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Abstract

In this paper a static model of technology choice by health care providers is presented. The model exhibits some stylized facts of technology adoption in the health care sector. We show that inefficiencies in technology adoption may result from intermediate technology providers. Technology improvements increase health care spending in a direct way – more costly techniques as new treatments are made available, and in an indirect way – increases of prices in all providers. This last channel seems to have been overlooked in the accounting of health care rising expenditures. It is also shown that coordination of providers' technology decisions, as performed by professional associations, may yield higher social welfare.

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1 Introduction

Technology has been considered a major determinant in health care soaring costs. In fact, Newhouse (1992) has argued persuasively on the need to give more attention to technological change, as it is probably the most important single driving force of high health care costs.[1]

Previous literature has focused mainly on technology improvements at the frontier, that is, development and adoption of new techniques. However, as it is readily recognizable, providers in the health care system differ in their technological content. A main contribution of the paper is to show that inefficiencies in technology choices are also likely to appear intramarginally. Think of nurses vs. physicians and general practitioners vs. specialists for example. The tasks performed by these various professional groups differ from country to country, which corresponds to different technology choices of each provider in a cross-country spectrum.

Here, we present a simple static model of technological choice (interpreted in a very broad sense) that has some interesting features. The model is closed related to existing models of vertical product differentiation and a directional constraint is imposed.[2]

The model highlights that market provision of technology is, in general, below the optimal level. This suggests that welfare losses due to technological change may not be as high as is usually believed and that effects running against what seems to be the conventional wisdom (too high technology levels) may exist.

In several countries, medical associations control access to the profession and impose guidelines and minimum standards for certification. In fact, medical associations usually have a powerful word to say in the delimitation of what a medical professional can and cannot do. This acting can be seen as a coordinated technology choice for providers. The role of medical associations and its interaction with technology choices has not, up to out knowledge, being treated earlier in the health economics literature. The model developed is suited to address this question.

Thus, this paper contributes to the understanding of two issues often not discussed in the literature: the role of general practitioners versus specialists (or nurses versus medical doctors) as technology choices, its implications for understanding health care expenditures growth, and the importance of medical associations in the determination of those choices.

The paper is organized as follows. Section 2 lays down the basic model and its properties.

[1]See also Weisbrod (1991) for a recent survey on the issue.

[2]See Tirole (1988) for a presentation of models of product differentiation and Cancian, Bills and Bergstrom (1995) for the introduction of directional constraints in models of hprizontal product differentiation.

Section 3 extends the analysis to price-setting considerations. Next, Section 4 investigates the form of technology improvements, with and without entry of new providers. A brief conclusion is provided in Section 5.

2 The model

Technology and medical specialization have special characteristics seldom analyzed in prior literature. An important feature is that more specialized providers can treat more complicated medical problems, as well as simpler cases. On the other hand, less sophisticated providers are not able to treat certain medical problems (in fact, they are not allowed to).

This suggests a modeling approach with some differentiation between providers. On the top of it, a directional constraint is imposed, reflecting a larger set of possible treatments for some providers.

Assume that medical specialization can be described by the type of illness a provider can treat. We subsum all the relevant characteristics of illness into a scalar indicator, θ. The incidence of illness in the population has support in $[0, \infty)$, with density function $f(\theta)$.[3]

This view of medical specialization as vertical product differentiation is a rough simplification. There are clearly different medical specializations which are at the same level of medical sophistication but aimed at distinct health problems. Choices between these options are not considered. The model should be viewed as describing a representative specialty. Adding more possible medical specializations would not change the main results. Since the cost of heavier notation outweights its benefits, only the simplest model is presented.

Suppose a provider chooses a technology level θ'. The directional constraint means that he can treat patients with illness of type $\theta \leq \theta'$. However, all the patients above θ' cannot be treated by this provider.

