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Abstract

This study introduces a theoretical framework for the economics of preventative healthcare. Mathematical models are used to explain how the price and utilization of prevention change depending on demand, as well as factors such as the price of a cure, the probability of illness, the efficacy of treatment, the probability of illness and cost functions. Different models are developed depending on the presence and level of health insurance and competition in preventative healthcare markets. Findings show the effect of various factors on the price of preventative healthcare, reveal the marginal effects of a change in the parameters on prices and suggest that under certain circumstances prevention is not the optimal choice.

JEL Classification: I11, L11

Keywords: Preventative healthcare; pricing.

Contents

1. Background

In an environment of rising healthcare costs and governments' efforts for cost containment, disease prevention can play an increasingly important role. Prevention does not necessarily reduce medical care costs, because often the intervention is delivered to a large group, only a very small fraction of which would get the disease without the intervention and thus incur treatment costs. However, even in the cases when prevention costs more than cure, it improves people's health, which implies higher levels of an individual's utility. It has been suggested that the rising value of life has made the US population move up the marginal cost schedule of life extension (Hall and Jones 2007), in which preventative case can play a significant role. The question for policy makers is, whether to cover the costs of preventative interventions on a case-by-case basis, given that the total burden of disease may be lower than the cost of prevention. Previous studies have focused on the economic implications of particular preventative interventions from a cost-benefit perspective (for example, see Macintyre et al 2000, Goldie 2002, van Baal 2006). In order to provide tools that can help answer questions regarding when prevention should be preferred to cure, we need to examine the market of preventative health care, taking into account demand and supply of preventative interventions and cure, optimal quantities and prices for each agent and how other parameters affect prices. This paper uses a theoretical model to study demand and pricing of preventative health care in the context of different market structures and healthcare insurance environments.

Prevention is the only case in which medical care does not afford satisfaction in the event of illness (Arrow 1963), while primary prevention constitutes of actions that reduce the occurrence or incidence of disease (Kenkel and Russell 1986).[1] The multidimensional nature of the cost of preventative care makes it particularly difficult to measure. For example, prevention concerns not only medical products, and the cost of prevention can be monetary or non-monetary. Exercise or reducing consumption of excess unhealthy products (such as cigarettes) also consists preventive care, which may not necessarily involve any kind of expenditure. Kenkel and Russell (1986) explore market failures that might lead to too little prevention from a societal perspective, specifically, moral hazard, externalities

[1] Kenkel and Russell also propose the existence of secondary and tertiary prevention. Our analysis is limted to primary prevention, since their definition of secondary prevention (actions that reduce or eliminate the health consequences of a disease given its occurrence) makes it difficult to distinguish between this kind of preventive care and cure.

and limited information. The authors suggest that in many cases, prevention is not cheaper than a cure, although it is still a desirable social policy. They also refer to some policies that might encourage prevention, such as subsidies and improved access to clinical preventative services. Grossman (1972) does not refer directly to preventative care, but talks about "investment in health", which could be considered as a preventative activity. According to the author, each person has a negatively inclined demand curve for health capital, which relates the marginal efficiency of capital to the stock, and an infinitely elastic supply curve. In a theoretical study, Hey and Patel (1983) suggest that "the quantity of preventative care purchased unambiguously increases with a fall in the price of preventative care, a fall in the price of curative care, an increase in the efficacy of preventative care, a decrease in the efficacy of curative care, a rise in the utility-when-healthy function, a fall in the utility when sick function, and an increase in the discount factor" (Hey and Patel 1983). Zweifel et al (2009) theoretically studied the optimal path of prevention and health insurance from an insurance perspective, distinguishing between observable and non-observable prevention related to insurance premiums. They suggest that prevention cannot be insured due to the absence of uncertainty surrounding this consumer choice. However, according to Ellis and Manning (2007), if consumers are not aware of the impact of prevention on the insurance premium, it is desirable for insurers to offer at least some coverage for preventative healthcare. The authors also suggest that the coinsurance rates for prevention and treatment are not the same.

The most obvious example of an intervention for which utilization requires monetary units is a vaccine. People are vaccinated to prevent contracting a certain disease. Vaccination may be cheap or expensive, and this greatly depends on the market status of the product, meaning the level of competition (if any) in the market.

As long as the intervention is in patent, no other producer can provide exactly the same product. While the intervention is patent protected, the producer acts as a monopolist if there are no other products with a high degree of substitutability. However, during the in-patent period, other firms can develop and sell products that serve the same goal (such as other vaccines for the same disease or "me-too" products in the case of drugs), because they are not exactly the same as the first product, and therefore do not infringe on patent rights. In this study we consider both the case of a product (such as a vaccine) being the only provider in the market, and the case of the presence of other products that serve the same goal of prevention.

Previous studies have shown that there is competition between different in-patent interventions. Kanavos, Costa-Font and McGuire (2007) suggest that in-patent statins (used for the prevention of heart disease) compete against each other. The authors suggest that competition follows a Cournot-model pattern. Danzon and Chao (2000) found some evidence of within therapeutic class competition in France, the UK, Italy and Germany. Ellison et al. (1997) also found evidence of within-class competition in the market of cephalosporins.

Individuals who are insured are not personally affected by the cost of prevention or treatment[2]. Thus, the price of prevention depends on whether consumers are insured or not. Usually health insurance will cover costs of an intervention. However, the choice to cover preventative care depends on its cost compared to a cure. If these costs are not covered by health insurance, the individual will have to make her own decision about whether her expected utility is higher when purchasing preventative care or not. Although the utility function of the insurer is based on the profit function, individuals' utility functions also include non-monetary factors, such as health level.

This paper is organized as follows: Section 2 presents the model and Sections 3, 4 and 5 discuss the cases of monopoly, Cournot competition and Stackelberg competition respectively. Subsections discuss the cases of demand originating from consumers with no insurance, consumers with full insurance, and an insurer. Section 6 concludes.

