

## Substitutability Between Drugs, Innovation, and Fiscal Policy in the Pharmaceutical Industry\*

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A theoretical model is developed in order to examine and explain the growth and welfare effects of fiscal policies in the pharmaceutical industry. When the fiscal instrument is a tax over pharmaceutical firms' profits, R&D by firms in the pharmaceutical sector results in growth if there is a generic market. Otherwise, a subsidy over pharmaceutical firms' profits should be considered to generate innovation in medicines. In terms of policy implications, our empirical results suggest that stimulating generic competition in the pharmaceutical sector is a main instrument to contain costs and promote welfare.

*Key Words:* Pharmaceutical Industry; Generic Market; Monopolistic Competition; Fiscal Policy.

*JEL Classification Numbers:* C63, H25, L65, O31.

### 1. INTRODUCTION

The healthcare sector has been growing over the years and in 2010 accounted for an average of 9.5% of gross domestic product (GDP) in OECD countries (OECD, 2012). Pharmaceutical expenditures are one of the major factors behind the growing expenditures in healthcare services, and stimulating generic competition is seen as one of the main instruments to contain costs. The price divergence between branded and generic pharma-

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ceutical goods is an important aspect of the public's growing concern over rising healthcare costs.

Healthcare is a dynamic sector where innovations take place, and that involves a significant share of countries' labor force (Bloom, Boersch-Supan, McGee and Seike, 2011). At the upstream of healthcare demand there is an array of intensive research intermediate activities such as pharmaceutical, biotechnology activities, and medical equipment. The pharmaceutical sector shows high research and development (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 following approval these are protected by intellectual property rights that help firms to recover the high costs incurred during the research and development process. The role of patents and market size in innovation has been emphasized in endogenous technological change models, where profit incentives are the engine of technological progress (Acemoglu and Linn, 2004, Aghion and Howitt, 1992, Ashraf and Mohabbat, 2010, Barro, 2013, Grossman and Helpman, 1991, Romer, 1990).

This paper relates the growth of the variety in medicines with the elasticity of substitution among them. In generic market, there is a high degree of substitutability among medicines, while in the branded medicines market the elasticity of substitution between any two medicines is very low. With the aim of keeping the pace of innovation in the pharmaceutical industry the government can alternate its fiscal policy between charging taxes over pharmaceutical firms' profits if there is a generic market, and choosing to subsidize pharmaceutical firms' research if there is a branded market.

With the aim of empirically testing the theoretical model, we use data from the pharmaceutical sector in the United States for the period between 2000 and 2010. In the empirical analysis we find a strong relationship between the pharmaceutical generic market and the growth rate of innovation when a tax rate is charged over pharmaceutical profits. If there is a branded market, the government should subsidize pharmaceutical firms in order to keep the pace of innovation and promote welfare. In terms of policy implications, our results suggest that to promote welfare, governments should support innovation rather than raise taxes. However, pressure to contain costs may lead a government to tax pharmaceutical firms' profits. This fiscal policy will enhance economic growth and promote welfare only in a generic medicines market framework. Therefore, patents' lifetimes should be flexible enough to assure generic competition in the pharmaceutical sector.

The rest of the paper is organized as follows. Section 2 discusses the related literature on the pharmaceutical industry. Section 3 presents the

pharmaceutical R&D based growth model and discusses the effects of the fiscal policy on equilibrium and welfare. Section 4 presents an empirical application of the theoretical model. Section 5 concludes.

## 2. RELATED LITERATURE

This section surveys the literature on the determinants of pharmaceutical firms' innovation pace, such as market concentration, market size, research costs, and fiscal policies chosen to foster the pharmaceutical sector's R&D.