An upper bound on technology choices, $\bar{\theta}$, is imposed. The approach means that some diseases will not be treated ($\theta > \bar{\theta}$) because of limited current medical knowledge (think of AIDS, for instance).[4]

Of course, it is also the case that health care professionals must have some minimum knowledge on how to treat patients. Thus, there is a lower bound $\underline{\theta}$ to technology choice. We normalize this lower bound to zero. As it shall be apparent below, this assumption is not crucial for the qualitative results and saves on notation.

Patients are fully insured. The importance of insurance form on technology choices cannot

[3]Population size is normalized to one.

[4]Alternatively, we may see the cost of provision of this technology level as very high (infinity, for example).

be overlooked. Since it is not our focus here, the full insurance assumption is made for convenience. The main implications of the analysis would go through in a more general model.[5] To make things simpler to start with, assume that providers act as price takers. Prices are set, for the moment, in an unspecified way. The only decision left to providers is its technology level, θ_i.

Suppose the market has two providers and $\theta_2 > \theta_1$, that is, provider 2 chooses a higher technology level than provider 1. This means that all demand for health care of type $\theta \in [\theta_1, \theta_2]$ is delivered by provider 2.

Health care demand of types $\theta \in [0, \theta_1]$ is shared between the two providers. These assumptions can be interpreted in the following way. Provider 1 is the general practitioner and provider 2 stands for the specialist or provider 1 is the nurse and provider 2 the physician.

Assume that a fraction q of population chooses provider 1 and $(1-q)$ patients are treated by provider 2. The choice between the two providers is not modelled explicitly. It may depend on prices of each provider and individual preferences (as geographic location, prior knowledge of providers, word-of-mouth advice, etc). One possibility that adds some more realism to the model is to assume $q = q(\theta), q' < 0$. That is, the propensity to choose a general practitioner over a specialist is decreasing in the acuteness of disease the individual has, $\hat{\theta}$. However, as there is little insight to gain from it, the simpler version is kept througout the paper.[6] Demand functions are then defined by

$$D_1 = qF(\theta_1) \tag{1}$$

$$D_2 = F(\theta_2) - qF(\theta_1) \tag{2}$$

We now turn to cost characterization. Provider i has unit costs c_i of treating a patient, and investment costs are determined according to a quadratic function:

$$IC = \frac{1}{2}\theta_i^2 \tag{3}$$

Implicitly, we assume that by investing the necessary amount, a given technology level can be attained. This may seem at odds with the uncertain nature of medical research. Note, however, that R & D spending aims at pushing forward medical knowledge ($\bar{\theta}$ in the model). We look at intermediate technology levels. Since most newly developed equipments and techniques are not usually immediately available, our assumption seems to be reasonable. The study of R & D spending is beyond the scope of the paper.

[5]For the reader interested in a recent analysis of the interaction between insurance form and technology levels. see Baumgardner (1991).

[6]Later on, the assumption of constant q is relaxed but in a different direction.

Treating a patient yields revenue p_i for provider i. Note that individuals with equal illness θ may pay different prices if they choose different providers. This corresponds to the notion that a visit to a specialist is more costly than a visit to a general pratictioner.

The objective function of providers is net income/profits from practice. One may argue that providers act also as patient agents. This is probably true, although the exact extent of this agency relation is not very clear. The qualitative results under our extreme assumption of no agency relation can still be obtained under milder forms of imperfect agency relations betweens patients and providers. Provider i's problem is

$$\max_{\theta_i} \Pi_i = (p_i - c_i)D_i(\theta_i) - \frac{1}{2}\theta_i^2, \qquad i = 1, 2 \tag{4}$$

Technology choices of providers can take place under two forms: a decentralized, non-cooperative, way; or a coordinated decision. In the first mechanism, each provider sets his technology level in an independent way. In particular, Nash behavior is assumed. A provider chooses his technology level taking as given the quality choices of the other.

