discussed for the reward system. How can the public bureaucracy know which innovations are worth trying and which are not? How should it decide? The public system does not confront itself with the market, so it faces the possibility to be very inefficient. Someone could say that academic research overcome this problem but it is not entirely correct. The decision where the funds go is not entirely driven by market incentives and this can distort the allocation of resources.

4.1.3 Final note

The reality is that it does not exist one system that can be perfect for every occasion. Patents can be useful for out-of-the-box innovation and for products that does not impact too much the citizens' welfare. Although for others kind of innovations, they can produce distortions that do not make the more in need enjoy the positive sides of the innovation. However, this goes beyond the scope of this work, and further and more applied research it is needed to answer these questions. One interesting historical summary of this has been given by Petra Moser [Moser, 2013]

5 Conclusions

This paper has tryied to formalize in an innovative way the main arguments of an alternative view on the basis of the growth theory. It has been done following a neoclassical approach in the framework of the endogenous growth models. For this purpose, it has been chosen the Romer 1990 model [Romer, 1990] and it has been rewritten without the assumption of monopolistic competition in the R&D sector. In fact, patents have been advocated to be the best incentive possible to lead innovation.

The main contribution of the thesis is the following. To argue why patents are not necessary to achieve this goal, a game theory model has been used as a tool to show it. Firstly, it has been formalized the classical view. Secondly, I pointed out its inconsistency following the work of Boldrin and Levine [Boldrin and Levine, 2008a]. In the end, the alternative way has been formalized.

To give robustness to this line of thinking, it has tested its subgame-perfect Nash Equilibrium in the Romer 1990 model. It showed that this view is consistent also in a general equilibrium model with a continuous time framework.

With this, the thesis wanted to contribute to the endogenous growth literature by reopening a discussion about the role of intellectual property rights in the context of economic growth. Moreover, it wanted to show that another approach is theoretically possible and that it could imply an increase in consumers' welfare if implemented correctly. However, this has not been shown yet and further research should be done in this regard, bringing support to this theory or proving wrong its results.

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6 Appendix

6.1 Abstract ENG

With this thesis, it is tried to rethink in a theoretical fashion, if patents are a necessary policy for fostering innovation. Building on the work of Boldrin and Levin [Boldrin and Levine, 2002] [Boldrin and Levine, 2008a], the paper shows a modification of the Romer 1990 [Romer, 1990] in which the patents assumption is relaxed. The main change is how the R&D firms decide the price taking into account the fact that they have no protection on their innovations. It is demonstrated that no patents are needed because in no case a Bertrand competition ever takes place. The economic tools used to achieve this results are game theory and general equilibrium analysis. The thesis contributes to the literature of classical endogenous growth models with continuous time lifting the patents assumption.

6.2 Abstract DE

In dieser Abschussarbeit wird es versucht theoretisch zu zeigen, ob die Patente eine zwangläufig Politik, um Innovation zu fördern ist. Anhand Boldrin und Levins Recherche [Boldrin and Levine, 2002] [Boldrin and Levine, 2008a], den Traktat diskutiert eine Überarbeitung von Romer 1990 [Romer, 1990] in dem die Patentenannahme entfernt wird. Das wichtigste Veränderung ist wie die R&D Firmen beschließen das Preis, beim Einschließen der fehlende Schutz für ihre Innovationen. Es ist beweist, dass die Patente nicht notwendig sind, denn es stehen nicht die Umstände für die Bertrandwette. Spieltheorie und Allgemeines Gleichgewichtsmodell sind die angewendete Werkzeug der Wirtschaft, um diese Ergebnisse zu liefern. Schließend beiträgt diesen wissenschaftlichen Arbeit zu den Literatur über klassische Endogene Wachstumstmodelle mit Continuous Time bei der Abschaffen von Patentenannahme.