Boldrin and Levine (2008) characterize the pharmaceutical sector as an example of a schumpeterian industry. According to Schumpeter (1942) technological innovations are more likely to be initiated by large firms than small firms in a dynamically competitive environment. They conclude that these firms operate under intellectual monopoly that benefits only the pharmaceutical firms, harming consumers and the progress of society due to rent-seeking and redundancy of research in the pharmaceutical sector. The market power of the pharmaceutical firms is one of the most highlighted traits of this sector, which 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, Epstein and Nicholson, 2007). Comanor and Scherer (2013) blame these mergers for the disappearance of firms that conducted frontline innovations, causing a decrease in the entire industry R&D's productivity. Despite this merging trend, Gambardella, Orsenigo and Pammolli (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. The pharmaceutical industry includes very different firms, from R&D intensive multinationals to small firms that are specialized in sales, and recently there is the expansion of biotechnology firms. According to Malerba and Orsenigo (2007), the pharmaceutical sector is a case where competition is similar to a model of patent races. 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. According to 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 the pharmaceutical sector has been the subject of recent research. Acemoglu and Linn (2004) focus on the importance of potential market size and the ability of the pharmaceutical sector to innovate. Their empirical model finds 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 toward these more profitable areas. Garber, Jones and Romer (2006) show that insurance plans reinforce the underconsumption of pharmaceutical products that are offered under monopoly, causing static and dynamic inefficiency. This causes the existence of unnecessary incentives, for pharmaceutical firms' innovation, which should be prevented by inserting limits on patents' lifetimes and on monopoly pricing. Cerda (2007) analyzes the creation of new drugs in the US pharmaceutical sector during the second half of the 20<sup>th</sup> century and relates it to the uninterrupted increase in this market size generated by a surge 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 pharmaceutical firms for developing new ones. Dubois, de Mouzony, Scott-Morton and Seabright (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.

Research and development (R&D) 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 agents. DiMasi, Hansen and Grabowski (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 support the introduction of patents over medicines as a way to guarantee pharmaceutical companies' profitability. Kremer (2002) concludes that developing countries' pharmaceutical market demand generates uncertainty in a sector that operates with high fixed R&D costs, and low marginal costs of production which leads to low research directed to cure diseases common to those countries such as tuberculosis or malaria. Toole (2012) empirically investigates the contribution of public research to the early stage of pharmaceutical innovation. He concludes that the flux of knowledge from academic research to the industry may reduce pharmaceutical firms' own investments in R&D and therefore reduce innovation costs.

Another strand of literature focuses on the impact and effectiveness of tax incentives to stimulate innovation in the pharmaceutical industry. R&D has characteristics of a public good, which justifies fiscal policies to stimulate innovation. Hall and Reenen (2000) find a unit-elastic response of R&D

to tax credits in OECD countries. They consider that the use of the tax system is preferable to a system in which the government finances or even conducts the R&D program directly. Corchuelo and Martínez-Ros (2009) conclude that in Spain tax incentives to R&D are effective only to large firms and those in high-technological intensity sectors. Busom, Corchuelo and Martínez-Ros (2012) go one step further by comparing tax incentives to subsidies as policy instruments to stimulate R&D and comparing them with the protection of intellectual property rights. They conclude that, provided there is protection of intellectual property, small and medium size firms are more likely to use tax incentives than subsidies to stimulate innovation, while large firms show ambiguous effects. Rao (2011) analyzes the effect of fiscal incentives on R&D, and concludes that the introduction of a global health tax credit in the United States would unlikely result in significantly more or better overall health R&D. 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. The author maintains 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 relates market characteristics of the pharmaceutical industry, branded and generic pharmaceutical market, with the introduction of taxes and subsidies to R&D and their effects on the growth rate of innovation in medicines and welfare.

### 3. THE MODEL

The theoretical model follows Grossman and Helpman (1991, Chapter 3), but we go one step further analyzing the degree of substitutability among medicines in the pharmaceutical sector, and how optimal fiscal policy can enhance economic growth and promote welfare depending on the degree of substitutability among medicines. We assume three types of economic agents: patients, healthcare providers, and producers of pharmaceutical drugs. We start by analyzing the behavior of each group of agents separately, and then examine the effect of fiscal policy on the equilibrium and welfare.