2. The Model

2.1 Variables and definitions

There are many factors that affect the price of preventative care. Cost of production influences prices and the per-unit cost of production must be covered in order for the production process to be profitable for the manufacturer. When the producer has some degree of market power, an increase in the marginal cost of production leads to an increase in prices. In the case of vaccines or drugs, the per-unit cost of production is very small. The most significant cost for vaccines is R&D fixed costs. R&D is considered a sunk cost and therefore does not affect pricing. Generic producers are not subject to R&D costs, but are not considered in this study as we focus on in-patent markets. A products' effectiveness is also a price determinant because it is a measure of quality: higher efficacy of prevention

[2] The behaviour of one patient alone cannot change the price of the insurance premium due to the large population of insured patients. Nevertheless, if all patients over-consume medicines this will have an effect on the price of the premium. Each patient separately though is unlikely to restrict consumption for this reason.

means lower future expected cost of cure. Purchasers of the product are willing to pay more if the expected increase in utility due the purchase increases. This will allow producers to charge a higher price if the product is expected to prevent a reduction in utility (illness) with a higher probability. Price of cure also affects price of prevention. If an individual does not purchase preventative care, she has higher probabilities of becoming ill, thus purchasing curative care and experiencing the disutility of being ill. The higher the price of the cure, the more willing the individual is to buy preventative care. Finally, market structure also affects prices. A monopolist provider of preventative care has more market power than when competitors are present.

Depending on which case applies, a model for each market structure is considered. Prices differ depending on the presence of competitors as well as the presence of insurance. For each case a different market structure applies. An individual suffers from additional disutility (apart from the monetary cost) from a state of illness.

We develop a theoretical framework that we use to study under which circumstances the purchase of preventative care may lead to an increase of the utility of agents. We study how prices change with changes in effectiveness, cost of production, price of cure, market structure and insurance coverage.

2.2 The baseline equations

Assume there are N individuals in an economy, all with health level h. All are vulnerable to a particular disease. The disease occurs with probability i to each individual (i is the same for all individuals), with $i \in (0,1]$. In case they become ill, their health level decreases by x_n, (where n denotes the individual), so the new health level is h-x_n. x_n is not the same for all individuals. It is uniformly distributed across the population. In case the individual contracts the disease, the cost of cure is p_2.

Individuals can reduce the probability of becoming ill by utilising preventative care. Preventative care is provided by a firm at price p_1. Consumers can choose to purchase zero or one unit of prevention. Preventative care is purchased once. Purchasing an extra unit offers no extra utility. Consumers that choose prevention reduce the probability of becoming ill by s (which is universal); s is a measure of effectiveness of the preventative good. The new probability of becoming ill is i-s. Therefore, even after taking preventative care, the individual might have to pay for cure (p_2) with probability i-s. Effectiveness, s, ranges from zero to i, with s=0 indicating perfect ineffectiveness of preventative care and s

= i indicating perfect effectiveness. In cases that the outcome is different, we will also consider the case in which s varies among individuals, while x is assumed to be common for all.

We consider a two-period model[3]. In the first period the individual makes her decisions about purchasing preventative care or not, and faces the probability of getting ill in period 2. Demand for preventative care is

$$q_1 = N\left(1 - F(x)\right) \qquad (1)$$

where q_1 is quantity of preventative care demanded, N is the population and $F(x)$ is the cumulative distribution function of the worsening of health level due to illness amongst the population. Only people in the upper levels of x (people whose health worsens more when having the specific disease) will purchase preventative care. People with x below the reference value x^* will not choose prevention, since their disutility of being ill is lower. We assume that x is uniformly distributed across the population. For simplicity, we also make the assumption that consumers are risk-neutral. These assumptions help simplifying the algebra when deriving the results, without affecting the direction of the changes as a result of a change in a determinant of price. $F(x)$ has a minimum value of 0 and a maximum value of 1. For any value of x higher than 1, $F(x)$ will be 1 and for any value of x lower than 0, $F(x)$ will be 0.

The provider of preventative care is a profit–maximizing pharmaceutical firm. The firm provides its product in a market, where individuals are the primary purchasers.[4] Costs are assumed to be linear, since this simplifies the analysis without affecting the results. Thus, the profit function of the firm is:

$$\pi = p_1 q_1(p_1) - q_1(p_1)\alpha \qquad (2)$$

where p_1 is the price of preventative care and α is the per unit cost of production, which is constant (linear cost or constant marginal cost assumption).

The first order condition for maximizing profits is:

$$\frac{\partial \pi}{\partial p_1} = q_1(p_1) + q'_1(p_1)p_1 - \alpha\, q'_1(p_1) = 0 \qquad (3)$$

Throughout the paper we assume that prices are strictly positive:

[3] A dynamic model with more than 2 periods could be introduced, but this would not add any insight to the model. The reason is that the goal is to see how price adapts to demand and this simplification does not affect the direction of results.
[4] Costs may be covered by health insurance (depending on the model discussed below).

$$p_1>0, \; p_2>0$$

The methodology used to determine demand for preventative health care is based on the vertical differentiation model by Tirole (1988). In that model, a demand function is constructed depending on how important higher quality is for each consumer. The main assumption is that consumers agree over the preference ordering, but some consumers are willing to pay a higher price than others for the same quality. In this study, consumers prefer a better-expected level of health to a worse one, but they have a different level of disutility for a given disease. We now proceed to see how pricing takes place under different circumstances.

3. One producer - Monopoly

The provider of the only product in a new therapeutic class acts as a monopolist in order to maximize profits. There is no competition from other substitutes that serve the same goal. The pricing decision is subject to consumer's demand function.

3.1 Demand by Consumers without health insurance

If the consumer chooses the preventative care her utility is:

$$U = h + \beta\left[(i-s)(h-x) + (1-(i-s))h\right] - (i-s)p_2\beta - p_1 \qquad (4)$$

By purchasing preventative care in period 1, the healthy person (with level of health h) reduces her utility by the price of the product, p_1. In period 2, discounted by β, her utility is the sum of the probability of becoming ill, (i-s), multiplied by the health level of an ill person (h-x) and the cost of cure (p_2), plus the probability of remaining healthy, (1-(i-s)), multiplied by the health level of a healthy person. h, s, i and x are constrained between 0 and 1. If she does not choose the preventative care, her utility is:

$$U = h + \beta\left[i(h-x) + (1-i)h\right] - ip_2\beta \qquad (5)$$

In this case, the utility in the first period is the health level of a healthy person, without any other costs, since the individual has not purchased any preventative care. Her utility in period 2, discounted by discount factor β, is the health level of a sick person (h-x) plus the purchase or preventative care, multiplied by the probability of getting ill, i, and the health level of a healthy person, h, multiplied by the probability of not becoming ill, 1-i. The probability of getting ill in equation (5) is reduced by s compared to equation (4), which is the reduction of the probability of getting ill due to the use of preventive care. We assume that the health level h enters the utility function linearly. This is a simplifying assumption, since if the health level would enter exponentially with 0<h<1 the analysis would become more complicated and the changes would be towards the same direction, with only the magnitude changing.

