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Price Controls for Medical Innovations in A Life-Cycle Perspective

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Abstract

Our analysis of the market for new medical technologies employs a novel life-cycle, macroeconomic perspective. Taking into account that healthcare utilization is biased toward old age, we show that through their positive effect on savings, price controls on medical innovations enhance both welfare and investment in medical R&D. Under partial equilibrium, these results reflect an increase in dynamic efficiency at the expense of static efficiency, whereas under general equilibrium, price controls can improve both static and dynamic efficiency, contrary to conventional wisdom. Remarkably, our results are obtained only under global price controls for the vast majority of medical technologies, whereas the selective regulation of a few technologies, such as pharmaceuticals alone, would yield conventional results.

Keywords: Medical Innovations, Price Regulation, Dynamic and Static Efficiency.

JEL classification: I-18; O-38.

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1. Introduction

According to conventional wisdom, the design of optimal price regulation for innovative technologies involves a tradeoff between static and dynamic efficiency: a lower price decreases innovator markup and, thus, improves static efficiency while impairing dynamic efficiency by weakening incentives to innovate. The present study shows that from a life-cycle perspective, price regulation for medical technologies may improve dynamic efficiency at the expense of static efficiency under partial equilibrium analysis, but may also improve both under general equilibrium analysis[1].

The medical sector is one of the most heavily regulated industries in all developed economies, and it is continually at the heart of public deliberations and political debate. Price controls on medical innovations are one of the regulations that have been repeatedly considered in some countries (as in the US, for example, during President Clinton's first administration) and used in others (such as Canada and the EU countries).

The study of optimal monopoly regulation, which sets both product quality and price, has its roots in the early contributions of Spence (1975), Sheshinski (1976) and Dixit (1979). These studies, however, were carried out using the static framework. Later studies identified and analyzed the tradeoff between the static and dynamic efficiency of price regulation where investment in capacity or R&D takes place before pricing. This literature has emphasized the inconsistency of regulators' optimal plans, which tends to overweight static efficiency after investment at the expense of dynamic efficiency (see for example Gilbert and Newbery 1994, Biglaiser and Riordan 2000 and Lyon and Mayo, 2005). In all of these studies, however, price regulation and patent policy affect only the investment decisions of the regulated firm; they do not affect demand. Distinct to this literature, the present study analyzes the effect of price regulation on both R&D effort and future demand. Central to the political debate, the regulation of markets for innovative medicines has attracted a correspondingly large body of empirical and

[1] In recent literature there is a growing interest in evaluating public health plans within a general equilibrium framework (see for example Bednarek and Pecchenino, 2002; Zhang et al., 2006 and Bhattacharya and Qiao, 2007), However, current literature on price regulation is confined to partial equilibrium analysis. Exceptional paper by Kelton and Rebelein (2007) employs general equilibrium framework to estimate the welfare gains from price control for pharmaceuticals. Nevertheless, the general equilibrium that is calibrated in this study is static, that is, of one period.

theoretical research (for recent examples, see Kelton and Rebelein ,2007; Atella et al. 2008; Bekke et al. 2008; Civan and Maloney 2009).

With health perceived as significantly complementary to all other economic activities, the literature on macroeconomic growth has emphasized the importance of the economic growth of progress in medical technology and health conditions through their effect on saving and investment decisions. While early papers on the transition from stagnation to growth were focused on changes in infant and child mortality, more recent papers have addressed later phases of economic development in which medical needs and expenditures are mostly associated with older individuals[2]. (See, for example, A'isa and Sanso 2006, Blackburn and Cipriani 2002, Chakraborty 2004.) These studies, however, do not deal with price regulation policy.

