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SUBSTITUTABILITY BETWEEN DRUGS, INNOVATION AND GROWTH IN THE PHARMACEUTICAL INDUSTRY*

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Abstract: This paper establishes a relationship between the elasticity of demand for pharmaceutical intermediates and the growth rate for these intermediates variety. We build a model that contains two sectors, one final good sector producing treatments, and one intermediate goods sector producing a differentiated input used in the final treatment. The effects on the medicaments varieties' growth rate of the introduction of a fiscal instrument over pharmaceutical producers' profits are discussed. When the fiscal instrument is a tax over intermediate firms' profits, R&D by firms in the pharmaceutical goods sector results in positive growth provided there is enough substitutability among intermediates assured by a patent system. Otherwise, a subsidy over pharmaceutical firms' profits should be considered to generate positive growth of innovation in medicaments.

Keywords: Monopolistic Competition, Pharmaceutical Industry, Fiscal Policy

1. INTRODUCTION

The increasing demand for healthcare has been at the center of an intense and unceasing discussion by political responsible especially in richer economies. Healthcare seems to be a voluminous and continuously growing sector representing in 2010 an average of 9.5% of gross domestic product (GDP) in OECD countries (OECD, 2012). The accelerated growth in the demand for healthcare contributes to an increase of public expenditures, requiring adjustments in production costs where its upstream industries such as pharmaceuticals can be decisive.

While the increase in government expenditures in healthcare converts any decision concerning this sector into a central public policy debate, healthcare is simultaneously a very vigorous and dynamic sector where major innovations take place, and that involves a

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significant share of countries' labor force (Bloom *et al.*, 2011). At the upstream of healthcare demand there is an array of intensive research intermediate activities such as pharmaceuticals, biotechnology activities and medical equipment, among others who fight to discover new products that can help them keep their production pace.

On a global scale, the pharmaceutical sector presents the highest R&D spending, a fundamental driver of companies' growth. This takes place within a market structure of an industry that is moderately concentrated and where innovation is indispensable for economic survival. Pharmaceutical firms must engage in expensive research with uncertain results in order to find new drugs, but after approval these drugs are protected by intellectual property rights that help firms to recover from the high costs incurred during the research and development process. The pharmaceutical firms operate in a monopolistically competitive market where each one produces and sells similar but not identical products, each facing a downward-sloping demand curve. These products are differentiated answering to consumers (patients advised by medical doctors) that have varied tastes and preferences.

In this paper we try to address the importance of innovation in medicaments from the pharmaceutical industry as an answer to the increasing demand for variety in healthcare. Healthcare is regarded as a final good production sector, where every patient requires a specific treatment, i.e., has a preference for variety. This singularity of health demand stimulates the innovative activity of the pharmaceutical sector by the expectation of a later monopoly power gain obtained by developing a molecule that serves a unique health condition. Investment in R&D assures a continuous growth in product variety and hence has a direct effect on consumers' welfare.

We construct a simple model relating pharmaceutical drugs innovation to current and future features of healthcare demand where we find that the monopolistic competition market structure under which these pharmaceutical firms operate is able to induce innovation provided the perfect incentives are activated. Our model follows Dixit and Stiglitz (1977) in the sense that our consumers have a love for variety in what concerns treatments. There is a monopolistically competitive intermediate pharmaceutical sector where new medicaments are being discovered and that enter the production function of medical treatments. Growth is determined by the rate of innovation in the pharmaceutical sector. In order to generate positive growth, pharmaceutical firms must operate in a market structure where the demand is elastic indicating that the higher the substitutability between intermediate products the greater the conditions for a successful growth of the entire sector.

This paper aims to offer a contribution to the literature by relating the growth of the variety in medicaments with the elasticity of the pharmaceutical market demand while at the same time relating it with government tax policy concerning the stimulus to innovation. With the aim of keeping the pace of innovation in the medicaments' industry the government can alternate its policy between charging taxes over pharmaceutical firms' profits if there is a reinforcement of the patent system, and choosing to subsidize these firms' research if it chooses not to strengthen the patent system.

The rest of the paper is organized as follows. Section 2 discusses the related literature on pharmaceutical industry market. Section 3 presents the pharmaceutical R&D based growth model discussing equilibrium and welfare. Section 4 evaluates the relationship between demand elasticity for pharmaceutical intermediates, overall growth and the tax policy over pharmaceuticals through a numerical simulation. Section 5 concludes.

2. RELATED LITERATURE

This section surveys the literature on pharmaceutical industry which analyses attributes of this sector that are considered important determinants of its firms' innovation pace, such as market concentration, market size, research costs, and public policies chosen to foster this sector global R&D.