The consumer seeks to maximize her utility. Thus, she will choose prevention if her utility is higher in this case rather than in the case in which she does not take prevention, or when:

$$h + \beta[(i-s)(h-x) + (1-(i-s))h] - (i-s)p_2\beta - p_1 \geq$$
$$h + \beta[i(h-x) + (1-i)h] - ip_2\beta$$
$$\Rightarrow x \geq \frac{p_1}{\beta s} - p_2 \qquad (6)$$

(x reflects the worsening of health due to illness). So the fraction of the population with an x larger than $\frac{p_1}{\beta s} - p_2$ will choose to take preventative care, since this is the fraction of the population whose health level worsens most if affected by the disease. People with x below the reference value x^* will not choose prevention because the disutility of being affected is lower. By substituting (6) into the demand function (1) we can rewrite q_1 as:

$$q_1 = N\left(1 - F\left(\frac{p_1}{\beta s} - p_2\right)\right) \qquad (8)$$

x is assumed to be distributed uniformly among the population so we can rewrite (8) as:

$$q_1 = N\left(1 - \left(\frac{p_1}{\beta s} - p_2\right)\right) \qquad (9)$$

Quantity of the preventative product is an increasing function of the total population, the price of cure, the discount factor and the effectiveness of the product, and a decreasing function of the price of preventative care.

From equations (8) and (9) it follows that if $1\text{-}F\left(\frac{p_1}{\beta s} - p_2\right) \leq 0$ => $1 - \left(\frac{p_1}{\beta s} - p_2\right) \leq 0$ => $\frac{p_2}{bs} \geq p_1$, nobody would purchase preventative care and that if $1\text{-}F\left(\frac{p_1}{\beta s} - p_2\right) \geq 1$ => $1 - \left(\frac{p_1}{\beta s} - p_2\right) \geq 1$ => $p_1 \geq bs(1+p_2)$, everybody would purchase preventative care.

We proceed to see what would happen when $\frac{p_2}{bs} < p_1 < bs(1+p_2)$.

The demand function for preventative care is

$$q_1 = N + Np_2 - \frac{N}{\beta s} p_1 \tag{10}$$

which is equivalent to
$$p_1 = \beta s + \beta s p_2 - \frac{\beta s}{N} q_1 \tag{11}$$

The first derivative of quantity with respect to price is: $q'_1(p_1) = -\frac{N}{\beta s} < 0$ (12)

By inserting (10) and (11) into the monopolist profit maximization function (3) we get:

$$N\left(1 - \left(\frac{p_1}{\beta s} - p_2\right)\right) - \frac{N}{\beta s} p_1 + a\frac{N}{\beta s} = 0$$

$$\Rightarrow p_1 = \frac{1}{2}(\beta s + \beta s p_2 + a) \tag{13}$$

The price of preventative care is an increasing function of the discount factor, the effectiveness of the product, the price of cure and the per-unit cost of production.

The partial derivatives of p_1 with respect to s, α and p_2 are:

$$\frac{\partial p_1}{\partial s} = \frac{\beta(1 + p_2)}{2} > 0$$

$$\frac{\partial p_1}{\partial a} = \frac{1}{2} > 0$$

$$\frac{\partial p_1}{\partial p_2} = \frac{\beta s}{2} > 0$$

The more effective the good is, the lower the expected disutility originating from illness, so there is space for higher disutility from increased expenses for purchasing prevention. A rise in the per-unit cost of production of the good will also lead to an increase in its price, as a result of the profit function maximization of the monopolist. Population size (N), the initial probability of getting ill in the absence of preventative care (i) and the disutility of illness (x) have no effect on the price of preventive care p_1 in this setting.

3.2 Demand by Consumers with full insurance

We now consider the case of a consumer who is fully insured and expresses demand for preventative health care herself. This is not a realistic case because health insurance expresses demand as a third party payer and is the party who negotiates prices with the provider. Nevertheless this example is of theoretical interest.

If the consumer chooses to take preventative care, her utility is:

$$U = h + \beta[(i - s)(h - x) + (1 - (i - s))h] \tag{14}$$

In period 1, the consumer has the utility of a healthy person with no health expenses because any purchase of preventative health care is fully covered. In period 2, discounted by β, her utility is the sum of the probability of becoming ill, (i-s), multiplied by the health level of an ill person (h-x), and the probability of remaining healthy, (1-(i-s)), multiplied by the health level of a healthy person (h). Cost of preventative care or cure does not enter her utility, since the consumer has full health insurance and expenses for purchasing preventative care or expenses due to potential illness are fully covered by the insurer.

If she chooses not to take preventive care, her utility is:

$$U = h + \beta[i(h-x) + (1-i)h] \tag{15}$$

In this case, the utility in the first period is the health level of a healthy person, without any other costs, as before. Her utility in period 2, discounted by discount factor β, is the health level of a sick person (h-x) plus the purchase or preventative care, multiplied by the probability of getting ill, i, and the health level of a healthy person, h, multiplied by the probability of not becoming ill, 1-i.

The consumer will choose to purchase preventative care if the utility when taking prevention is higher than the utility when not making the purchase:

$$h + \beta[(i-s)(h-x) + (1-(i-s))h] \ > \ h + \beta[i(h-x) + (1-i)h] \tag{16}$$

$$\Rightarrow \ \beta sx > 0$$

which holds for every $x > 0$ and $s > 0$. This means that the consumer will take preventative care if it has even the slightest positive effect on her health ($s > 0$) and the possible illness causes even the slightest disutility to the consumer. In this case, demand is N (given that $x \in [0, 1]$). Hence, demand equals the total population and is perfectly inelastic. Consumers do not pay for preventative care (as they are fully insured) so they demand the same amount of prevention at any price level. This can be considered as moral hazard because consumers ‘consume’ more preventative care than what they would have if they were not insured and they express demand for preventative care even if the cost is higher then the total expected cost of illness. This, of course, has some limit, as the funds of insurers are finite. Therefore, there is some maximum point for price p_1.