Inspired by this literature, the present study shows that when we account for the concentration of medical needs and spending on the elderly, both savings which build future demand for medical technologies and medical R&D investment may increase under price regulation. We first obtain this result by analyzing the long-term interaction between consumers and a single innovator in a partial equilibrium setup with a two-period timeline. In the first period, young consumers decide how much to save whereas the innovator decides how much to invest in R&D. Current savings, which build future demand, increase with the observed R&D effort and decrease with the expected price of the innovative technologies[3]. On the other hand, the R&D effort is more profitable if future demand and price are higher. Because the price of the innovative technology is set in the second period, after saving decisions were made, this interaction between consumers and innovators may involve a holdup problem. In this case, the price and quality of the medical technologies are too low. An effective price cap, either set in advance or expected to be set, can compensate for the lack of self-commitment by innovators.

[2] In the year 2004, 85% of lifetime expenditures of the average American were spent after the age of 55, and health expenditures of the American retiree (age 65 and above) was 3.3 times larger than for the working age person (Source: US department of Health and Human Services, National Health Expenditures Data, Health Expenditures by age, 2004).

[3] Hamermesh (1985) provides evidence that individuals' subjective life expectancies exceed actual present life expectancy, reflecting expectations of improved health conditions and/or technologies in the future. Becker Philipson and Murphy (2007) argue that the expectations of severely ill people that an innovative cure will be developed can explain the heavy health expenditures of terminal care. On the side of innovators, Acemoglu and Linn (2004) document the response of medical R&D effort to long term *expected* demographic ageing.

Nevertheless, the increase in R&D investment is associated with higher markup, and thus, dynamic efficiency increases at the expense of static efficiency.

Similar holdup problems in the absence of commitment to price and quality have been analyzed by Farrell and Gallini (1988) and Shepard (1987), respectively. These studies have shown that when the utilization of a certain technology or service involves lock-in effects, the monopolistic supplier may benefit from committing by not taking advantage of locked-in consumers. In these studies, the monopoly acts to weaken its own future market power by licensing the technology in advance, and thus, licensing serves as a commitment device.

Nevertheless, in the following general-equilibrium analysis, we allow for multiple different medical technologies to be developed by non-cooperative innovators. Here, any private incentive to commit vanishes because the marginal effect of the single innovator on aggregate saving decisions diminishes with the number of different medical technologies. In addition, under a general equilibrium, saving and investment decisions are subject to aggregate resource constraints, and a free-entry-like condition results in a zero profit condition. The general equilibrium analysis implies that price regulation may improve both static efficiency and dynamic efficiency: that is, it may decrease actual prices and increase investment in medical R&D and thereby improve welfare.

The remainder of the paper is developed as follows. The second section of this article presents the basic model. The third section analyzes the implications of price regulations under partial equilibrium. The fourth section expands the analysis into a general equilibrium framework, and the fifth section discusses the results and concludes this study.

2. The Model

Consumers

In an economy of constant population size normalized to 1, consumers live two periods: "Adulthood" and "elderly". During adulthood they are "young" and during elderly they are "old." When they are young, they are endowed with a given monetary income, I , and only derive utility from consumption, c_1. When old, consumers derive utility from consumption, c_2,

and from medical good, z. The marginal utility derived from healthcare services is positively dependent on the quality of the medical technology utilized, q. The price of healthcare services (relative to consumption services) is denoted p, and the price of the consumed good is normalized to 1. Healthcare services that use different technologies may have different prices[4]. To simplify the exposition and without altering our qualitative results, we assume no time preference and zero interest rate. Putting the above characteristics together, consumer's lifetime utility is given formulated as:

(1) $U\ c_1, c_2, z, q\ = c_1^{\alpha} +\ q \cdot z^{\ 1-\alpha} \cdot c_2^{\ \alpha} \qquad 0 < \alpha < 1$

This functional form allows us to focus on relevant inter-temporal substitution affects that lies at the core of our analysis, since the elasticity of substitution between consumption good and health services within the second period is zero. Consumers maximize their utility by allocating their income over their two periods of life and by choosing their preferred medical technology among those available in the market. The maximization of consumer utility is subject to the following budget constraint:

(2) $c_1 + c_2 + p \cdot z = I$

We denote the level of savings as:

(3) $s = I - c_1$

An optimal allocation of savings with respect to health and consumption goods in the second period is defined by the standard first-order conditions as follows:

(4a) $z = \dfrac{1-\alpha\ \cdot s}{p}$

(4b) $c_2 = \alpha \cdot s$

By using Equations (3), (4a), and (4b), we present utility as a function of savings and of the quality and price of medical technology:

[4] Throughout the paper we focus on progress in medical technology. However, allowing for technological progress also in the consumption sector would not affect our qualitative results.