Under the second case, an institution sets the treatments prescribed by each provider. This institution can be a governmental body, which may be, naturally, heavily influenced by medical associations. The existence of governmental legislation on licensing is typical of these effects. These licensure procedure includes a large spectrum of health care providers (physicians, dentists, nurses, pharmacists, etc). On the top of legal requirements, it is not uncommon to see voluntary quality certification given by medical associations.

Also, the "certificate of need" laws present in many US states do perform the same type of coordination, as they specify the number of beds (in hospitals and nursing homes, for example) and heavy equipments (like MRI). This regulation restricts entry, which is the aspect that received more attention, but it also defines the relative technology position of distinct providers, which is the focus of the paper.[7]

A common feature to several countries is the existence of powerful medical associations. These associations usually have a (strong) word on admissions to practice of new professionals, either at early stages, as university admissions, or through a certification role (or both). They have also an important role in 'ethical' provisions for the medical profession. This role goes well beyond monitoring. It really sets the boundaries of medical activities that professionals with a given certificate can perform. This is stronger than simple licensure. Of course, specialty certification may also be an informative signal.

[7] For a more detailed discussion of "certificate of need" laws see Joskow (1981). A classical reference for empirical evidence on their significance in Salkever and Bice (1976).

Hence, 'technology choices' can also be determined by medical associations. Thus, we term coordinated decision the technological choices taken by a medical association on behalf of its members.

Thus, looking at both decision-making processes seems desirable. Moreover, since there is no reason to believe that any of them yields a socially optimal outcome, comparative welfare assessments are warranted.

■ **Decentralized choices** Consider first the Nash equilibrium, that is, providers make their technology choices in a decentralized way. First-order conditions yield the following expressions for the optimal choice of technologies, defining implicitly θ_1 and θ_2:[8]

$$(p_1 - c_1)f(\theta_1)q = \theta_1 \quad (5)$$

$$(p_2 - c_2)f(\theta_2) = \theta_2 \quad (6)$$

The conditions have the standard interpretation of marginal benefits (right-hand side) being equal to marginal costs (left-hand side).

A necessary condition for technology choices to be consistent with the initial assumption of $\theta_2 > \theta_1$ is $(p_2 - c_2) > q(p_1 - c_1)$. If specialists have higher margins that lower technology providers this condition is clearly satisfied.

The model specification implies that the technology choice for a provider is independent of the other provider. This is so because prices are fixed and the proportion of individuals below θ_1 who go to a general practitioner, q, does not depend on providers' technology. This feature is direct consequence of our modeling approach and does not hold in more general settings.

■ **Coordination of choices** In the case of joint technology choices, the problem to be solved is the maximization of joint profits:

$$\max_{\{\theta_1,\theta_2\}} \Pi = (p_1 - c_1)F(\theta_1) - \frac{1}{\theta_1^2} + (p_2 - c_2)\left(F(\theta_2) - qF(\theta_1)\right) - \frac{1}{2}\theta_2^2 \quad (7)$$

First-order conditions of the problem can be rearranged to:

$$(p_2 - c_2)f(\theta_2) = \theta_2 \quad (8)$$

$$qf(\theta_1)\left[(p_1 - c_1) - (p_2 - c_2)\right] = \theta_1 \quad (9)$$

[8] We also assume that second-order conditions are satisfied: $(p_1 - c_1)f'(\theta_1)q - 1 < 0$; $(p_2 - c_2)f'(\theta_2) - 1 < 0$.

For the choice of the lower technology to be interior, it is required the margin for general practitioners to sufficiently exceed that of specialists.[9] Otherwise, the medical association will prefer to deliver all health care by the provider with the highest margin (thus $\theta_1 = 0$).

Comparison of optimal choices in the two decision mechanisms shows that specialists have the same technology level whether choices are made in a decentralized or centralized way. At the margin, for the high technology provider, there is no competition from other providers. Hence, marginal private returns are independent of the existence or not of coordination. However, it is clear that coordination of decisions implies a lower technology level for the other provider under centralized decisions.