#### 3.1. Patients

Consider a representative patient who maximizes the following utility function from healthcare consumption,

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

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,

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

In Equation (2),  $m_{tj}$  corresponds to consumption of each medicine  $j$  at time  $t$  and  $\alpha$  to the weight each medicine has in aggregate consumption. Patients love variety concerning medicines (Dixit and Stiglitz, 1977). The total set of medicines in the economy is given by the interval  $[0, n_t]$ . There is constant elasticity of substitution between any two medicines,  $\varepsilon$ , such that  $\varepsilon = \frac{1}{1-\alpha}$ .

The maximization of (1) allows us to determine the growth rate of consumption of healthcare,

$$\frac{\dot{c}}{c} = r - \rho, \quad (3)$$

where  $r$  is the real interest rate and  $\rho$  corresponds to the rate of intertemporal preference.

In this economy there are two sectors of production, a healthcare service sector perfectly competitive, and a pharmaceutical sector that operates under monopolistic competition.

### 3.2. Healthcare Providers

Healthcare providers provide a treatment service,  $T_t$ , that employs human capital,  $L_T^1$ , and a set of medicines,  $m_j$ . The treatment service is provided as follows:

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

In Equation (4) technological progress is represented by an increase in the variety of medicines,  $n$ . Assuming the symmetry condition,  $\int_0^n m_{tj}^{\alpha} dj = nm^{\alpha}$ , Equation (4) becomes:

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

<sup>1</sup>Human capital is usually identified with the characteristics of the worker who contributes to his productivity, and therefore is more appropriate in dealing with sectors that are devoted to innovation.

Taking the treatment service,  $T_t$ , 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), total revenue corresponds to the generated income, and total cost is the sum of human capital costs, and the cost of medication.

From the maximization of profits the price of medicine  $j$  is:

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

and the wage rate is:

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

**3.3. Pharmaceutical Sector**

At the upstream end of the healthcare providers there is the pharmaceutical sector where each firm owns a patent over a medicine,  $m_j$ , to produce it. To create a new medicine a firm has to employ  $L_M$  units of human capital, such as:

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

with  $n$  the number of medicines available in the economy, and  $1/a$  the productivity of innovation.

From the maximization of profits the price of medicine  $j$  is:

$$p_j = \frac{w_M}{\alpha}, \tag{10}$$

and the quantity produced is:

$$m_j = \left( \frac{w_M}{\alpha^2 L_T^{1-\alpha}} \right)^{\frac{1}{\alpha-1}}. \tag{11}$$

The pharmaceutical firm's profits become:

$$\Pi_j = \alpha^{\frac{1+\alpha}{1-\alpha}} L_T w_M^{\frac{\alpha}{\alpha-1}} (1 - \alpha). \tag{12}$$

**3.4. Equilibrium Factor Prices**

At the steady state, the innovation growth rate,  $g$ , is constant, such that  $g = \frac{\dot{n}}{n}$ . Assuming the symmetry condition  $\Pi_j = \Pi$ , and  $m_j = m$ , and

substituting (11) in Equation (5), we obtain:

$$T_t = L_T n \alpha^{\frac{2\alpha}{1-\alpha}} w_M^{\frac{\alpha}{\alpha-1}}. \quad (13)$$

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

$$\frac{\dot{T}}{T} = \frac{\dot{n}}{n} + \left( \frac{\alpha}{\alpha-1} \right) \frac{\dot{w}}{w}. \quad (14)$$

Agents are indifferent between working in one or the other sector, and thus the wages paid by healthcare providers and by pharmaceutical firms are identical. Equating Equation (8) to Equation (11), we obtain the human capital market equilibrium wage rate:

$$w = (1-\alpha)^{1-\alpha} n^{1-\alpha} \alpha^{2\alpha}. \quad (15)$$

There exists a tax rate over pharmaceutical firms' profits,  $\tau$ , that is constant and known by all agents. This tax is transferred to consumers in the form of a lump-sum transfer. Free-entry conditions in the pharmaceutical sector impose a positive rate of innovation:

$$\int_0^\infty e^{-rt} (1-\tau) \Pi_j dt = \frac{wa}{n}, \quad (16)$$

where  $r$  is the interest rate that is constant at the steady state, and therefore Equation (16) can be rewritten as