Boldrin and Levine (2008) characterize the pharmaceutical sector as an example of a Schumpeterian industry, recalling that according to Schumpeter (1942) technological innovations are more likely to be initiated by large rather than small firms in a dynamically competitive environment. They conclude that the circumstance that these firms operate under intellectual monopoly generates lack of competition that solely benefits the pharmaceutical firms, harming consumers and the progress of society due to rent-seeking and redundancy in research on pharmaceuticals. The market power enjoyed by pharmaceutical firms is one of the most highlighted traits of this sector that has experienced mergers and acquisitions, mainly during the late 1980s and 1990s, contributing to the increase in industry concentration without consequently creating positive long term value (Danzon *et al.*, 2007). Comanor and Scherer (2013) blame these mergers for the disappearance of firms that conducted frontline innovations, causing a decrease in entire industry R&D productivity. The pharmaceutical industry has suffered an increase in R&D costs due to a productivity shock that is latent in the decrease of the number of new molecular entities approved between 1970 and 2000. The pharmaceutical firms tend to explain the merge wave as a response to the loss of productivity but the authors sustain the reverse: the mergers and acquisitions have partially destroyed the R&D in this industry. Despite this merging trend, Gambardella *et al.* (2001) analyzing the European pharmaceutical industry and comparing it with other countries find that the degree of concentration in this industry has been consistently low. Along with these authors the pharmaceutical industry is populated by very different firms, starting by multinationals which correspond to global firms with their property spread across different countries, moving on to smaller firms that are specialized in sales and are less R&D intensive, and recently there is the expansion of biotechnology firms. They refer, however, that Europe is lagging behind in the pharmaceutical sector because it has a less competitive market for this sector as a whole. According to Malerba and Orsenigo (2007) the pharmaceutical sector is a case where competition is similar to a model of patent races. The pharmaceutical industry has an overall low level of concentration that tends to be maintained at a global scale, but this feature is not replicated at a single therapeutic area where concentration is typically higher. The market is dominated by incumbents that have warranted revenues in old products and new entrants usually cannot expect to displace the incumbents and have difficulties in creating their own protected niche. In line with Danzon and Keuffel (2013) the appropriate economic model of the pharmaceutical industry is either monopolistic competition or oligopoly with product differentiation, indicating that there is some concentration in the production of drugs.

Market size for these pharmaceutical companies has also been the subject of recent research. Kremer (2002) defines developing countries' pharmaceutical market demand as insignificant, a situation that generates uncertainty in a sector that operates with high fixed R&D costs and low marginal costs of production leading to low research directed to cure diseases common to those countries such as tuberculosis or malaria. Acemoglu and Linn (2004) focus on the relevancy of potential market size and the ability of the pharmaceutical sector to innovate. They build an empirical model where controlling for U.S. demographic trends they find a positive relationship between the increase in potential market size for a drug category and the increase in the number of new drugs in that same category. Market size increases profits and technological change is then directed towards these more

profitable areas. Market size conditioned by health insurance has been considered by Garber *et al.* (2006) questioning if it could exert an excessive incentive to innovation. The authors report that the insurance plans exaggerate the under-consumption of pharmaceutical products that are offered under monopoly, causing static and dynamic inefficiency. This causes the existence of unnecessary incentives for pharmaceutical firms' innovation that should be prevented by inserting limits on patents lifetime and on monopoly pricing. Cerda (2007) analyses the creation of new medicaments in the US pharmaceutical sector during the second half of the 20th century and relates it to the uninterrupted increase in this market size generated by an upsurge in population. The increase in population was endogenously determined by the decrease in mortality rate caused by new drugs and is simultaneously an important incentive for pharmaceuticals when discovering and developing new drugs. Dubois *et al.* (2011) establish an empirical relationship between market size and innovation in the pharmaceutical industry. By making potential market size dependent on three different types of factors, namely: demographic and socio-economic change; the degree of competition among pharmaceutical companies as well as their strategies in innovation, cost cuts and customers' disputes; and, public policies, they found positive significant elasticities of innovation to the potential market size, underlining a value of 25.2% for their preferred specification. Desmet and Parente (2010), although not focusing on the pharmaceutical industry, had already concluded that a larger market, by increasing the price elasticity of demand, would simplify the adoption of more productive technologies because larger markets increase competition and the substitution between goods hence increasing the price elasticity of demand. This results in a decrease in mark-ups, obliging firms to augment their sales to break-even but simultaneously forcing them to a dimension that facilitates technology adoption by being able to pay for R&D fixed costs. In a recent study, de Mello-Sampayo and de Sousa-Vale (2012) establish an empirical relationship between the increase in health care expenditures per capita and the share of health expenditures on medicaments estimating that this type of expenditure contributes significantly to the increase in total health expenditure per capita with an elasticity of 5.6%. Such conclusion points to an induced demand for drugs from general health care demand.

Research costs are another important concern among studies dedicated to pharmaceutical industry analysis. As the increase in competition in the market for medicaments decreases the overall costs for society, it may, at the same time, decrease the incentives to innovate by eroding pharmaceutical companies' profitability and their capability to invest in research. Research and development in the pharmaceutical industry is an expensive activity and therefore, to be encouraged requires barriers to entry that guarantee that the incumbents are able to cover the costs incurred while developing new molecules. DiMasi *et al.* (2003) estimate the cost of research and development for 68 new drugs from a survey of 10 pharmaceutical firms. They find that these costs have been growing substantially and tend to change with the degree of R&D uncertainty and with the stage of the product development life-cycle. Their conclusions tend to support the introduction of patents over medicaments as a way to guarantee pharmaceutical companies' profitability. Toole (2012) focusing on data from the biomedical research empirically investigates the contribution of public basic research to the early stage of pharmaceutical innovation, namely drug discovery. His estimations point to a lagged increase of 1.8% in the number of new molecular entities after a 1% increase in the stock of public basic research. He concludes that the flux of foundation knowledge from academic research to the industry may reduce pharmaceutical firms own investments in R&D and therefore reduce innovation costs.