The intuition is simple. Under joint profit maximization, the decision maker faces a tradeoff not present in independent decisions. As before, the marginal benefit from an increase in θ_1 is the margin accrued to the provider. The marginal costs, on the other hand, include investment costs *and* the margin lost by provider 2 in those patients that could be treated by provider 2 and are now treated by the general practitioner. The internalization of this 'cost' under centralized decisions motivates a lower technology choice for the general practitioner. This is so even in the absence of explicit interaction between providers' choices if made in a non-cooperative way. This can be easily seen rewriting the condition for optimal choice of the low technology level:

$$qf(\theta_1)(p_1 - c_1) = qf(\theta_1)(p_2 - c_2) + \theta_1 \tag{10}$$

The model yields a empirically testable prediction: one should see a greater difference in 'technological sophistication' between general practitioners and specialists in countries where medical associations are stronger (in the control they can exert over access to the profession). Of course, the comparison can also be made with other providers. For example, the relative roles played by nurses versus physicians.

■ **Welfare comparisons** The existence of divergence in technology choices with and without coordination between providers warrants the need to evaluate both solutions against each other and against a social optimum benchmark. Before any policy prescriptions can be drawn from the analysis, it is necessary to identify the welfare bias associated with each allocation.

The social welfare measure considered is total surplus accrued from health care spending

[9] This condition is still compatible with $\theta_2 > \theta_1$.

net of investment costs:

$$W = vF(\theta_2) - qF(\theta_1)c_1 - c_2(F(\theta_2) - qF(\theta_1)) - \frac{1}{2}\theta_1^2 - \frac{1}{2}\theta_2^2 \tag{11}$$

where v is the utility from treatment, measured in monetary units.[10] The optimal technology decisions are defined by the solution to

$$\theta_2 = (v - c_2)f(\theta_2) \tag{12}$$

$$\theta_1 = (c_2 - c_1)qf(\theta_1) \tag{13}$$

From these conditions, it is easy to check that for $v > p_2$, there is too little investment in the higher technology from a social point-of-view. This is due to the well-known appropriability effect of Arrow (1962). The social gains from an extra unit of technology are higher than the private returns for $p_2 < v$. The social optimum implies that not all clinical problems are treated as θ_2 is finite. Even if the diseases spectrum has an upper bound $\bar{\theta}$, the optimality condition may define an optimal $\theta_2^* < \bar{\theta}$. Thus, optimal choices may or may not imply that delivery of health care uses the better technology available.

More interesting is the result on the technology level of provider 1. The socially optimal level of technology for the general practitioner is higher than the value originated in the coordinated case. To see this, rewrite the optimality condition for θ_1 under coordination as

$$f(\theta_1)q(p_1 - p_2) + (c_2 - c_1)qf(\theta_1) = \theta_1 \tag{14}$$

Since it is natural to assume $p_2 > p_1$ (as specialists are better paid than general practitioners),[11] the implicit value of θ_1 is lower than in the social optimum. Hence, coordination of choices originates underprovision of technology.

Comparison of the social optimum with the decentralized choice allocation does not render a definite conclusion. There will underprovision of low technology if $p_1 > c_2$. Otherwise, a too high technology level is implemented. The reason for this ambiguity is clear. From a social point-of-view, individuals should be treated by a lower technology provider as long as it is cheaper to do so. The reference oppportunity cost for a social planner is the treatment cost by provider 2. So, the social gain of one more unit of θ_1 is the cost not borne by provider 2. Under private decentralized decisions, the return on an extra unit of technology for provider 1 is the price earned, p_1. Hence, private and social marginal returns of investment in technology

[10] For simplicity, a constant utility from treatment is assumed. The analysis can be easily generalized in this respect.

[11] Of course, one should endogeneize price determination and obtain $p_2 > p_1$ as a result from the model. This is taken up in the next section, although casual observations seem to give support to the assumption.

differ in general and is not possible to state whether private or social returns will be higher. The sign of the bias associated with the Nash equilibrium cannot be determined a priori.