$$\frac{(1-\tau) \Pi_j}{r + \alpha g} = \frac{wa}{n}. \quad (17)$$

Now, using Equations (3), (9), (12), and (15), equation (17) simplifies to

$$g = \frac{\alpha(1-\tau)L/a - \rho}{1 + \alpha(1-\tau)}. \quad (18)$$

It follows from equation (18) and the previous assumptions on the parameters the following comparative statics:

$$\frac{\partial g}{\partial L} > 0, \text{ and } \frac{\partial g}{\partial(1/a)} > 0,$$

the greater the human capital (i.e. the higher  $L$ ) and the greater the productivity of innovation (i.e. the higher  $1/a$ ), the higher the growth

rate. Conversely, an increased rate of intertemporal preference lowers the rate of innovation.

$$\frac{\partial g}{\partial \rho} < 0.$$

This result stems from the fact that a higher time preference increases the firm's opportunity cost of not immediately innovating. With regard to the tax rate, we obtain that the greater the tax rate (i.e. the higher  $\tau$ ), the lower the growth rate, i.e.:

$$\frac{\partial g}{\partial \tau} < 0.$$

The more elastic is the substitution between any two medicines, the higher is the growth rate, i.e.:

$$\frac{\partial g}{\partial \varepsilon} > 0.$$

The intuition behind this result is that the more the medicines become substitutes, the greater the incentive for the pharmaceutical firm to innovate in order to have the new, and exclusive medicine's monopoly.

### 3.5. Welfare Analysis

Finally, we analyze the effects on welfare of the fiscal policy under analysis. Welfare is equal to the utility level that the representative agent can get with the fiscal policy. Profits are not incorporated into welfare because profits from the pharmaceutical sector are zero due to the free-entry condition. Profits of the firms are strictly positive and it is assumed that all of the firm's income is redistributed to the agents via wage payments and lump-sum transfer of tax revenue.

Rearranging Equation (18), we know that  $L = ag + (1 - \alpha)T/w_T$ . At the steady state, and assuming that all treatments are provided to patients,  $T = c$ , we have the following steady-state consumption level of healthcare,

$$c = \frac{L + a\rho}{(1 - \alpha)(1 + \alpha(1 - \tau))} w. \tag{19}$$

Using Equations (1), (18), and (19), we obtain the long-term utility level:

$$U = \frac{1}{\rho} \left[ \log \left( \frac{L + a\rho}{(1 - \alpha)(1 + \alpha(1 - \tau))} \right) + \log w_0 \right] + \frac{(1 - \alpha) [\alpha(1 - \tau) L/a - \rho]}{\rho^2 [1 + \alpha(1 - \tau)]}, \tag{20}$$

and calculate the effect of the tax rate on welfare:

$$\frac{dU}{d\tau} = \frac{\alpha}{\rho^2 [1 + \alpha(1 - \tau)]^2} [\alpha\rho(2 - \tau) - (1 - \alpha)L/a]. \tag{21}$$

Thus,  $\tau$  is given by:

$$\tau = 2 - \frac{(1 - \alpha)L/a}{\alpha\rho}. \quad (22)$$

The tax rate,  $\tau$ , as given by equation (22), is optimal only if it implies  $g > 0$ . Substituting equation (22) into equation (18) we obtain:

$$g(\tau) > 0 \iff \frac{L}{a} > \frac{\rho}{1 - \alpha}. \quad (23)$$

For  $\tau > 0$ , we verify that:

$$L/a < 2\alpha\rho/(1 - \alpha). \quad (24)$$

This result shows that if the government taxes pharmaceutical firms' profits, the equilibrium growth rate is positive only if  $\varepsilon > 2$ . The tax rate on pharmaceutical firms' profits may promote economic growth when there is a high degree of substitutability among medicines. Thus, the development of a competitive generic medicines market in which medicines are close substitutes is compatible with a tax rate that enhances growth and thus promotes welfare. If we are in the presence of a branded market, i.e. the medicines do not have close substitutes,  $\varepsilon < 2$ , the alternative to obtain positive growth is for the government to subsidize pharmaceutical firms, and the subsidy in this model is given through a tax credit, such as  $s = -\tau$ .