Changes in the level of effectiveness of prevention (s) will not affect the price or quantity demanded. All consumers are strictly better off by pursuing preventative care because they do not pay for it (or because their individual purchasing behaviour does not affect health insurance contributions). The only case in which there would be a difference would be when s changes from s = 0 to s > 0, since in the first case they would be indifferent between purchasing care or not and in the second case they would all demand this good. But we have assumed that $s > 0$, because the product is supposed to have at least a marginal positive effect. The price of cure, p_2 would also not have any effect on demand and consequently on the price. Individuals will purchase the good no matter what the price of cure is as they are always strictly better off. As long as $\alpha < p_1$ max, a change in α will not affect price or quantity. If α exceeds the maximum possible price, the quantity supplied will be zero. The size of population (N), the initial probability of getting ill (i) and the disutility of illness (x)[5] again have no effect on the price of preventive care p_1.

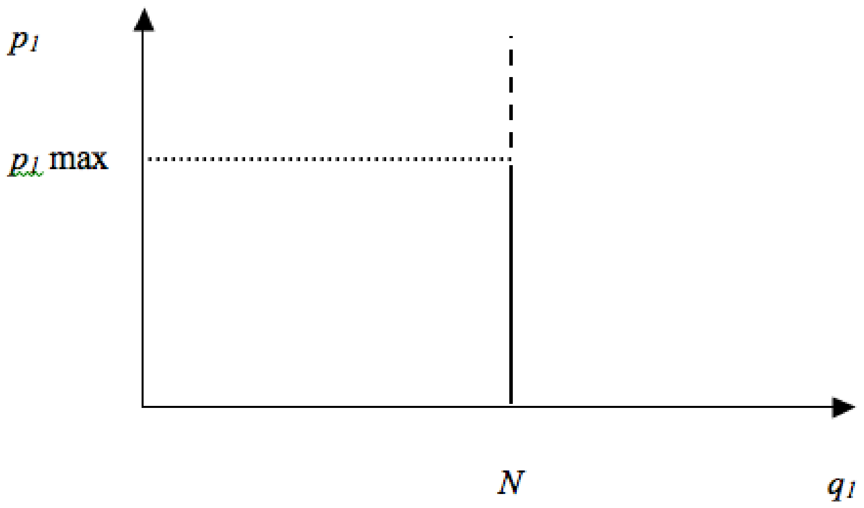

FIGURE 1

In this particular monopoly market, the single provider will sell at the maximum possible price at which there will be demand N, as long as profits are positive.

A more realistic case would be the presence of co-payments on behalf of patients. A co-payment only for prevention and no co-payment for cure would be equivalent to case 3.1, with $p_2 = 0$ and p_1 equal with the amount of the co-payment. The new price function would be

$$p_1 = \frac{1}{2}(\beta s + a)$$

The partial derivatives of p_1 with respect to s, α and p_2 would be:

[5] Given that $x > 0$

$$\frac{\partial p_1}{\partial s} = \frac{\beta}{2} > 0$$

$$\frac{\partial p_1}{\partial a} = \frac{1}{2} > 0$$

If both prevention and cure are subject to co-payments, the solution would be the same as case 3.1, with p_1 and p_2 being the amount of co-payment for prevention and cure respectively. Consequently, co-payments would change the outcome from a very high price to a more reasonable finite price of prevention.

3.3 Demand by cost minimizing insurer

Demand originating from a fully insured individual is an interesting theoretical case, but in practice it is health insurance that normally expresses demand as a third-party payer. Cost minimization is vital for health insurance given rising health care costs. Preventative care is costly, but may also help avoid future costs for cure of a disease, since some insured will avoid falling ill if they consume preventative care. The insurer is interested in covering preventative costs because this decreases expected future health costs, as long as the total cost of prevention does not exceed the monetary cost of cure. The variable representing individuals' utility originating from their health level does not enter the insurer's utility function.

3.3.1 Different disutility from illness across individuals

Suppose disutility from illness (x) varies across individuals. This is the same assumption made in previous cases.

If the individual takes preventative care, the cost for the insurer are equal to:

$$C_{ins} = -(i-s)p_2\beta - p_1 \tag{17}$$

This is the price paid in period 1 for preventative care, plus the cost of cure, multiplied by the (reduced by s) probability of becoming ill in period 2, discounted by β. If the insured individuals choose not to take preventative care, the cost for the insurer is:

$$C_{ins} = -ip_2\beta \tag{18}$$

This concerns only costs in period 2, since in period 1 no preventative care is purchased. Costs involve the price of cure, p_2, multiplied by the probability i of getting ill, discounted by the discount factor β.

The insurer will cover the preventative care costs if

$$-(i-s)p_2\beta - p_1 > -ip_2\beta \Rightarrow \quad p_1 < s\,\beta\,p_2 \qquad (19)$$

If this relation holds, then the insurer covers preventative care. Individuals then take all the preventive care the insurer covers because they are strictly better off by taking it without paying. Thus, demand is N for price $p_1 < s\beta p_2$ and 0 for price $p_1 > s\beta p_2$.