A different strand of the literature has been discussing the impact and effectiveness of tax incentives to stimulate innovation in the pharmaceutical industry although without arriving to an unambiguous conclusion. Because R&D has characteristics of a public good there exists

the fear that the rate of new innovations may come to a halt and therefore it is defended that there is room for fiscal stimulus. Hall and Reenen (2000) investigating OECD countries find a unit-elastic response of R&D to tax credits. They consider that the use of the tax system is preferable to a system where the government finances or even conducts the R&D program directly because firms tend to use the credits to fund the R&D projects that have the highest private rate of return while the government will tend to choose the projects with the highest spillover gap. This choice by the government has a tendency to fail due to uncertainty in knowledge delivery and to the presence of vested interests that define its priorities. The effectiveness of tax incentives to R&D in Spain has been the subject of an empirical analysis in Corchuelo and Martínez-Ros (2009). They identify two groups of firms, large firms and small and medium enterprises concluding that on average tax policy fosters technological effort but the former firms are more likely to use tax incentives on innovation while the later report barriers to using those policy instruments facilities. They also conclude that this policy is only effective to large firms and in high-technological intensity sectors. Busom *et al.* (2012) go one step further by confronting tax incentives to subsidies as policy instruments to stimulate R&D and comparing them with the protection of intellectual property rights. They too divide firms in two groups, small and medium size enterprises and large firms and conclude that, provided they have protection of their intellectual property, small and medium size enterprises are more likely to use tax incentives than subsidies while large firms show ambiguous effects. Rao (2011) analyses the effect of fiscal incentives on R&D focusing on the health sector and in particular on the pharmaceutical firms' activity and concludes that the introduction of a global health tax credit in the United States would unlikely result in significantly more or better global health R&D. Instead, direct funding to companies or partnerships should be considered as a way to reach better results. Yin (2008) also studies the impact of political incentives, namely, the relationship between the tax incentives introduced by the Orphan Drug Act (ODA) and the rate of pharmaceutical R&D in terms of new clinical trials. His results indicate that ODA had a significant impact on rare diseases drug development with a 69% increase in the annual flow of new clinical trials for drugs for these rare diseases. The author stands that tax credits can stimulate stocks and flows of pharmaceutical R&D but that the effectiveness of this policy depends on revenue potential of the specific markets. Therefore, small markets require larger tax credits or even additional policies.

The present paper stands in between these different bulks of the literature by connecting market size features of the pharmaceutical industry, namely its eminent demand increase in developed countries as a result of a growing expenditure in healthcare, with supply side facets of this market such as the introduction of taxes and subsidies to R&D and its effects on the growth rate of innovation in medicaments along with welfare.

3. THE MODEL

In this section an endogenous growth model with expanding variety is considered for the healthcare sector. This model is based on Grossman and Helpman (1991, chapter 3) and assumes three types of economic agents: households that demand for treatments, treatment producers and producers of pharmaceutical medicaments. We begin by analyzing the behavior of each group of agents separately, and then we analyze equilibrium, and finally welfare.

3.1. Households

Consider a representative consumer that maximizes the following utility function from medical care consumption,

$$U = \int_0^{\infty} e^{-\rho t}\, U(c_t) dt, \tag{1}$$

where the instantaneous utility function is a continuous and differentiable function with partial derivatives $U' > 0$ and $U'' < 0$. This concave utility function is presented under a simple logarithmic specification: $U(c_t) = ln\, c_t$. Consumption is a composite variable defined as follows,

$$c_t = \left(\int_0^{n_t} m_{tj}^{\alpha}\, dj\right)^{1/\alpha}\ ,\ 0 < \alpha < 1. \tag{2}$$

In Equation (2), m_{tj} corresponds to consumption of each medicament *j* at time *t*. Households have available to consume an infinite set of medicaments in the interval $[0; n_t]$. Note also that α corresponds to the weight each medicament has in aggregate consumption.

The maximization of Equation (1) allows determining the growth rate of consumption of healthcare

$$\frac{\dot{c}}{c} = r - \rho, \tag{3}$$

where *r* is the real interest rate and ρ corresponds to the rate of intertemporal preference. The final treatment is assumed to be the numeraire.

In this economy there are two sectors of production, a treatment sector perfectly competitive, and a pharmaceutical sector where there exists monopolistic competition.

3.2. Healthcare producers

Healthcare producers produce a final treatment good T_t employing human capital (L_T)[1] and a set of pharmaceutical intermediate goods m_j. The production function that represents their technology is:

$$T_t = L_T^{1-\alpha} \int_0^n m_{tj}^{\alpha} dj. \tag{4}$$

In Equation (4) technological progress is represented by an increase in the medicaments variety, *n*. Symmetry implies $\int_0^N m_{tj}^{\alpha} dj = n m^{\alpha}$; then Equation (4) becomes:

$$T_t = L_T^{1-\alpha} n^{1-\alpha} (nm)^{\alpha} = L_T^{1-\alpha} n m^{\alpha}. \tag{5}$$

Taking, as referred, the healthcare good as the numeraire, profits in this sector are given by:

$$\pi_t = L_T^{1-\alpha} \int_0^n m_{tj}^{\alpha}\, dj - w_T L_T - \int_0^n p_j m_{tj} dj. \tag{6}$$

In Equation (6), revenues correspond to the generated income (the outcome of the productive process), and costs are the sum of human capital costs and the cost of acquisition of medicaments by the final producer of treatments.

[1] Human capital is usually identified with the characteristics of the worker that contribute to his productivity and therefore is more appropriate in dealing with sectors that are devoted to innovation.