From a welfare point-of-view, direct comparison of the centralized allocation and the decentralized outcome originated ambiguous results. Since both mechanisms of technology determination give the same choice of θ_2, welfare comparison amount to welfare effects of diferent choices of θ_1.

The change in welfare can be written as

$$\Delta = W^c - W^d = \left[(c_2 - c_1)q[F(\theta_1^c) - F(\theta_1^d)]\right] + \left(\frac{1}{2}\theta_1^{d^2} - \frac{1}{2}\theta_1^{c^2}\right) \tag{15}$$

Under our working assumptions, the first term is negative and the second term positive (as $\theta_1^d < \theta_1^c$). It is nevertheless possible to show that

$$\begin{cases} \Delta > 0 & if \quad p_1 > c_2 \\ \Delta < 0 & if \quad p_1 < c_2 \end{cases}$$

To establish it, make $\theta_1^c = \bar{\theta}_1^d$ and consider effect of a marginal increase in θ_1^d:

$$\frac{\partial \Delta}{\partial \theta_1^d} = -q(c_2 - c_1)f(\theta_1^d) + \theta_1^d \tag{16}$$

Using the first-order condition for the optimal choice of θ_1 in the decentralized allocation, it results that evaluation at optimal value of θ_1^d yields

$$\frac{\partial \Delta}{\partial \theta_1^d} = (p_1 - c_2)f(\theta_1^d)q$$

This marginal effect has the sign of $(p_1 - c_2)$ and the expression's sign is independent of θ_1^d. Hence, the marginal effect does not change sign over the integration path (from $\tilde{\theta}_1^d$ to θ_1^d).

Briefly, the decentralized decision process is welfare superior when $p_1 > c_2$. In this case, the choice of θ_1^d is below to the social optimum. On the other hand, it is welfare inferior for $p_1 > c_2$ (θ_1^d is above the social optimum). Therefore, it is not clear whether coordination of technology choices is welfare improving or not with respect to decentralized choices.

3 An extended model: flexible prices

In this section, a previous assumption is relaxed. We assume heretofore that providers make a price choice. A two-stage game describes how the 'market' works. In the first stage, providers make their technology choice. Then, in the second stage, they set the prices for their services. As usual, the model is solved by backward induction.

Following previous section strategy, a major change to the model is now introduced. The price set by each provider does influence relative demand of patients who have a choice (that is, patients with illness of type $\theta < \theta_1$). In particular, we assume the following functional form:

$$q = \gamma_0 + \gamma_1(p_2 - p_1) \tag{17}$$

That is, the proportion of patients going to provider 1 is a declining function of his price and an increasing function on rival's price. The linearity assumption is made for expositional convenience.[12]

Defining $\lambda = F(\theta_2)/F(\theta_1)$, providers' objective functions can be written as

$$\Pi_1 = (\gamma_0 - \gamma_1(p_1 - p_2))(p_1 - c_1)F(\theta_1) - \frac{1}{2}\theta_1^2 \tag{18}$$

$$\Pi_2 = F(\theta_1)\left[\lambda - (\gamma_0 - \gamma_1(p_1 - p_2))\right](p_2 - c_2) - \frac{1}{2}\theta_2^2 \tag{19}$$

Maximization with respect to own prices yields the following equilibrium solutions for the price game:

$$p_1 = \frac{1}{3\gamma_1}\{\gamma_0 + 2c_1\gamma_1 + c_2\gamma_1 + \lambda\} \tag{20}$$

$$p_2 = \frac{1}{3\gamma_1}\{-\gamma_0 + c_1\gamma_1 + 2c_2\gamma_1 + 2\lambda\} \tag{21}$$

Given the price equilibrium, the associated value of q is

$$q^* = \frac{\gamma_0 + \gamma_1(c_2 - c_1) + \lambda}{3} \tag{22}$$

Straightforward derivations give the following comparative statics results. Upgrading the best technology available, θ_2, leads to increases in both prices.[13] The intuition is simple: if the technology of provider 2 improves,the number of captive patients increases. Therefore, the incentive to set a lower price for provider 2 decreases, since he has a greater stock of captive demand. Since prices are strategic complements, in equilibrium both prices will be higher. Conversely, if provider 1 upgrades his technology, price competition between providers is stiffer and both prices decrease.