(5) $$U\ s\ =\ I-s^{\ \alpha}+\left(\frac{1-\alpha\ \cdot q}{p}\right)^{1-\alpha}\cdot\alpha^{\alpha}\cdot s$$

Maximizing (5) with respect to savings, we calculate the optimal savings level $s*$:

(6) $$s^{*}=I-\left(\frac{\alpha\cdot p}{1-\alpha\ \cdot q}\right)$$

An interior solution that satisfies Equation (6) requires a minimal ratio of quality to price of health technology[5]. Substituting the optimal saving level back into Equation (5), we obtain the following indirect-utility function

(7) $$\begin{aligned} V\ I,p,q\ &= v_1(I,p,q)+v_2(I,p,q)= \\ &=\alpha^{\alpha}\cdot\ 1-\alpha\ ^{1-\alpha}\cdot\left[\left(\frac{q}{p}\right)^{-\alpha}+\left(\frac{q}{p}\right)^{1-\alpha}\cdot I\right] \end{aligned}$$

Note that consumer welfare depends positively income and on the ratio of quality to price of the medical technology in use (for any positive level of savings).

Producers

In this section we analyze a partial equilibrium in which production is only modeled for the healthcare sector. In each period, a maximum of two medical technologies are available: "old" or "generic" and "new" or "innovative." New medical technology is developed via investments in a R&D process with certain known outcomes. The development process lasts one period. The innovative technology is sold in the market under patent protection in the following period. When its patent protection expires after one period, the technology is imitated, and its generic versions are sold by competitive producers at their constant marginal cost, mc, which is independent of the quality of the medical good being produced. We denote the innovative patent-protected technology of each period and the generic technology of each period as q^{m} and q^{c},

[5] This minimal ratio is given by: $\left(\frac{q}{p}\right)_{\min}=\frac{\alpha}{I\cdot\ 1-\alpha}$

respectively, where $q_1^m = q_2^c$, namely the innovative technology of the first period becomes the generic technology of the second period. Innovation (quality-improving) technology is linear:

(8) $q_2^m = \phi \cdot R_1^m$

The vertical competition with old technology defines the limit (per-unit) price for the new technology, denoted p^m:

(9) $p^m = \frac{q^m}{q^c} \cdot mc$

According to (9), innovator's markup is equal to the relative quality of the new technology compared with the old one. Given that, the innovator chooses optimal R&D investment to maximize the following profit function, accounting for the effect of current R&D investment on future demand for the innovative technology:

(10) $\pi\ R\ = z(\phi R) \cdot mc \cdot \left(\frac{\phi R}{q^c} - 1 \right) - R$

3. Partial Equilibrium Analysis

In this section we identify the potential long-term holdup problem along the dynamic interaction between saving decisions and the innovators' Investment and pricing decisions. We show that this hold up problem can be unraveled by price regulations set in advances or expected to be set.