The first order conditions for the final goods producers give us the factor demand functions (i.e., the rental price of pharmaceutical capital and the wage rate):

$$p_j = \alpha L_T^{1-\alpha} m^{\alpha-1}, \tag{7}$$

and

$$w_T = (1-\alpha) L_T^{-\alpha} n m^{\alpha}. \tag{8}$$

3.3. Pharmaceutical sector

At the upstream of the production of healthcare there is a pharmaceutical sector in which each firm owns a patent over a medicament m_j and uses such patent to produce the medicament. In this sector, human capital is the only factor of production. To invent a new medicament m_j a firm has to employ L_M units of human capital; thus, the production function of pharmaceutical intermediates is

$$\dot{n} = \frac{n}{a} L_M, \tag{9}$$

with *n* the number of pharmaceutical varieties available on the economy, $1/a$ the productivity of innovation and L_M human capital used in production of medicaments.
Profits of active intermediate firms are given by

$$\pi_j = p_j m_j - w_M m_j. \tag{10}$$

The maximization of (10) subject to (7) gives the following first order conditions, with solutions for quantity and prices of intermediate goods:

$$m_j = \lambda, \tag{11}$$

$$p_j = \frac{w_M}{\alpha}, \tag{12}$$

and

$$m_j = \left(\frac{w_M}{\alpha^2 L_T^{1-\alpha}} \right)^{\frac{1}{\alpha-1}}. \tag{13}$$

Replacing (12) and (13) on the profits Equation (10) we obtain

$$\pi_j = \alpha^{\frac{1+\alpha}{1-\alpha}} L_T w_M^{\frac{\alpha}{\alpha-1}} (1-\alpha). \tag{14}$$

3.4. Equilibrium factor prices

Assuming the economy locates on the steady-state, we are able to characterize equilibrium factor prices. In the steady state, we verify that $\gamma = \frac{\dot{n}}{n}$, $\frac{\dot{T}}{T} = \frac{\dot{c}}{c} = \frac{\dot{w}}{w}$ and $\gamma > 0$. We consider a constant human capital workforce ($L_T = L_0$), allocated between the two sectors of production, treatments and medicaments:

$$L = L_T + L_M.$$

Agents are indifferent between working in either sector, but in steady-state the proportion of the workforce that belongs to each sector is time-invariant.

Assume $\pi_j = \pi$ and $m_j = m$, i.e., the symmetry assumption. Substituting (13) in Equation (5), we obtain

$$T_t = L_T n \alpha^{\frac{2\alpha}{1-\alpha}} w_M^{\frac{\alpha}{\alpha-1}} \tag{15}$$

Log-differentiating this expression we calculate the available treatments' growth rate as

$$\frac{\dot{T}}{T} = \frac{\dot{n}}{n} + \left(\frac{\alpha}{\alpha-1}\right)\frac{\dot{w}}{w}. \tag{16}$$

Because agents reveal indifference between working in one or in the other sector, the wage paid by treatment firms and by pharmaceutical firms must be identical. Equating (8) and (13), we obtain the human capital market equilibrium wage for this economy:

$$w = (1-\alpha)^{1-\alpha} n^{1-\alpha} \alpha^{2\alpha}. \tag{17}$$

There is free-entry in the medicaments' sector. This implies a positive rate of innovation:

$$\int_0^\infty e^{-rt}(1-\tau)\,\pi_j dt = \frac{wa}{n}, \tag{18}$$

where *r* is the interest rate and τ is a tax on pharmaceutical firms' profits. [2] The interest rate must be constant at the steady-state, and therefore Equation (18) can be rewritten as

$$\frac{(1-\tau)\pi_j}{r+\alpha\gamma} = \frac{wa}{n}. \tag{19}$$

Now, using Equations (3), (9), (14) and (17), equation (19) simplifies to

$$\gamma = \frac{\alpha(1-\tau)L/a - \rho}{1+\alpha(1-\tau)}. \tag{20}$$

From Equation (20) it is possible to analyze which are the main determinants of pharmaceutical innovation growth in the steady state. We directly observe that an increased human capital and a higher productivity of innovation are beneficial in terms of innovation growth. On the contrary, an increased rate of intertemporal preference lowers the rate of innovation. Relatively to the impact of the tax rate over the rate of innovation, we can compute the following derivative: $\frac{\partial\gamma}{\partial\tau} = \frac{\alpha(\rho - L/a)}{[1+\alpha(1-\tau)]^2}$. This derivative indicates that the rate of innovation in the pharmaceutical sector grows with the tax over profits as long as the rate of intertemporal preference is above the productivity of innovation times the amount of available human capital. However, as one will regard in the next section, the maximization of utility excludes the possibility of $\rho > L/a$ being a feasible condition, and therefore an increase on the taxes over profits will imply a decline in the rate of innovation.