#### 4. EMPIRICAL APPLICATION

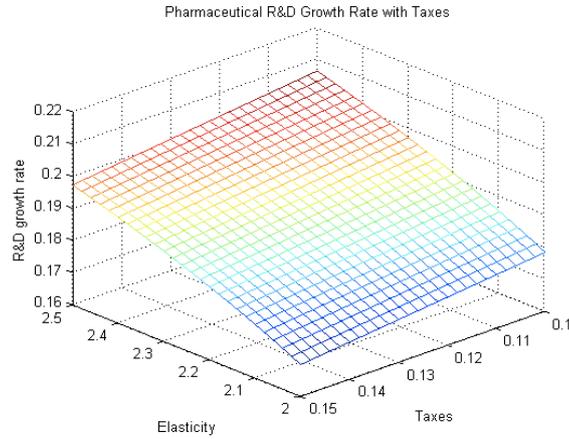
The data in the present empirical application pertain to pharmaceutical sector in the United States between 2000 and 2010<sup>2</sup>. Figures 1 and 2 provide a sensitivity analysis of the growth rate under the fiscal policies for different degrees of substitutability among medicines. Figures 3-6 show the welfare analysis under the fiscal policies for different degrees of substitutability among medicines.

Figure 1 shows the variation of the growth rate, Equation (20), for values of  $\tau$ , and for  $\varepsilon > 2$ . It is shown that it is possible to raise taxes and obtain the high levels of innovation when there exists high substitutability among medicines. Thus, this corroborates the model's analytical result that a competitive generic medicines market is compatible with a fiscal policy that enhances economic growth.

Figure 2 shows the sensitivity analysis of the growth rate, Equation (18), for values of  $s$ , and for  $\varepsilon < 2$ . With subsidies,  $g$ , the growth rate of new

<sup>2</sup>See Appendix for data sources and description.

FIG. 1.



$$\rho = 0.037, L = 17008, a = 259, 2 < \varepsilon < 2.5$$

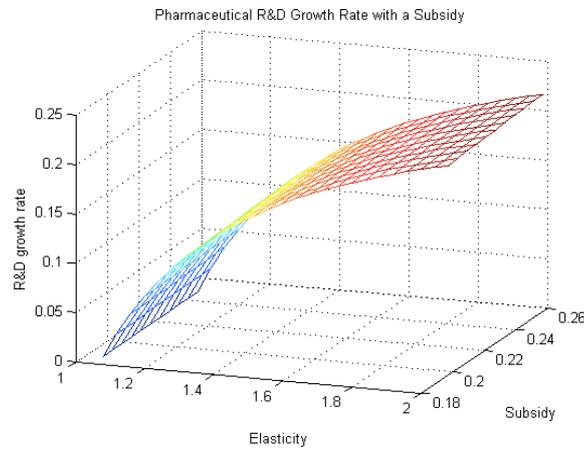
medicines rises when  $\varepsilon$  is close to 2 and the subsidy is high. When there is a low degree of substitutability between any two medicines, the innovation growth rate is not very sensitive to the fiscal policy. Comparing Figure 1 with Figure 2, it is clear how important the development of a competitive generic medicines market is for achieving higher levels of innovation in the pharmaceutical sector.

Figures 3-6 show the sensitivity analysis of the utility level, Equation (20), for different values of the parameters of the model,  $\tau$ ,  $s$ , and  $\varepsilon$ . Figures 3 and 4 present the welfare analysis when a tax is being charged over pharmaceutical firms' profits and there is a high degree of substitutability among medicines, i.e.  $\varepsilon > 2$ . Figures 5 and 6 present the welfare analysis when the pharmaceutical firms are receiving a subsidy and there is a low degree of substitutability among medicines, i.e.  $\varepsilon < 2$ .

Figure 3 shows the variation in the level of utility when the profits are taxed and for  $\varepsilon > 2$ . Although the welfare decreases with taxes, it is possible to raise taxes and obtain the highest level of welfare when there exists high substitutability among medicines.