Equilibrium is characterized by a triplet $q^m, p^m, s*$ that solves the following sequential interaction between consumers and the innovator of medical technology: in the first period, the innovator chooses its R&D investment first. Then young consumers observe current innovative technology and current R&D investments so that they may correctly evaluate the quality of innovative and generic medical technologies that will be available in the market as these same consumers grow old. They use these observable qualities to decide how much to consume and

how much to save while taking into account the future prices that they expect to pay for each available technology. Then, trading of medical goods takes place in the second period.[6]

Intuitively, there are potential complementarities between R&D investment and saving decisions: the greater the saving and thereby future demand, the more profitable it will be to invest in an innovative medical technology, and the better future technological quality, the higher will be any associated optimal savings, so long as the price of the innovative technology does not increase too much relative to its quality. However, absent creditable commitment mechanism these potential complementarities cannot be utilized. As consumers expect the new technology to be sold at the limit price defines in equation (9), optimal saving level is irresponsive to current R&D investment, as obtained by substituting the monopolistic price and quality in equation (6):

$$(11) \qquad s^* = I - \left(\frac{\alpha \cdot mc}{1-\alpha \ \cdot q^c} \right)$$

By substituting this optimal saving into the profit equation (10), and maximizing for the optimal R&D investment, we obtain the following first-order condition:

$$(12) \qquad f.o.c : \pi'(R)=0 \Rightarrow \sqrt{\phi \left[q^c \cdot \ 1-\alpha \ \cdot I - \alpha \cdot mc \right]} = \phi \cdot R^m = q^m$$

It can be shown that a monopoly's profit is positive when levels of existing generic technology are not too high or too low. That is, if the quality of the existing technology is very poor, savings (and, in turn, demand) may be too low to justify innovation. If, however, the quality of the existing technology is very high, it becomes too costly to further increase demand by improving quality. In addition, in order to profit, the quality of the innovative technology should be at least twice as good as the quality of the old technology, i.e., $q^m > 2 \cdot q^c$. Thus, the price of the innovative technology should satisfy $p^m \geq 2 \cdot mc$. Another necessary condition for a positive profit is given by: $I > \frac{16 \cdot \alpha \cdot mc}{1-\alpha^{\ 2} \phi}$, that is income is high enough relative to marginal cost normalized to the marginal productivity of R&D invest.

[6] In fact, the only crucial assumption regarding the timeline is that the price is set after savings decisions are taken.

Price Regulation

We now analyze equilibrium under price controls for medical innovations. Note, however, that to have any effect on saving decisions, price regulation should be expected in advance. Then, it serves as an effective policy device for enforcing a price commitment. We denote the maximal regulated price as $p^{\max}$ and the quality chosen by the monopoly under a price ceiling policy as $q^{\max}$. The innovator that operates under the effective price ceiling solves the following maximization problem:

$$(13) \qquad \max_{R}: \pi \ R = \underbrace{\left[\frac{1-\alpha \ \cdot I}{p^{\max}} - \frac{\alpha}{q(R)} \right]}_{z(p^{\max})} \cdot \ p^{\max} - mc \ - R$$

The first-order condition for profit maximization is given by the following expression:

$$(14) \qquad \pi'(R)=0 \ \Rightarrow q^{\max} = \sqrt{\phi \cdot \alpha \cdot \ p^{\max} - mc}$$

Note that in contrast to the optimal R&D investment absent regulation, under price ceiling optimal R&D investment is independent of the quality of old technology. Price ceiling is effective only if it results in R&D investment for which quality-to-price ratio is higher than absent regulation that: $\frac{q^{\max}}{p^{\max}} > \frac{q^c}{mc}$. Substituting $q^{\max}$ for the explicit expression given in (14), we obtain that price regulation is effective if:

$$(15) \qquad \frac{\sqrt{\phi \cdot \alpha \cdot \ p^{\max} - mc}}{p^{\max}} > \frac{q^c}{mc}$$

Condition (15) holds if: $\phi \cdot \alpha > \frac{4 \cdot \ q^{c\ 2}}{mc}$**,** and if the ceiling price is set to be not too above or too low from $\frac{\phi \cdot \alpha}{2}\left(\frac{mc}{q^c} \right)^2$. By definition, effective price ceiling improves consumers' surplus by raising the quality to price ratio. Differentiating the left side of (15) for $p^{\max}$ we find that the price ceiling that maximizes consumer's utility is: $p^{\max} = 2 \cdot mc$. Such a price ceiling will be

effective if $q^c < \frac{\sqrt{\phi \cdot \alpha \cdot mc}}{2}$. We have shown that in the non-regulated market under such price level innovator's profit is zero. However, under such an effective price ceiling profit is positive if $I^2 > \frac{16 \cdot \alpha \cdot mc}{1-\alpha^{\,2}\phi}$ (this condition is necessary but not sufficient for positive profit, absent price regulation).