3.5. Welfare

We know that $\alpha\gamma + \frac{(1-\alpha)T}{w_T} = L$, and assuming that $c = T$ (because there is no investment in this economy), we have the following steady state consumption level of healthcare,

[2] We choose to introduce taxes over profits and we will center our later discussion on how taxes over intermediate firms' profits can determine growth and welfare.

$$c = \frac{L+a\rho}{(1-\alpha)(1+\alpha(1-\tau))} w. \quad (21)$$

Using Equations (1), (20) and (21) we obtain the long term level of utility:

$$U = \frac{1}{\rho}\left[\log\left(\frac{L+a\rho}{(1-\alpha)(1+\alpha(1-\tau))}\right) + \log w_0\right] + \frac{(1-\alpha)[\alpha(1-\tau)L/a-\rho]}{\rho^2[1+\alpha(1-\tau)]} \quad (22)$$

From Equation (22) it is straightforward to calculate the impact of the tax on utility

$$\frac{dU}{d\tau} = \frac{\alpha}{\rho^2[1+\alpha(1-\tau)]^2}[\alpha\rho(2-\tau) - (1-\alpha)L/a] \quad (23)$$

This implies an expression for τ given by

$$\tau = 2 - \frac{(1-\alpha)L/a}{\alpha\rho} \quad (24)$$

Equation (20) is valid only for $\gamma > 0$ so the optimal τ has to imply a positive growth rate. We find:

$$\gamma(\tau) > 0 \Leftrightarrow \frac{L}{a} > \frac{\rho}{1-\alpha} \quad (25)$$

Note that, for $\tau > 0$, we verify

$$\frac{L}{a} < 2\alpha\rho/(1-\alpha) \quad (26)$$

Combining Equations (25) and (26) we know that, for$\alpha > 1/2$, we verify $\tau > 0$ and $\gamma > 0$, otherwise we have $\tau < 0$ (a subsidy) so that $\gamma > 0$. Being α the elasticity of substitution between the intermediate varieties, there is a relationship between α and ε, the elasticity of demand, where $\varepsilon = 1/(1-\alpha)$.

With positive taxes over profits the pharmaceutical firm has to operate under elastic demand ($\varepsilon > 2$) to assure a positive growth of innovation in pharmaceutical medicaments and to simultaneously not damage welfare. This implies that if the government wants to tax pharmaceutical firms' profits and maintain the path of varieties growth then the medicaments produced by each firm must be sufficiently differentiated from the medicaments produced by its competitors. Therefore, the protection of intellectual property rights ought to be maintained in order to maintain the product differentiation that assures firms' profits, while at the same time this system has to be flexible enough to assure that through time pharmaceutical medicaments become close to perfect substitutes. If the demand for different medicaments is not sufficiently elastic ($\varepsilon < 2$), the alternative to obtain positive growth of medicaments innovation and without causing a welfare loss is for the government to subsidize pharmaceutical firms' profits.

In the monopolistically competitive environment where pharmaceutical firms operate, if the increase in the number of pharmaceutical varieties is an aim, there must be incentives for pharmaceuticals to produce differentiated goods. These incentives should come in the form of a patent system that guarantees exclusivity of the single product sold by each pharmaceutical firm but that assures that with time the products tend to become more and more close substitutes, that is to say that the patent must have a limited lifetime. Choosing to support a time-limited patent system, the government will be able to charge taxes over

pharmaceutical firms' profits. Alternatively, these incentives can come in the form of subsidies to production when there is not enough substitutability between medicaments produced by pharmaceutical firms.

4. SIMULATIONS RESULTS

In this section we perform simulations of growth rate and utility. The data in the present simulation analysis consists of pharmaceutical industry in the United States between 2000 and 2010. Figures 1 and 2 provide a sensitivity analysis of the growth rates values, Equation (20), with respect to the parameters of the model: τ and ε.[3] The simulations confirm the results of the discussion presented in Section 3.5.

Figure 1 shows a sensitivity analysis of the growth rate, Equation (20), for positive values of τ therefore, for an economy in which the government is charging taxes over profits, and for $\varepsilon > 2$ as discussed in section 3.5. It is shown that higher levels of taxes decrease the pharmaceuticals' R&D growth rate and that γ rises when demand is more elastic. Figure 1 also reveals that γ is more sensitive to ε than to τ.

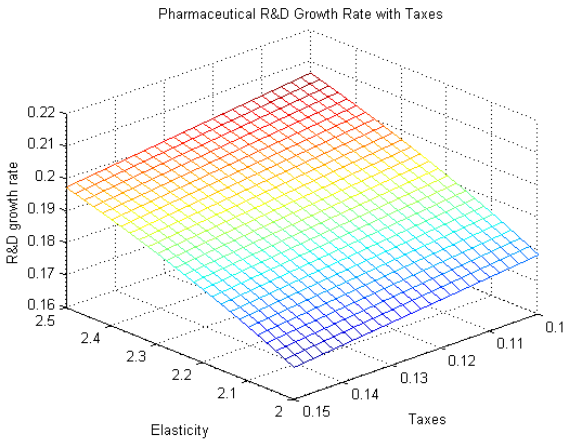

Figure 1: $\boldsymbol{\rho = 0.037; L = 17008; a = 259; 2 < \varepsilon < 2.5}$

Figure 2 reveals the sensitivity analysis of the growth rate value, Equation (20), with respect to the parameters of the model, s [4] and ε, therefore for an economy that is subsidizing innovation costs (a negative τ) and for $1 < \varepsilon < 2$ as showed in section 3.5. With subsidies, γ, the growth rate of new medicaments rises when ε is high and s moves towards its maximum level (a higher subsidy). Figure 2 reveals that for this elasticity range, the innovation growth rate is not very sensitive to the policy measure. The analysis of Figure 2 also makes possible to notice that when the elasticity of demand is just slightly above the unit-elasticity the innovation growth rate will be just faintly above zero, independently of the level of the subsidy that is being granted. Comparing Figure 1 to Figure 2 it is clear how important is the elasticity of demand for the level of innovation growth rate that can be achieved when compared to the importance of the variation in the level of the tax policy.