This feature is consistent with explanations of rising health care costs based on technology improvements. The model highlights that not only is the superior quality provider

[12]The parameters $\gamma_0 > 0$ and $\gamma_1 > 0$ must be set such that $q \in [0, 1]$. We assume throughout that such conditions hold: $\gamma_0 - \gamma_1 v \geq 0$ and $\gamma_0 + \gamma_1 v \leq 1$. For example, $\gamma_1 = 1/2v, \gamma_0 = 1/2$ satisfy the conditions stated.

[13]Of course, availability of new treatments may be interpreted as a cost reduction from very high to affordable levels.

likely to have a higher price at a better technology level, but interaction between providers can also generate higher prices at all levels of health delivery (provided prices are strategic complements).

This reveals a source by each technology improvements feeds rising costs. The direct effect consists in the availability of new, more costly, techniques. It is pointed out as the main element in costs' spiral by Newhouse (1992). This is certainly true, as the example of MRI scanners shows. These technological breakthroughs make available better techniques and equipments and to more people. There is, nonetheless, an indirect effect. This indirect effect operates through higher induced prices at intermediate technology levels. So far, no account for this effect has been made in the literature. Its empirical significance is still to be measured.[14]

Proceeding back to the first stage, first-order conditions for profit maximization in technology choices are:

$$\begin{aligned} \frac{\partial \Pi_1}{\partial \theta_1} &= (p_1 - c_1) q f(\theta_1) - \theta_1 + \gamma_1 (p_1 - c_1) F(\theta_1) \frac{\partial p_2}{\partial \theta_1} - \frac{2}{3} \gamma_1 \frac{f(\theta_1)\, F(\theta_2)}{F(\theta_1)\, F(\theta_1)} \\ \frac{\partial \Pi_2}{\partial \theta_2} &= (p_2 - c_2) f(\theta_2) - \theta_2 + (p_2 - c_2) F(\theta_1) \gamma_1 \frac{\partial p_1}{\partial \theta_2} \end{aligned}$$

Rearranging the first expression,

$$\frac{\partial \Pi_1}{\partial \theta_1} = f(\theta_1) \left(\frac{1}{3} (\gamma_0 + \gamma_1 (c_2 - c_1)) - \frac{F(\theta_2)}{F(\theta_1)} \right) - \theta_1$$

Given the restrictions placed on γ_0 and γ_1, it is the case that $\gamma_0 + \gamma_1 (c_2 - c_1) < 1 < F(\theta_2)/F(\theta_1)$. Therefore, $\partial \Pi_1 / \partial \theta_1 < 0$ and $\theta_1 = 0$ in equilibrium.

Comparison of results with the previous section is not easy as q is itself a function of technology choices (through equilibrium prices). To get a feeling of the additional effects introduced by price flexibility, suppose q was equal to previous section value. Then, a higher level of technology is chosen by provider 2 and a provider 1 sets a lower θ_1. Providers want to move apart in the technology spectrum as a way to relax price competition.

In the case of flexible prices, the coordination role of medical associations may be extended to price-setting behavior. This is probably true for physicians (where the two categories of providers in the context of our model are general practitioners and specialists). The assumption is less tenable in what regards nurses and physicians as the two providers in our model as each professional association will push forward proposals for payments for its

[14] Simple, back-of-the-envelope, calculations are not possible as one should distinguish different sources of rising prices in intermediate technology providers. Future empirical research on the topic should be pursued.

members only. Even within medical associations, colleges or boards will be concerned mainly with their members.