Proposition1: *An effective price ceiling can be welfare Pareto improving and quality enhancing. In this case the price of medical technologies is higher under regulation.*

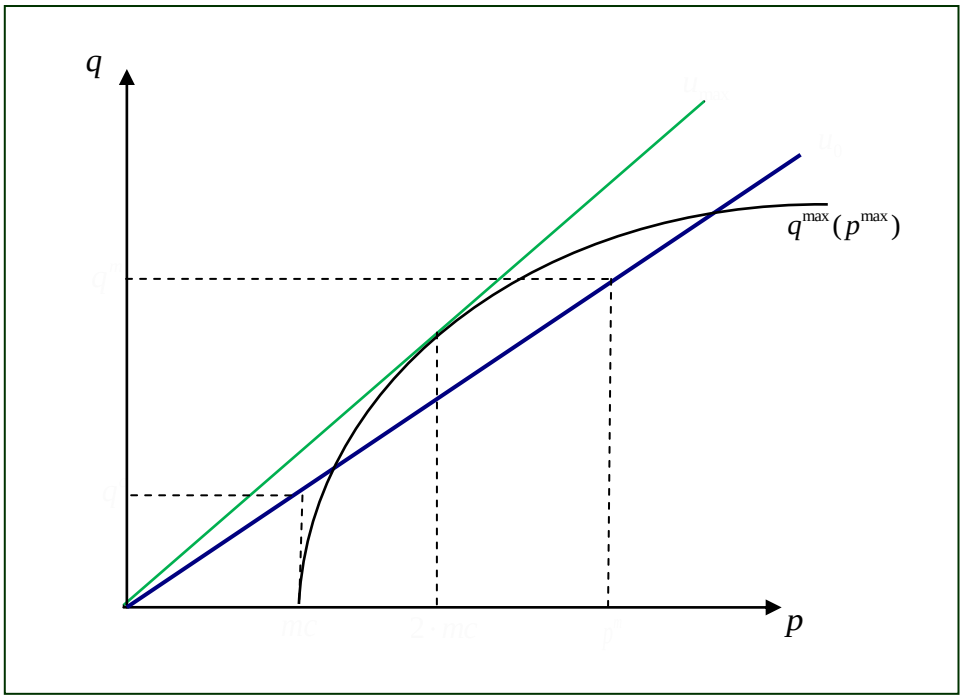
Proof:

If the quality of existing technology is low enough and income is high enough, compared with the marginal cost, then condition (15) is satisfied and the quality of the innovative technology may be as low as $q^m = 2q^c$. Then, according to (14), setting the price to be $p^{\max} > \frac{4q^{c2}}{\phi\alpha} + mc$, ensures that $q^{\max} > q^m = 2q^c$. If in addition $\frac{1-\alpha \cdot I}{\alpha} > \frac{4q^c}{\alpha\phi} + mc$, it is guaranteed that under the price ceiling profit is positive, and thus both consumers and producers gain from such price regulation. *Q.E.D.*