[3] As referred earlier in this paper, this parameter represents demand elasticity and is related to α being defined as ε=1/(1-α).
[4] This parameter is introduced to represent a subsidy (negative values for τ) in order to distinguish the analysis for a tax and for a subsidy.

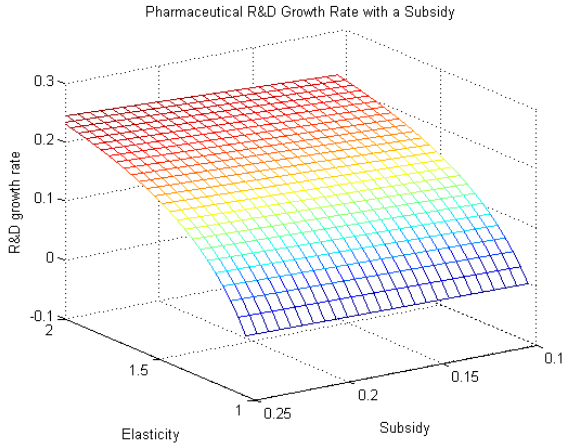

Figure 2: $\boldsymbol{\rho = 0.037; L = 17008; a = 259; 1 < \varepsilon < 2}$

Figures 3-6 reveal the sensitivity analysis of the utility level, Equation (22), for different values of the parameters of the model, τ, s and ε. Figures 3-4 represent the sensitivity analysis of welfare when a tax rate is being charged over pharmaceutical firms' profits and for $\varepsilon > 2$, while figures 5-6 represent the sensitivity analysis of welfare when the pharmaceutical firms are receiving a subsidy and for an elasticity range of $1 < \varepsilon < 2$. [5]

Figure 3 respects to the variation in the level of utility when $\varepsilon > 2$ and for increasing tax rates. The results described for the growth rate of innovation, Figure 1, are confirmed with the utility analysis. It is possible to raise taxes and simultaneously obtain higher although decreasing levels of welfare provided there is a high elasticity of demand. The joint evaluation of these two figures also shows that welfare is more sensitive to variations in the tax levels when compared to innovation growth rates.

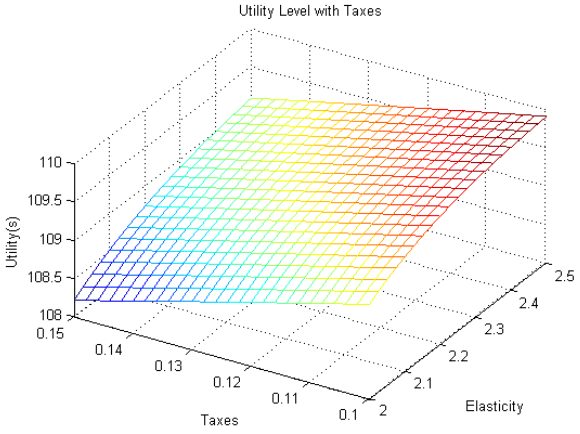

Figure 3: $\boldsymbol{\rho = 0.037; L = 17008; a = 259; 2 < \varepsilon < 2.5}$

The sensitivity analysis of welfare with respect to τ and γ is displayed in Figure 4. The utility level increases when the growth rate of medicaments, γ, is high and τ moves towards its minimum level and is considerably more sensitive to the growth rate of innovation than to changes in tax levels.

[5] Note that the minimum value for this parameter is related to the minimum value for α.

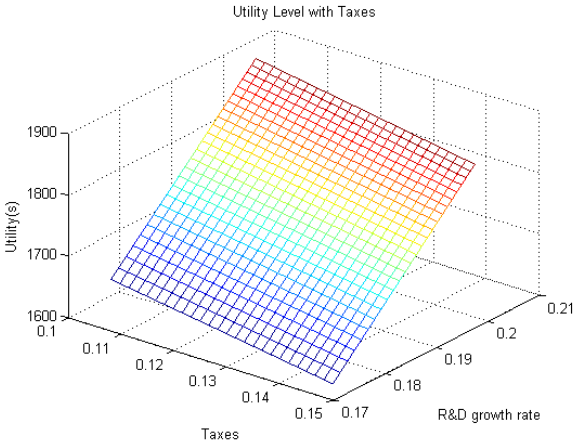

Figure 4: $\boldsymbol{\rho = 0.037; L = 17008; a = 259; 2 < \varepsilon < 2.5}$

Comparing Figures 3-4 we note that welfare does not depend too strongly on the tax rate, but it depends on elasticity. Jointly, the figures reveal that for high levels of elasticity ($\varepsilon > 2$), welfare rises with the innovation rate under any value of the tax rate charged over profits. Figure 5 represents variations in the long term level of utility against the parameters of the model, ε and s (a subsidy). The range of variation of elasticity is between 1 and 2, indicating that $\alpha < 1/2$ as concluded from the analysis of Equation (26). As reported in respect to innovation growth rate from the analysis of Figure 2, changes in welfare are more sensitive to changes in elasticity values than to changes in the tax policy. Nevertheless, the long term level of utility is significantly more sensitive to changes in the level of the subsidy in comparison to the sensitivity of the innovation growth rate, Figure 2. Utility rises as the elasticity increases but the effects over long run utility are decreasing indicating that when a subsidy is being granted there is some satiation of consumers in what refers to variety. Relating the effects of the two alternative tax policies over utility and controlling for different levels of the elasticity of demand, Figures 3 and 5, we note that the long run level of utility is always higher in the presence of a subsidy when compared to taxes and that this result is verified even for the lower levels of elasticity that where considered for the sensitivity analysis of the former tax policy.