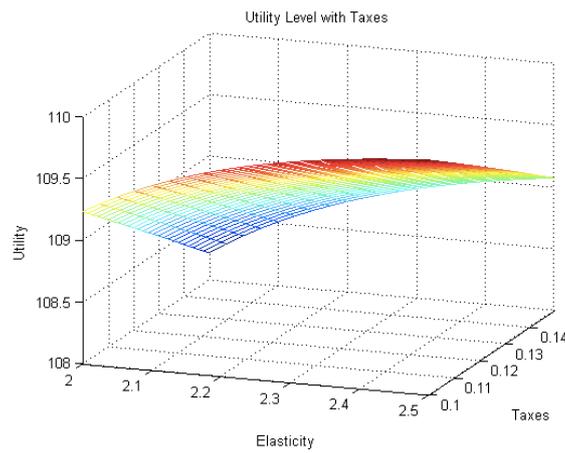
The sensitivity analysis of welfare with respect to  $\tau$  and  $g$  is shown in Figure 4. The utility level increases when the growth rate of medicines,  $g$ , is high and  $\tau$  moves toward its minimum level. Welfare is considerably more sensitive to the growth rate of innovation than to changes in the tax rate. The policy implication of this result is that to promote welfare, a government should promote innovation rather than raise taxes.

FIG. 2.



$$\rho = 0.037, L = 17008, a = 259, 1 < \varepsilon < 2$$

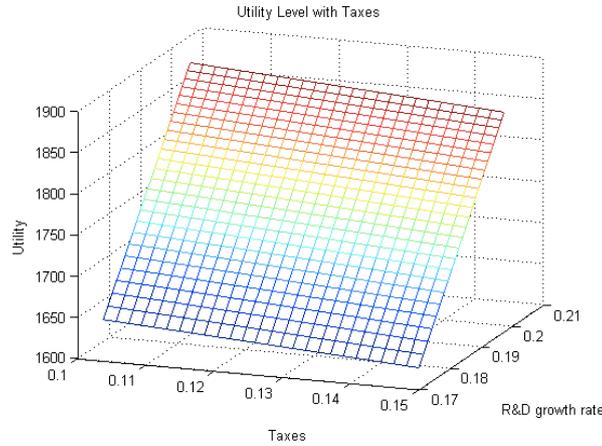
FIG. 3.



$$\rho = 0.037, L = 17008, a = 259, 2 < \varepsilon < 2.5$$

Comparing Figures 3 and 4 we conclude that welfare depends more on the degree of substitutability among medicines than on the tax rate. These figures show that for high levels of elasticity of substitution, welfare rises with the innovation rate under any value of the tax rate charged over

FIG. 4.



$$\rho = 0.037, L = 17008, a = 259, 2 < \varepsilon < 2.5$$

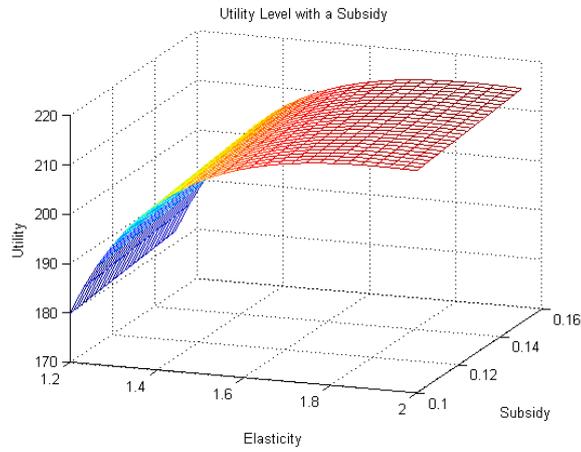
profits. Again, we conclude that to promote welfare, a government should stimulate the development of a competitive generic medicines market.

Figure 5 presents variations in welfare with respect to  $\varepsilon$  and  $s$ , when there is a low degree of substitutability among medicines. Changes in welfare are more sensitive to changes in elasticity values than to changes in the subsidy. Nevertheless, Comparing Figure 2 with Figure 4, the long-term level of utility is significantly more sensitive to changes in the level of the subsidy than is the innovation growth rate. Comparing the effects of the two alternative fiscal policies on welfare when controlling for different levels of substitutability, as shown in Figures 3 and 5, we note that the long-run level of utility is higher under a subsidy than under taxes.