Figure 1 illustrates Proposition 1 and the comparison between the regulated and non regulated equilibrium when price ceiling can be effective. In the diagram, the horizontal and vertical axis measure price and quality of the innovative technology, respectively. The solid blue linear line, denoted u_0 is the indifference curve which represents the reservation utility defined by the quality to price ratio $\frac{q^c}{mc}$. The quality and price of the innovative technology in the non regulated market define a point on the reservation indifference curve. The positive profit condition requires $q^m > 2 \cdot q^c$, and according to (12) q^m is increasing with income. The concave curve represents the reaction function of the regulated innovator, given by equation (14). For the price range within which this function is above the reservation indifference curve, price regulation is effective. Finally the green indifference curve denoted $u_{\max}$ represents the maximal utility that can be achieved by an effective price ceiling of $p^{\max} = 2 \cdot mc$. Note that in case that

reservation utility is high enough price regulation may not be effective and that effective price ceiling can be either higher or lower than the unregulated price. Not also that because R&D investment is increasing with an effective maximal price stimulated R&D investment only at the expense of higher static inefficiency reflected in a higher markup.

Figure 1: Equilibrium with an Effective Price Ceiling



In accordance with our results thus far one would expect to empirically observe self-commitment to future prices in the medical sector, in the form of pre-licensing for example, or through reputational strategic pricing when allowing repeated interaction between consumers and innovators. While testing for reputational pricing considerations is difficult, voluntary pre-licensing in the pharmaceutical industry for example is hard to be found. Obviously long term contracting for future licensing is not trivial. Nevertheless, from the theoretical stand point, commitment may not be prevailed under equilibrium once we allow for multiple medical products innovated by different innovators, as we do in the next section.

Suppose for example that when old consumers utilize n different medical goods, still under the Cob-Douglas functional form: $u\ c_1, c_2, z_i, q_i\ = c_1^{\ \alpha} + \prod_{i=1}^{n} q_i \cdot z_i^{\ \frac{1-\alpha}{n}} \cdot c_2^{\ \alpha}$.

Here, saving's response to a marginal decrease in the quality-to-price ratio of a single medical good decreases with the number of medical goods - n, and so the incentive to commit diminishes as n increases (as pointed out by Stokey ,1995, p. 474). In addition given that all other innovators are committing, the incentive to deviate from such a hypothetical equilibrium is stronger the more innovators there are, as each innovator tends to free ride other's commitment.

4. General Equilibrium Analysis

In this section, we expand our analysis to include a general equilibrium framework to re-examine and validate the results obtained from the partial equilibrium analysis. We assume a continuum of different technologies, so the number of innovators is large enough to eliminate any private incentive for commitment to price. In addition, under a general equilibrium, saving and investment decisions are more tightly related, subject to the aggregate resources use constraint. Furthermore, under the general equilibrium, firms (innovators) earn no profit. We still assume that consumption is storable at zero interest and depreciation rates, but we add an alternative channel for saving: R&D investment, which takes the consumption good as its sole input.

Preferences:

A continuum of different medical goods, indexed by $i \in 0,1$, is utilized according the following cob-Douglas preferences:

(1) $\quad u\ c_1, c_2, z_i, q_i\ = c_1^{\ \alpha} + Z^{1-\alpha} c_2^{\ \alpha}$

Where Z is an aggregator for medical goods utilization, given by $Z = \exp^{\int_0^1 \ln q_i z_i di}$. As before, the price of the consumption good is normalized to one. Under the assumed preferences, demand for each medical good remains as in section 2:

(2) $$z_i = \frac{1-\alpha \cdot s}{p_i}$$

Production:

The production of both consumption and medical goods takes labor as a sole input. Each agent supplies one unit of labor inelastically when young and retires when old. In this setup, the old (who are the owners of the latest innovative medical technologies) hire the young to work in the production of healthcare services. We assume that labor markets are perfectly competitive and that production technologies are linear and identical for all medical industries. Thus, the per-worker production functions of the two sectors are given by

(3) $c = l_c$

(4) $z_i = h \cdot l_{z_i}$

Where h is the relative productivity of the health sector (with productivity in the consumption sector normalized to one), and $\int_0^1 l_i di$ is the share of the labor supplies that a representative worker devotes to the production of medical goods. Under the constant (unitary) productivity of labor in the consumption sector, the wage in this sector is equal to the price of the consumption good, which is also one. Equilibrium in the labor market requires that wages across sectors be equal, and thus, the marginal cost of production in the medical sectors is given by $mc = \frac{1}{h}$, which is the relative productivity of the consumption sector with respect to the health sector. Under the assumed normalizations, worker income is one.