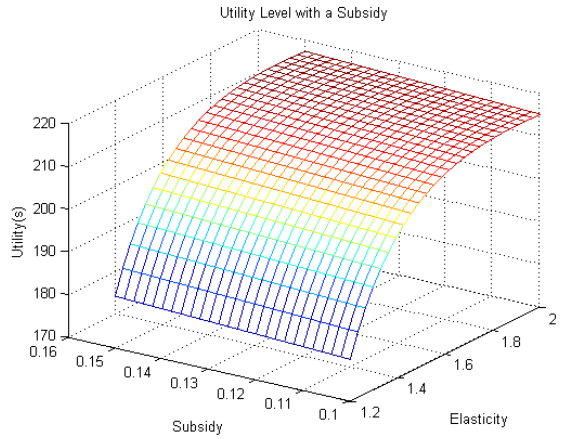

Figure 5: $\boldsymbol{\rho = 0.037; L = 17008; a = 259; 1 < \varepsilon < 2}$

Figure 6 relates rises in welfare to increases in the level of the subsidy, s, and in the innovation growth rate,γ. The figure reveals that the welfare level is very sensitive to the value of the innovation growth rate but it is not very sensitive to the level of the subsidy. The

appraisal of Figure 4 and Figure 6 reveals that it is possible to reach higher levels of welfare when there is a subsidy to innovation costs than under a tax over pharmaceutical firms' profits, but the results on the innovation growth rate show that this rate starts from smaller values and is more variable when a subsidy is being granted than when a tax rate is being charged. Additionally, we also notice that welfare is more sensitive to changes in the level of taxes than to changes in the levels of the subsidies.

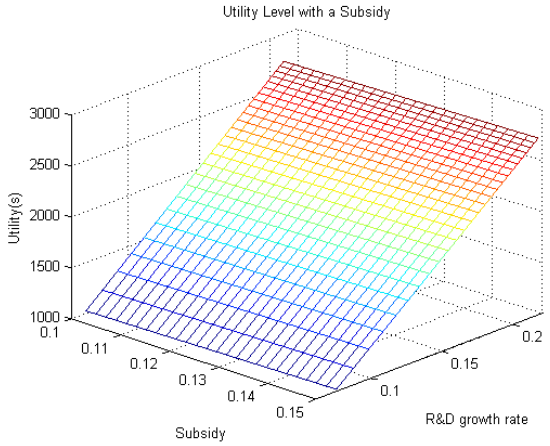

Figure 6: $\boldsymbol{\rho = 0.037; L = 17008; a = 259; 1 < \varepsilon < 2}$

Our simulation results confirm our previous analytical results. The elasticity of demand is a determinant feature of the level of innovation growth rate for pharmaceuticals. Higher levels of the growth rate and welfare are possible even in the presence of tax rates over profits, provided this demand elasticity is also high.

5. CONCLUSION

In this paper we discuss how the market size for pharmaceuticals' new medicaments can be an important feature of their performance in terms of the innovation growth rate on medicaments. The market size is being represented by the elasticity of demand for pharmaceuticals' new medicaments. This analysis has shown that if the pharmaceutical firms have the proper incentive to innovate they will increase their new medicaments growth rate and consequently expand welfare.

In our model, we introduce a government that charges a tax over pharmaceutical firms' profits and reveal that if the elasticity of demand for new medicaments is above 2 it is possible to tax pharmaceutical firms' profits and maintain positive values for their innovation growth rate and therefore increase economy's welfare. Otherwise, for values of the elasticity under 2 it is possible to obtain positive values for the innovation growth rate of new medicaments if the pharmaceutical firms are granted with a subsidy.

We have provided an empirical application, based on United States data, to support these results. The results are not very sensitive to changes in the values of the tax policy, especially in the presence of a subsidy, and show a significant response of the growth rate of innovation and welfare to variations in the level of the elasticity of demand.

The policy implication is that to improve innovation in the pharmaceutical industry it is important to consider one of two alternatives, either a patent system that reinforces the pharmaceuticals firms wish to innovate and therefore guarantees the diversity that is required by the healthcare sector while taxes are charged over pharmaceutical firms profits, or a

system based in granting subsidies to innovation and that does not require a high degree of substitutability of medicaments where the supply of new medicaments to the healthcare sector will arise at a smaller pace. Confronting the costs and benefits of either one of these two policies should be the object of further research.

REFERENCES

Acemoglu, D. and Linn, J., 2004. Market size in innovation: Theory and evidence from the pharmaceutical industry. *Quarterly Journal of Economics*, 119(3), pp.1049-1090.

Bloom, D.E., Boersch-Supan, A., McGee, P. and Seike, A., 2011. Population aging: Facts, challenges, and responses. *PGDA Working Paper*, 71.

Boldrin, M. and Levine, D. K., 2008. *Against intellectual monopoly*. Cambridge: Cambridge University Press.

Busom, I., Corchuelo, M. B. and Martínez-Ros, E., 2012. Tax incentives or subsidies for R&D? *UNU-Merit Working Papers*, 2012-56.