Nevertheless, at the technology-setting stage, definition of practice limits of nurses and physicians is easier to coordinate. Hence, the natural assumption in this case is non-cooperative price-setting behavior, while coordination may prevail for technology choices.

This means that the second stage (the price game) is similar for both coordinated and decentralized technology choices. Coordination of decisions means that the cross-effect of technology choice is internalized,increasing the technology gap. As before, widening of the technology difference between providers reduces price competition in the second stage. The first-order derivatives are:

$$\begin{aligned}\frac{\partial \Pi}{\partial \theta_1} &= q(p_1 - c_1)f(\theta_1) - \theta_1 - (p_2 - c_2)qf(\theta_1) + \frac{\partial \Pi_1}{\partial p_2}\frac{\partial p_2}{\partial \theta_1} + \frac{\partial \Pi_2}{\partial p_1}\frac{\partial p_1}{\partial \theta_1} < 0 \\ \frac{\partial \Pi}{\partial \theta_2} &= (p_1 - c_2)f(\theta_2) - \theta_2 + \frac{\partial \Pi_2}{\partial p_1}\frac{\partial p_1}{\partial \theta_2} + \frac{\partial \Pi_1}{\partial p_2}\frac{\partial p_2}{\partial \theta_2}\end{aligned}$$

From these expressions, it is clear that coordination adds two new effects. First, there is the internalization of the loss of margin of provider 2 in the optimal choice of provider 1, as in the fixed-price model. Second, in both choices, it is now included the effect on the other provider's profits from the change in prices induced by technology. This effect is negative in the condition for the optimal determination of θ_1 $(\partial\Pi_2/\partial p_1 \times \partial p_1/\partial\theta_1 < 0)$ and positive in the condition for the choice of $\theta_2(\partial\Pi_1/\partial p_2 \times \partial p_2/\partial\theta_2 > 0)$. Thus, both effects reinforce the forces for an increasing gap between technologies.

The main insight from this section is that price competition motivates a bigger gap in technologies between providers. This gap is larger under coordinated choices of technology, as the decision process internalizes negative cross-effects.

4 Technology improvements

Since the bulk of increased costs is attributed to technological change, it is of interest to investigate the comparative statics effects of technology improvements. In the context of the model, technology improvements consist in changes in $\bar{\theta}$, the upper bound on medical knowledge. The discovery of $\hat{\theta} > \bar{\theta}$ (or the possibility to treat this type of illness at affordable cost) may give rise to different cases. The possibilities are (i) operation of the new technology by provider 2, which upgrades his abilities; and (ii) a third provider enters the market. These two cases are explored below.

4.1 New possibilities for provider 2

An interesting case occurs when provider 2's choice of technology is constrained by the existing medical knowledge (that is, $\theta_2^* > \bar{\theta}_2$.) Under exogenously determined prices, the optimal value of θ_1 remains the same. Discovery of new technologies that allow for the treatment of more difficult health problems does not have any impact over the technology level of provider 1.

The same is not true with endogenously determined prices. If $\theta_2 = \bar{\theta}$ and new therapeutical techniques lead to $d\theta_2 = d\bar{\theta} > 0$, for a constant θ_1, both prices increase in the price-game equilibrium. The effect upon the technology level θ_1 is more subtle. Take the decentralized decision process. The effect of an exogenous change in $\bar{\theta}$ can be found performing a comparative statics exercise $(d\theta_1/d\bar{\theta})$. The sign of this expression is negative. Since we started from $\theta_1 = 0$, the choice under coordination in technology decisions and price competition does not change.

The adoption of new technologies has therefore two main effects over spending in health care. First, there is a direct effect: the cost associated with the new treatments available. This is the more visible effect and the one usually mentioned on the measurement of technology as a justification for rising health care costs.