Innovation:

We still assume certain R&D outcomes as before; that is, innovation does not involve uncertainty: $q_{i,t} = \phi R_{i,t-1}$. By also maintaining the assumption of price competition in the product market, we are left with one innovator for each medical good. Innovators finance their R&D investment through borrowing in the credit market with the interest rate $1+r$. The return on R&D investment in industry i is defined by

(5) $1+r_i = \frac{PS_i}{R_i}$

Where the industry surplus is given by

(6) $PS_i = z_i \ p_i - mc = \frac{1-\alpha \cdot s \cdot 1+r}{p_i} \ p_i - mc$

Equilibrium:

In equilibrium, the return on R&D investment is equal across sectors; that is, $1+r = \frac{PS_i}{R_i}, \forall i$.

Due to the symmetry across different medical industries, we can denote the equilibrium quality in price in all industries as q^* and p^*, and the indirect utility function can be written as:

(7) $U = 1-s^{\alpha} + \left(\frac{q \ 1-\alpha}{\hat{p}} \right)^{1-\alpha} \alpha^{\alpha} \cdot 1+r \cdot s$

The first-order condition implies the following optimal saving level:

(8) $s^* = 1 - \frac{p^n \cdot \alpha}{q^n \cdot 1-\alpha \cdot 1+r^{\frac{1}{1-\alpha}}}$

Note that savings should pay for healthcare during old age and therefore must exceed the innovator surplus and, according to (4), R&D investment. This means that in equilibrium, some of the savings are made through storage at a zero (net) interest rate, and therefore, the rate of return on R&D investment is also zero, meaning that $PS_i = R_i$, $\forall i$ .Note that once allowing for innovation process of uncertain outcomes (success) and free entry to the innovation market, we would get a similar condition of zero expected profit. Substituting the zero interest rate and the explicit expression for R&D investment, we obtain the equilibrium equation that defines the equilibrium saving level, denoted as s^e:

(9) $s^e = 1 - \frac{p^2 \alpha}{\phi \cdot s^e \cdot 1-\alpha^{2} \cdot \left(p - \frac{1}{\theta} \right)}$

Using the implicit functions theorem, we obtain the derivative of the equilibrium saving level with respect to the price of new medical technologies:

$$(10)\quad \frac{\partial s^e}{\partial p} = -\frac{s^e \cdot \alpha \cdot p\left(p - \frac{2}{\theta}\right)}{\left(p - \frac{1}{\theta}\right) \cdot \left[\phi \cdot \left(s^e\right)^2 \cdot (1-\alpha)^2 \cdot \left(p - \frac{1}{\theta}\right) - p^2\alpha\right]}$$

Proposition 2: *For intermediate quality levels of existing medical technologies, if marginal cost is low enough and R&D productivity is high enough, effective price controls result in a lower price and higher R&D investment.*

Proof:

The expression in brackets in the denominator of (8) takes a positive value whenever $\frac{1-\alpha}{\alpha} > 2 \cdot \frac{p}{q} = \frac{2}{q^c \cdot \theta}$. This condition is satisfied if α is sufficiently low relative to the marginal cost to generic quality ratio. Then, if $p > \frac{2}{\theta}$, the equilibrium saving level increases with the decline in price. This condition, however, is satisfied if the quality ratio $\frac{q^n}{q^c}$ is greater than two: $p > \frac{2}{\theta} \Rightarrow \frac{q^n}{q_c \theta} > \frac{2}{\theta} \Rightarrow q^n > 2q^c$. By substituting the optimal savings given in (8) with the explicit surplus expression (6), which equals optimal R&D investment, we find that $q^n > 2q^c$ if:

$$\phi\ (1-\alpha)\ \cdot \left[1 - \frac{\alpha}{q^c \cdot \theta\ (1-\alpha)}\right] > 4q^c$$

That is, for intermediate quality levels of existing medical technology, price regulation works to increase R&D investment if marginal cost is low enough and R&D productivity is high enough. Q.E.D.