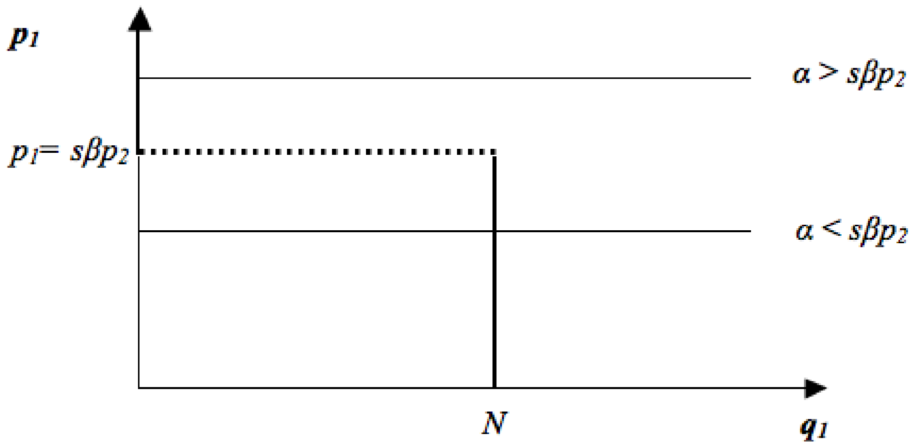

FIGURE 2

Given this demand function, the firm will sell preventative care only if it has nonnegative profits. Since cost is linear, it will provide the good only if $\alpha < p_1 = s\beta p_2$. If indeed $\alpha < p_1 =$ $s\beta p_2$, the firm will supply the product at price $p_1 = s\beta p_2$, leading to revenue maximization of $q_1 * p_1 = N * s\beta p_2$. $\alpha > p_1$ is highly unlikely in a pharmaceutical market with small per unit costs. If the firm sets a higher price, her supply and profits will be zero. By setting a price lower than $s\beta p_2$, its profits will be lower than if the price was $s\beta p_2$, since they will provide the same quantity (N) at a lower price.

A monopolist would sell at $p_1 = s\beta p_2$. This is the only point at which marginal revenue is not zero (marginal revenue is zero for $0 < q < N$ and for $q > N$ and $p_1 * N$ for $q = N$). The highest possible difference between total revenue and total cost for the firm would be exactly at the point where $q = N$. Thus the monopolist is willing to sell quantity N at price $p_1 = s\beta p_2$.

3.3.2 Different effectiveness levels across individuals

We now consider the case in which effectiveness of preventative care varies across individuals. s is uniformly distributed across individuals, with $s \in [0,1]$, while x is common for all consumers. We make this assumption because this is the case in which the insurer will not purchase preventative care for everyone, but only for the consumers with a high s. In 4.1 and 4.2 we did not have to make this distinction because the results would have been the same.

As above, the insurer will cover the preventative care costs if

$$-(i-s)p_2\beta - p_1 > -ip_2\beta \qquad \Rightarrow \qquad s \geq \frac{p_1}{p_2}\frac{1}{\beta} \tag{20}$$

Demand for preventative care is then

$$q_1 = N(1-F(s)) \tag{21}$$

Substituting s into equation (21) gives us:

$$q_1 = N\left(1-F\left(\frac{p_1}{\beta p_2}\right)\right) \tag{22}$$

which due to the assumption of uniform distribution of s among the population, is equivalent to:

$$q_1 = N\left(1-\frac{p_1}{\beta p_2}\right) \tag{23}$$

The fraction of the population that is covered increases with the cost of cure and the discount factor and decreases with the price of prevention.

Equation (23) is equivalent to

$$p_1 = \beta p_2 - \frac{\beta p_2}{N} q_1 \tag{24}$$

The first derivative of q_1 with respect to p_1 is

$$\frac{dq_1}{dp_1} = -\frac{N}{\beta p_2} \tag{25}$$

Substituting equations (24) and (25) into the profit maximizing equation (3) of the monopolist gives us:

$$N\left(1-\left(\frac{p_1}{\beta p_2}\right)\right) - N\frac{p_1}{\beta p_2} + N\frac{\alpha}{\beta p_2} = 0 \tag{26}$$

$$\Rightarrow \; p_1 = \frac{\beta p_2 + \alpha}{2} \tag{27}$$

$$\frac{\partial p_1}{\partial a} = \frac{1}{2} > 0$$

$$\frac{\partial p_1}{\partial p_2} = \frac{\beta}{2} > 0$$

Price of preventative care increases with the price of cure and the per-unit cost of production. The difference compared to the case of universal effectiveness s across individuals is that now only a fraction of the population receives preventative care. In the previous case, either all consumers or none received this care.

An increase in the effectiveness of prevention (s) would lead to an increase in its price p_1. The same will hold for the price of cure, p_2. An increase in the price of cure will lead to an upward shift of p_1, as the monopolist can now take advantage of the fact that prevention becomes more profitable for the insurer, so an increase in p_1 can fill in that gap.

4. Multiple competitors providing preventative healthcare – Cournot Competition

Assume only two firms participate in the preventative care market (duopoly case). Both firms, A and B are identical, produce similar products of the same therapeutic class, have the same production function and enter the market simultaneously. Cost of R&D is a sunk cost, so it does not play a role in this analysis. The post-R&D cost functions are the same for both firms. This is the case of a Cournot duopoly (Cournot 1838).

4.1 Demand by Consumers without insurance

As seen in the initial analysis in the monopolistic case (section 3.1) and according to equation (6), a consumer without insurance will choose prevention if her utility is higher in this case rather than in the case in which she does not take prevention, or when

$$x \geq \frac{p_1}{\beta s} - p_2 \qquad (6)$$

So the fraction of the population with an x larger than $\frac{p_1}{\beta s} - p_2$ will choose to take preventative care due to the fact that this is the fraction of the population whose health level worsens most if affected by the disease. People with x below the reference value will not choose prevention, since the disutility of being affected is lower.

Substituting in the same manner as in the previous section, gives us the following demand function

$$q_1 = N\left(1-\left(\frac{p_1}{\beta s} - p_2\right)\right) \tag{28}$$

which is equivalent to $q_1 = N - Np_2 - \frac{N}{\beta s} p_1$ (29)

This is the demand function and is equivalent to

$$p_1 = \beta s + \beta s p_2 - \frac{\beta s}{N} q_1 \tag{30}$$

With two players in the market, the function becomes:

$$p_1(q_1^A + q_1^B) = \beta s + \beta s p_2 - \frac{\beta s}{N}\left(q_1^A + q_1^B\right) \tag{31}$$

The profit function for firm A is:

$$\pi^A = (\beta s + \beta s p_2 - \frac{\beta s}{N}(q_1^A + q_1^B))q_1^A - \alpha q_1^A \tag{32}$$

First order conditions are:

$$\frac{\partial \pi}{\partial q_1^A} = 0 \qquad \Rightarrow \qquad q_1^A = \frac{N}{2}\left(1 + p_2 - \frac{1}{N} q_1^B - \frac{\alpha}{\beta s}\right) \tag{33}$$