The sensitivity analysis of welfare with respect to  $s$  and  $g$  is shown in Figure 6. Welfare is very sensitive to the innovation growth rate but it is not very sensitive to the subsidy. Figures 4 and 6 show that to promote welfare, it is better to give a subsidy to innovation rather than to tax pharmaceutical firms' profits. Additionally, we observe that welfare is more sensitive to changes in the level of taxes than to changes in the levels of the subsidies.

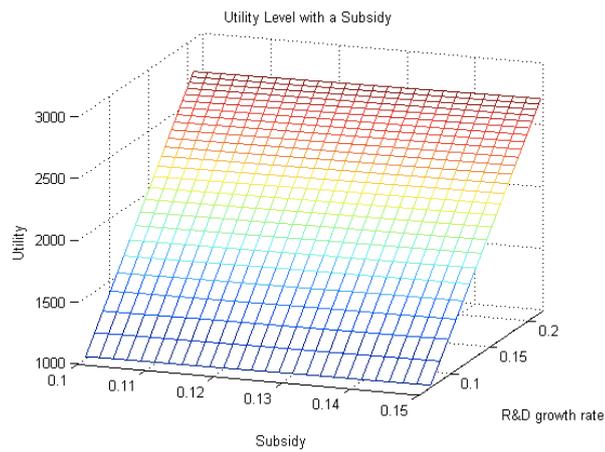
Our simulation results confirm the model's analytical results. The degree of substitutability among medicines is determinant for the innovation growth rate in the pharmaceutical sector. Higher levels of the growth rate and welfare are possible even in the presence of tax rates over profits, provided there is a high degree of substitutability among medicines. Our empirical results suggest that stimulating generic competition in the

**FIG. 5.**



$$\rho = 0.037, L = 17008, a = 259, 1 < \varepsilon < 2$$

**FIG. 6.**



$$\rho = 0.037, L = 17008, a = 259, 1 < \varepsilon < 2$$

United States pharmaceutical sector is a main instrument to contain costs and promote welfare.

## 5. CONCLUSION

This paper has discussed the implications of different types of pharmaceutical markets, generic versus branded markets, for optimal fiscal policies.

The analysis has been performed in the context of an endogenous growth model with technological change. The government can attribute a subsidy to research in a pharmaceutical branded market or tax profits in a generic market. The comparison of the different fiscal policies with respect to their impact on the innovation growth rate and welfare of the economy in steady state depends on the degree of substitutability among medicines. The innovation rate is lower if instead of taxing pharmaceutical firms' profits in a generic medicines market, a government chooses to subsidize pharmaceutical firms in a branded market. It is also shown that welfare increases with the innovation rate under any fiscal policy. However, the positive effect of the innovation rate on welfare is more pronounced under subsidy than under taxes on profits.

In terms of policy implication, our findings suggest that to promote welfare, a government should cultivate innovation rather than raise taxes. However, pressure to contain costs may lead the government to tax pharmaceutical firms' profits. This fiscal policy will enhance economic growth and promote welfare only in a generic medicines market framework. Therefore, the protection of intellectual property rights should be flexible enough to assure that there is generic competition in the pharmaceutical sector.

## APPENDIX: DATA

The simulations relate to the growth rate obtained in Equation (18) and to the utility level obtained in Equation (20). These simulations were performed using data from the pharmaceutical sector in 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). The parameters from the equations of the growth rate and utility are defined as:

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

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

$\tau$ : 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 were 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 times the percentage average 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 2000-2010.

$a$ : 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 relative to “Full-time equivalent researchers in pharmaceuticals” from the OECD database, for the year 2000.

TABLE 1.

Parameter Values			
	Mean	Maximum	Minimum
$\alpha$	0.5	0.99	0.01
$\rho$	0.037	0.06	0.032
$\tau$	0.13	0.149	0.107
$s$	0.07	0.10	0.05
$L$	18028	19402	17975
$a$	259	-	-

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