Thinking about general equilibrium in the dynamic context of repeated interaction between innovators and consumers, proposition 2 implies that effective price regulation is plausible in light of exogenous increases in the productivity of medical R&D or reductions in production

cost. Such productivity improvements may be viewed as a major breakthrough in medical science or medical technology that can be used to create a major quality improvement through the R&D process. Equivalently, a sufficient exogenous productivity increase in the consumption sector would also work to satisfy the conditions that are required for proposition 2 to hold.

5. Discussion and Conclusions

We have analyzed the market for new medical technologies from a novel long-term, macroeconomic perspective. The novelty of the present study lies in how it considers saving's response to price regulation and analyzes the dynamic efficiency of the interaction between consumers and innovators within a general equilibrium framework. And thus our results relate the current literature on price controls in the health sector that is written in the partial equilibrium framework, to the literature on health and macroeconomic growth. The focus on medical utilization at old age is crucial to our results, because it ensures that an effective price regulation induces inter-temporal substitution effect in favor of consumption during old age, and thereby stimulates saving and investment.

Some empirical studies have documented a negative effect of expected or actual price regulation for innovative pharmaceuticals on R&D effort in this industry. (See, for example, Giaccotto et al., 2005; Golec and Vernon, 2006). These empirical findings, however, do not necessarily contradict our theoretical results; our model does predict that selective price regulation for a small fraction of medical technologies would only yield the standard results because savings responses would be small in that case. According to the OECD Health Data (2010)[7], in 2008, expenditures on pharmaceuticals and other nondurable medical goods in the US did not exceed 12% of national health expenditure.

In reality, most health expenditures are being paid through health insurance, whether private or public. The insurers, of whom there are relatively few, may have sufficient market power to ease the holdup problem under study through bargaining over price. We can easily model this reality in our framework. Denoting the relative bargaining power of the monopoly as $0 < \beta < 1$,

[7] Available at: http://www.oecd.org/document/16/0,3343,en_2649_34631_2085200_1_1_1_1,00.html .

we would find that with no regulation, the monopoly price is $p^m = \frac{\beta \cdot q^m \cdot mc}{q^c}$, while optimal savings are given by $s^* = I - \left(\frac{\alpha \cdot \beta \cdot mc}{1-\alpha \cdot q^c} \right)$. In fact, adding β is equivalent to improving the quality of the generic technology.

Note that weakening patent protection for medical technologies may yield equivalent results: allowing for the imitation of inferior-quality variants may ensure a quality-to-price ratio that is higher than the initial reservation ratio. Such a policy can restrict the maximal quality of the imitated technology to the level $\gamma \in 0,1$. For example, when $\gamma = \frac{mc}{P^{max}}$, the equilibrium that prevails under price regulation will be achieved. However, if imitation is costly, such a policy becomes less effective because no one will assume this cost knowing that its imitative technology is dominated by an innovative one.

In our model, any effective price regulation leads to increase in savings and thereby, counter-intuitively, to an increase in health expenditure. If we allow short-term price elasticity to be smaller than one, in accordance with empirical estimations, the shift in resources from medical to consumption goods in the second period will result in an overall in decrease health expenditures if regulation results in a lower price. However, in cases where effective regulation results in a higher price and higher quality, it may still lead to an increase in health expenditures.

Note that it is sufficient that consumers and innovators expect future price regulation to enhance savings and R&D effort, whereas the actual implementation of price caps is necessary to improve consumer welfare. In this context, current price regulations—those for pharmaceutical drugs, for example—may create expectations regarding future regulation policy for other innovative medical technologies as well.

Finally, we should note that medical technologies are being sold in the global market and that the policy implications derived from this study should therefore be viewed from a global perspective.

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