By symmetry, $q_1^B = \frac{N}{2}\left(1 + p_2 - \frac{1}{N} q_1^A - \frac{\alpha}{\beta s}\right)$ (34)

After substituting and rearranging, the equilibrium quantities are:

$$q_1^{A*} = q_1^{B*} = \frac{N}{3}\left(1 + p_2 - \frac{2\alpha}{\beta s}\right) \tag{35}$$

Total quantity is $q_1 = q_1^A + q_1^B$ (36)

Substituting into the demand function gives us price p_1:

$$p_1 = \frac{1}{3}\left(\beta s + \beta s p_2 + 6\alpha\right) \tag{37}$$

The partial derivatives of p_1 with respect to s, α and p_2 are:

$$\frac{\partial p_1}{\partial s} = \frac{\beta}{3} > 0$$

$$\frac{\partial p_1}{\partial a} = 2 > 0$$

$$\frac{\partial p_1}{\partial p_2} = \frac{\beta s}{3} > 0$$

As expected, an increase in preventative care effectiveness (*s*) will trigger a price increase. The more effective the good is, the lower the expected disutility originating from illness, so there is space for higher disutility from increased expenses for purchasing prevention. A rise in the per-unit cost of production of the good will also lead to an increase in its price. A decrease in the price of cure is also expected to lead to an increase in the price of prevention. If cure becomes cheaper, a proportion of the population will not demand preventative care for that given price, because their expected utility will be higher than if not purchasing preventative care. This will lead the provider of prevention to decrease the price of her product. The size of population (*N*), the initial probability of getting ill (*i*) and the disutility of illness (*x*) have no effect on the price of preventive care p_1.

4.2 Demand by Consumers with full insurance

As discussed in section 3.2, in this theoretical case, demand equals the whole population and is perfectly inelastic. Consumers do not pay for preventative care out-of-pocket so they demand the same amount of prevention, regardless the price. As explained in section 3.2, this is a case of moral hazard. In a quantity competition model, such as the Cournot model, the price would be set at the highest possible level (theoretically an infinite price, but in practice a very high price). The competition among the two firms is in the field of quantity. In this case there are multiple equilibria. There is an equilibrium if $q_1^{A*} + q_1^{B*} = N$. Any nonnegative combination of quantities adding up to N is an equilibrium. For example, $\left(q_1^{A*}, q_1^{B*}\right) = \left(N - 500, 500\right)$ is an equilibrium.

4.3 Demand by cost-minimizing insurer

4.3.1 Different disutility from illness across individuals

Suppose disutility from illness (*x*) varies across individuals. This is the same assumption made in case 4.1. The insurer will cover the preventative care costs if

$$-\left(i - s\right)p_2\beta - p_1 > -ip_2\beta \qquad \Rightarrow \qquad p_1 < s\,\beta\,p_2$$

If this holds, then the insurer covers preventative care. Individuals then take all the preventive care the insurer covers (as in section 3.3.1) due to the fact that they are strictly better off by consuming it without paying (Figure 2). Therefore, demand is N for price $p_1 < s\beta p_2$ and 0 for price $p_1 > s\beta p_2$. In this case, both firms will sell the product in the market at price $p_1 = s\,\beta\,p_2$, which is the price that maximizes their profits. Competition is in the field of quantity sold, and not pricing, so they do not deviate from this point. Concerning quantity, again, there are multiple equilibria. Any sum of supplies of the two firms adding up to N is an equilibrium. In other words, there is an equilibrium if $q_1^{A*} + q_1^{B*} = N$. Given this demand function, the firm will sell preventative care only if it has nonnegative profits. Since cost is linear, it will provide the good only if $\alpha < p_1 = s\beta p_2$. If indeed $\alpha < p_1 = s\beta p_2$, the firm will supply the product at price $p_1 = s\beta p_2$ because this will maximize its profits, $q^*p_1 = N^* s\beta p_2$. If the firm sets a higher price, its supply and profits will be zero. By setting a price lower than $s\beta p_2$, it will have a profit lower than if the price was $s\beta p_2$, since they will provide the same quantity (N) at a lower price.

4.3.2 Different effectiveness across individuals

As above, the insurer will cover the preventative care costs if

$$-(i-s)p_2\beta - p_1 > -ip_2\beta \qquad \Rightarrow \qquad s \geq \frac{p_1}{p_2}\frac{1}{\beta} \tag{38}$$

Demand for preventative care is then

$$q_1 = N(1 - F(s)) \tag{1}$$

Substituting s in equation (16) gives us:

$$q_1 = N\left(1 - F\left(\frac{p_1}{\beta p_2}\right)\right) \tag{39}$$

which due to the assumption of uniform distribution of s among the population, is equivalent to:

$$q_1 = N\left(1 - \frac{p_1}{\beta p_2}\right) \tag{40}$$

$$\text{or} \;\; p_1 = \beta p_2 - \frac{\beta p_2}{N} q_1 \tag{41}$$

The demand function for the product is

$$p_1 = \beta p_2 - \frac{\beta p_2}{N} q_1 \tag{42}$$

With two players in the market, the function becomes:

$$p_1(q_1^{A!} + q_1^{B}) = \beta p_2 - \frac{\beta p_2}{N}\left(q_1^{A} + q_1^{B}\right) \tag{43}$$

The profit function for firm A is:

$$\pi^A = (\beta p_2 - \frac{\beta p_2}{N}(q_1^A + q_1^B))q_1^A - \alpha q_1^A \tag{44}$$

First order conditions are:

$$\frac{\partial \pi}{\partial q_1^A} = 0 \qquad \Rightarrow \qquad q_1^A = \frac{N}{2}\left(1 - \frac{1}{N} q_1^B - \frac{\alpha}{\beta p_2}\right) \tag{45}$$

By symmetry,

$$q_1^B = \frac{N}{2}\left(1 - \frac{1}{N} q_1^A - \frac{\alpha}{\beta p_2}\right) \tag{46}$$

After substituting and rearranging, the equilibrium quantities are:

$$q_1^{A*} = q_1^{B*} = \frac{N}{3}\left(1 - \frac{\alpha}{\beta p_2}\right) \tag{47}$$

Total quantity is

$$q_1 = q_1^A + q_1^B = \frac{2N}{3}\left(1 - \frac{\alpha}{\beta p_2}\right) \tag{48}$$

Substituting into the demand function gives us the price p_1:

$$p_1 = \frac{1}{3}(\beta p_2 + 2\alpha) \tag{49}$$

The partial derivatives of p_1 with respect to α and p_2 are:

$$\frac{\partial p_1}{\partial a} = 2/3 > 0$$

$$\frac{\partial p_1}{\partial p_2} = \frac{\beta}{3} > 0$$

Consequently, in this setting price of prevention increases with per-unit cost of production and with price of cure.