Cerda, R., 2007. Endogenous innovations in the pharmaceutical industry. *Journal of Evolutionary Economics*, 17(4), pp.473-515.

Comanor, W. S. and Scherer, F. M., 2013. Mergers and innovation in the pharmaceutical industry. *Journal of Health Economics*, 32(1), pp.106-113.

Corchuelo, M. B. and Martínez-Ros, E., 2009. The effects of fiscal incentives for R&D in Spain. *Technical Report,* 09-23, Universidad Carlos III de Madrid.

Danzon, P.M., Epstein, A. and Nicholson, S., 2007. Mergers and acquisitions in the pharmaceutical and biotech industries. *Managerial and Decision Economics*, 28(4-5), pp.307-328.

Danzon, P.M. and Keuffel, E.L., 2013. *Regulation of the pharmaceutical-biotechnology industry, in economic regulation and its reform: What have we learned?* NBER/ University of Chicago Press, Chicago.

de Mello-Sampayo, F. and de Sousa-Vale, S., 2012. Financing health care expenditure in the OECD countries: Evidence from a heterogeneous, cross-sectionally dependent panel. *ISEG School of Economics and Management Working Paper,* WP34/2012/DE,

Desmet, K. and Parente, S. L., 2010. Bigger is better: Market size, demand elasticity, and innovation. *International Economic Review*, 51(2), pp.319-333.

Di Masi, J.A., Hansen, R.W. and Grabowski, H.G., 2003. The price of innovation: new estimates of drug development costs. *Journal of Health Economics*. 22, pp.151-185.

Dixit, A.K. and Stiglitz, J. E.,1977. Monopolistic competition and optimum product diversity. *The American Economic Review*, 67(3), pp.297-308.

Dubois, P., de Mouzon, O., Scott-Morton, F., and Seabright, P., 2011. Market size and pharmaceutical innovation. [online] Available at: <http://idei.fr/doc/wp/2011/dmss.pdf> [Accessed 12 June 2013].

Gambardella, A., Orsenigo, L. and Pammolli, F., 2001. *Global competitiveness in pharmaceuticals: A European perspective.* Enterprise papers-European Commission, Brussels.

Garber, A.M., Jones, C.I., and Romer, P.M., 2006. Insurance and incentives for medical innovation, *NBER Working Papers Series*, 12080.

Grossman, G.M. and Helpman, E., 1991. *Innovation and growth in the global economy*. Cambridge, MA: Massachusetts Institute of Technology.

Hall, B. and Reenen, J.V., 2000. How effective are fiscal incentives for R&D? A review of the evidence. *Research Policy*, 29(4-5), pp.449-469.

Kremer, M., 2002. Pharmaceuticals and the developing world. *Journal of Economic Perspectives*, 16(4), pp.67-90.

Malerba, F. and Orsenigo, L., 2007. Innovation and market structure in the dynamics of the pharmaceutical industry and biotechnology: Towards a history-friendly model. *Industrial and Corporate Change*, 11(4), pp.667-703.

OECD, 2012. *Health at a glance: Europe 2012*. Paris: OECD Publishing.

Rao, A., 2011. *Can a R&D tax credit expand investment in product development for global health?* Memo, Center for Global Health R&D Policy Assessment.

Schumpeter, J., 1942. *Capitalism, socialism, and democracy*, 5th, 1994 ed, London: Routledge.

Toole, A.A., 2012. The impact of public basic research on industrial innovation: Evidence from the pharmaceutical industry. *Research Policy*, 41(1), pp.1-12.

Yin, W., 2008. Market incentives and pharmaceutical innovation. *Journal of Health Economics*, 27(4), pp.1060-1077.

APPENDIX

The simulations relate to the growth rate obtained in Equation (20) and to the utility level obtained in Equation (22). These simulations where performed using data from the United States for the period 2000-2010. The values of the parameters, as well as the ranges used in the simulations of growth rates and the utility level, were drawn from the Organization for Economic Cooperation and Development (OECD database) and can be seen in Table 1. The parameters from the equations of the growth rate and utility are defined as:

α: The parameter of elasticity of substitution between any two medicaments, ε, being $\varepsilon = \frac{1}{(1-\alpha)} > 1$, $0 < \alpha < 1$.

ρ: The discount rate is proxied by the United States "long-term government interest rate", from OECD database, for the period 2000-2010.

τ: The tax rate is proxied by the United States "taxes on income and profits" from the OECD database, for the period 2000-2010.

s: The data on subsidies to innovation costs where not available, therefore the range of variation for this variable was picked arbitrarily.

L: Labor force in the healthcare sector is proxied by United States "total labor force", from

OECD database, for the period 2000-2010 × the average in percentage of "employment in the health and social sectors as a share of total civilian employment" for the United States from the OECD Annual Labor Force Statistics for the period 2003-2008.

a: The parameter a is proxied by "business enterprise R&D expenditures in pharmaceuticals at constant prices and PPPs" from the OECD database, for the year 2000 / "Full-time equivalent researchers in pharmaceuticals" from the OECD database, for the year 2000.

Table 1: Parameter Values

	Mean	Maximum	Minimum
α	0.5	0.99	0.01
ρ	0.037	0.06	0.032
τ	0.13	0.15	0.10
s	0.15	0.25	0.10
L	18,028	19,402	17,975
a	259	-	-