Second, there is an indirect effect. This effect works through changes in prices of health care services. The important point is that all prices rise. There is a natural increase in the price of the high technology provider, as he upgrades and investment costs have increased. Since prices are strategic complements, price interaction between providers leads to a price increase also in the lower technology providers. This indirect channel of rising health care spending seems to have been overlooked in health care growth accounting.[15] Changes in relative prices of providers may be induced by technological change, and the data does not contradict this interpretation.[16]

4.2 Entry of a higher technoloogy provider

In this subsection, another avenue for technology upgrading is considered. The new technology is made available to a third provider that enters the market.

For simplification, prices are again exogenously determined.[17] Suppose that a new technology $\theta_3 > \theta_2$ is made available to another provider. Demand for health care services is now

[15] This is the case, for example, in Newhouse (1992) and Weisbrod (1991).

[16] See Phelps (1993, chapter 2). Again, there is a need for empirical research that disentangles the different forces behind relative price changes.

[17] They could be introduced in a way analogous to previous sections.

distributed in the following way:

$$\begin{aligned} D_1 &= q_1 F(\theta_1) \\ D_2 &= q_2 F(\theta_1) + s_1 \left[F(\theta_2) - F(\theta_1)\right] \\ D_3 &= F(\theta_3) - (q_1 + q_2) F(\theta_2) - s_1 \left[F(\theta_2) - F(\theta_1)\right] \end{aligned}$$

That is, provider 1 gets a share q_1 of patients with illness of tyoe $\theta < \theta_1$. Provider 2 has a share q_2 of patients with $\theta < \theta_1$ and a share s_1 of patients characterized by $\theta \in (\theta_1, \theta_2]$. Finally, provider 3 captures all demand above θ_2 and below θ_3 and shares $(1 - s_1)$ in patients in $(\theta_1, \theta_2]$ and $(1 - q_1 - q_2)$ in patients with $\theta \leq \theta_2$.

Under non-cooperative decision making, the first-order conditions for profit maximization are

$$\begin{aligned} \frac{\partial \Pi_3}{\partial \theta_3} &= f(\theta_3)(p_3 - c_3) - \theta_3 = 0 \\ \frac{\partial \Pi_2}{\partial \theta_2} &= s_1 f(\theta_2)(p_2 - c_2) - \theta_2 = 0 \\ \frac{\partial \Pi_1}{\partial \theta_1} &= q_1 f(\theta_1)(p_1 - c_1) - \theta_1 = 0 \end{aligned}$$

Under the natural assumptions of $q_1 < q$ and $s_1 < 1$, as demand is now splitted among a larger number of providers, technology in the intermediate providers decreases. This brings into the model two observed effects of introducing new technologies: (a) some patients not treated before have now access to health care (under the new technologies) – this is a demand creation effect; and (b) the new technology is also used in patients treated under lower technology levels – demand diversion effect.

Since in this stylized model both intermediate providers decrease their technological content, it results a greater health expenditure associated with previous patients. Thus, the effects at work are quite different from the ones associated with technological upgrade of the highest technology provider.

5 Final remarks

The model showed that besides considerations about technological change as an aggregate, efficiency considerations on the allocation of different levels of technology to distinct providers also have significance. In particular, it was argued that technology improvements have an indirect effect that contributs to rising health care costs. The indirect effect works through induced changes in prices of intermediate technology providers. This indirect effect adds to the usual direct effects of discovery of more costly technologies, made available to a larger number of patients. The accounting of the indirect effect is still to be made.

The role of medical associations as institutions that coordinate the choice of technology across providers is also addressed. The internalization of effects across providers leads to a too low level of technology for intra-marginal providers. However, it is not possible to state unambiguously whether existence of such coordinating institutions yields welfare gains over a non-coordinated choice of technologies. We found a negative relation between the strength of medical associations and intermediate technology levels. It is also shown, in the simplest model, that who introduces the innovation does matter for technology choices.

The observed disparities among countries in relative importance of nurses to medical doctors, or general practitioners to specialists, to mention the most obvious examples, hint that a better understanding of how such choices come about is a fruitful research area.

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