5. Sequential Entry – Stackelberg Competition

Due to sequential entry in preventative healthcare markets, the Stackelberg model (Stackelberg 1952) may be more appropriate than the Cournot model. As in the Cournot case, in the Stackelberg model we consider the case of a duopoly: There is the initial provider (first move player) that provides the first preventative product in the particular market and a competitor that provides a substitute. Therefore, the initial provider may act as a leader in the market. The other provider is a follower.

5.1 Demand by Consumers with no insurance

Again, as in section 4.1, a consumer without insurance will choose prevention if her utility is higher in this case rather than in the case in which she does not take prevention, or when

$$x \geq \frac{p_1}{\beta s} - p_2 \qquad (6)$$

so we get the following demand function, as in section 4.1

$$q_1 = N\left(1 - \left(\frac{p_1}{\beta s} - p_2\right)\right) \qquad (8)$$

We shall now examine a sequential version of duopoly, known as the Stackelberg model. The demand function for the product can be written as:

$$p_1 = \beta s + \beta s p_2 - \frac{\beta s}{N} q_1 \qquad (50)$$

With two players in the market, the function becomes:

$$p_1(q_1^A + q_1^B) = \beta s + \beta s p_2 - \frac{\beta s}{N}\left(q_1^A + q_1^B\right) \qquad (51)$$

Assume that firm A has a first-move advantage, so $\pi^{\mathrm{A}} > \pi^{\mathrm{B}}$.

The profit function for firm B is:

$$\pi^B = (\beta s + \beta s p_2 - \frac{\beta s}{N}(q_1^A + q_1^B))q_1^B - \alpha q_1^B \qquad (52)$$

First order conditions are:

$$\frac{\partial \pi}{\partial q_1^{\mathrm{B}}} = 0 \qquad \Rightarrow \qquad q_1^B = \frac{N}{2}\left(1 + p_2 - \frac{1}{N} q_1^A - \frac{\alpha}{\beta s}\right) \ (53)$$

This is firm B's reaction function, which is taken by firm a and incorporated into firm A's profit function:

The profit function for firm A is:

$$\pi^A = (\beta s + \beta s p_2 - \frac{\beta s}{N}(q_1^A + q_1^B))q_1^A - \alpha q_1^A \qquad (54)$$

$$\Rightarrow \pi^A = \left[\beta s + \beta s p_2 - \frac{\beta s}{N}\left(q_1^A + \frac{N}{2}\left(1 + p_2 - \frac{1}{N} q_1^A - \frac{\alpha}{\beta s}\right)\right)\right] q_1^A - \alpha q_1^A \qquad (55)$$

First order conditions are:

$$\frac{\partial \pi}{\partial q_1^A} = 0 \qquad \Rightarrow \qquad q_1^A = \frac{N}{2}\left(1 + p_2 - \frac{\alpha}{\beta s}\right) \qquad (56)$$

Substituting (53) into (56) gives:

$$q_1^B = \frac{N}{2}\left(1 + p_2 - \frac{1}{N}\left(\frac{N}{2}\left(1 + p_2 - \frac{\alpha}{\beta s}\right)\right) - \frac{\alpha}{\beta s}\right) \tag{57}$$

$$\Rightarrow \; q_1^B = \frac{N}{4}\left(1 + p_2 - \frac{\alpha}{\beta s}\right) \tag{58}$$

$q_1 = q_1^A + q_1^B \;\; \Rightarrow$

$$q_1 = \frac{3N}{4}\left(1 + p_2 - \frac{\alpha}{\beta s}\right) \tag{59}$$

Substituting in the demand function gives:

$$p_1 = \beta s + \beta s p_2 - \frac{\beta s}{N}\left(\frac{3N}{4}\left(1 + p_2 - \frac{\alpha}{\beta s}\right)\right) \tag{60}$$

$$\Rightarrow \; p_1 = \frac{1}{4}\left(\beta s + \beta s p_2 + 3\alpha\right) \tag{61}$$

As expected, the price in the Stackelberg model is lower than the price in the Cournot model (Mas-Collel et al 1995, Dastidar 1997).

The partial derivatives of p_1 with respect to s, α and p_2 are:

$$\frac{\partial p_1}{\partial s} = \frac{\beta}{4} > 0$$

$$\frac{\partial p_1}{\partial a} = 3/4 > 0$$

$$\frac{\partial p_1}{\partial p_2} = \frac{\beta s}{4} > 0$$

The directions of the changes for this model have the same interpretation as the Cournot model. The only difference concerns the magnitude of the changes, since here we have a leading firm that has a larger market share.

5.2 Demand by Consumers with full insurance

This case of consumers with full insurance is identical to case 4.2. Demand equals the total population and is perfectly inelastic. Consumers do not pay for preventative care (they are fully insured) so they demand the same amount of prevention, at all price levels (Figure 1).

In a quantity competition model such as the Stackelberg model, the price would be set at the highest possible level (theoretically an infinite price, but in practice a very high price). Competitors compete in terms of quantity and there are multiple equilibria. The equilibrium is $q_1^{A*} + q_1^{B*} = N$ and any nonnegative combination of quantities adding up to N is an equilibrium.

5.3 Demand by cost-minimizing insurer

This section has the same setup as section 4.3. The insurer aims at minimizing her expenses.

5.3.1 Different disutility from illness across individuals

Like case 5.3.1, the insurer will cover the preventative care costs if

$$-(i-s)p_2\beta - p_1 > -ip_2\beta \qquad \Rightarrow \qquad p_1 < s\,\beta\,p_2$$

If this holds, the insurer covers preventative care. Individuals then choose preventive care (Figure 2), because they are strictly better off by taking it without paying. Demand is *N* for price $p_1 < s\beta p_2$ and 0 for price $p_1 > s\beta p_2$. In this case, both firms will sell the product in the market at price $p_1 = s\,\beta\,p_2$, which is the price that maximizes their profits.

5.3.2 Different effectiveness across individuals

We now consider the case in which effectiveness varies across individuals, while *x* is common for all consumers. *s* is uniformly distributed, with s $\in$ [0,1]. We make this assumption, since this is the case in which the insurer will not purchase preventative care for everyone, but only for the consumers with a high *s*.

As above, the insurer will cover the preventative care costs if

$$-(i-s)p_2\beta - p_1 > -ip_2\beta \qquad \Rightarrow$$

$$s \geq \frac{p_1}{p_2}\frac{1}{\beta} \qquad (62)$$

Demand for preventative care is then

$$q_1 = N\big(1 - F(s)\big) \qquad (18)$$

Substituting *s* in equation (18) gives us:

$$q_1 = N\left(1 - F\left(\frac{p_1}{\beta p_2}\right)\right) \qquad (63)$$

which due to the assumption of uniform distribution of s among the population, is equivalent to:

$$q_1 = N\left(1 - \frac{p_1}{\beta p_2}\right) \qquad (64)$$

$$\text{or } p_1 = \beta p_2 - \frac{\beta p_2}{N} q_1 \qquad (65)$$

Demand for preventative care is

$$p_1 = \beta p_2 - \frac{\beta p_2}{N} q_1 \qquad (66)$$

We now set up the Stackeberg competition model:

Assume that firm A has a first-move advantage, so $\pi^{\mathrm{A}} > \pi^{\mathrm{B}}$.

The profit function for firm B is:

$$\pi^B = (\beta p_2 - \frac{\beta p_2}{N}(q_1^A + q_1^B))q_1^B - \alpha q_1^B \qquad (67)$$

First order conditions are:

$$\frac{\partial \pi}{\partial q_1^{\mathrm{B}}} = 0 \qquad \Rightarrow$$

$$q_1^B = \frac{N}{2}\left(1 - \frac{1}{N} q_1^A - \frac{\alpha}{\beta p_2}\right) \qquad (68)$$

This is firm B's reaction function, which is taken by firm a and incorporated into firm A's profit function. The profit function for firm A is:

$$\pi^A = (\beta p_2 - \frac{\beta p_2}{N}(q_1^A + q_1^B))q_1^A - \alpha q_1^A \qquad (69)$$

$$\Rightarrow \pi^A = \left[\beta p_2 - \frac{\beta p_2}{N}\left(q_1^A + \frac{N}{2}\left(1 - \frac{1}{N} q_1^A - \frac{\alpha}{\beta p_2}\right)\right)\right] q_1^A - \alpha q_1^A$$

First order conditions are:

$$\frac{\partial \pi}{\partial q_1^A} = 0$$

$$\Rightarrow \qquad q_1^A = \frac{N}{2}\left(1 - \frac{\alpha}{\beta p_2}\right) \qquad (70)$$

Substituting (70) into (68) gives:

$$q_1^B = \frac{N}{4}\left(1 - \frac{\alpha}{\beta p_2}\right) \qquad (71)$$

$$q_1 = q_1^A + q_1^B \quad \Rightarrow$$

$$q_1 = \frac{3N}{4}\left(1 - \frac{\alpha}{\beta p_2}\right) \qquad (72)$$

Substituting in the demand function gives:

$$p_1 = \beta p_2 - \frac{\beta p_2}{N}\left(\frac{3N}{4}\left(1 - \frac{\alpha}{\beta p_2}\right)\right) \quad \Rightarrow \quad p_1 = \frac{1}{4}\left(\beta p_2 + 3\alpha\right) \qquad (73)$$

The partial derivatives of p_1 with respect to α and p_2 are:

$$\frac{\partial p_1}{\partial a} = 3/4 > 0$$

$$\frac{\partial p_1}{\partial p_2} = \frac{\beta}{4} > 0$$

Again, price of prevention in this setting increases with cost of production and price of cure.

6. Concluding Remarks

This paper has examined demand and pricing of preventative care in different settings and under different optimizing strategies of individuals and insurers. We conclude that in the case of one provider of preventative care, the price of preventative health care increases with a rise in effectiveness of the product, the cost of production and the price of the cure. The case of fully insured individuals is an exception, in which demand equals the entire population, since individuals face no cost of purchase. An insurer covers preventative care for the entire population only if effectiveness and the discount factor are high enough, and nobody if not. This result changes if we assume that effectiveness of the product varies across the population. In the latter case, a part of the population has preventative care covered, and the general findings hold for this case as well. The fraction of the population that is covered increases with the cost of cure and the discount factor and decreases with the price of prevention.

Oligopoly models were also created in order to explain the case of the presence of multiple competitors in a market. Oligopoly prices are lower than the monopoly price for each particular case. Prices are lower when demand originates from an insurer, due to the fact that the insurer is concerned about money inflows and outflows and does not face any other disutility due to illness, apart from the cost of purchasing curative care. The price in the model of sequential entry is lower than in the model of simultaneous entry.

This paper sets out a simple model to compare prices of preventative care across various regimes. In an environment of rising health costs, prevention is very important as it decreases the likelihood of need to cure illnesses in the future. However, prevention is not always the best solution, as costs may be too high compared to cure and disutility of illness, taking into account the probability of illness, while depending on the source of demand and the level of insurance cover, quantities of prevention purchased and the number of people covered may differ significantly.

With this simple model we come up with a number of testable predictions about the differences in prices across countries and insurance schemes. However, the model makes a number of restrictive assumptions. While these are unlikely to affect the testable predictions of the model, future research will seek to relax these assumptions and test predictions empirically.

Appendix

Index of Symbols

h	health level of healthy person
β	discount factor ($1/(1+r)^t$, with t=1 because we have a 2-period model)
i	probability of getting ill
s	reduction of the probability of getting ill due to the use of preventive care. It is an indication of the effectiveness of preventative care.
x	worsening of health level due to illness
p_1	price (or cost) of preventative care
p_2	price (or cost) of cure
α	per unit cost of production of preventative care

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