Appendix C. Analysis of a market with n Physicians [21]

In this appendix we look at a scenario where competition is heightened by the presence of a large number of physicians in the market. This is particularly relevant to the present paper's conclusions, considering that we found the limited sampling and information asymmetries to allow physicians to offer subpar services and charge high fees due to their control over a captive demand. To be precise, those patients who only had access to one physician and based their decision on a single positive anecdote were, for all effects, part of a monopolistic market operating on the side of the competitive one.

Here we study the ability choices of a large set of physicians who compete in a market in terms of the fee they charge (a price) and the quality of their service (an ability).

The literature would suggest that more competitive pressure on a specific physician might give him incentives to increase the quality of the service he offers or push his fee closer to the marginal cost. Indeed, the mechanism that allowed low-ability Physicians to focus on their captive markets is essentially altered in the presence of strong competition. A market with a large number of physicians implies smaller captive segments for each provider, thus affecting their incentives to focus on them. It is interesting to consider whether a more competitive market could correct the distortions found in this paper's main model, leading to potential regulatory insights for a social planner to examine.

We find that low-ability physicians still can participate in the market despite the large number of competitors. Indeed, increasing the number of providers has a minimal impact over the participation decisions of patients. The anecdote-based reasoning the patients follow makes the existence of superior but unknown suppliers irrelevant. That is, if a patient decides to visit a physician upon finding a positive anecdote, it may not matter that she is unaware of a large number of high-ability rivals.

In terms of their equilibrium pricing strategies, the availability of more physicians entails a decrease in the information consumers have across the market, allowing for high equilibrium fees. This is a counter-intuitive result, since more competition would not be be expected to lead to prices different to the marginal cost. No matter how small, the captive market segment causes physicians to price as monopolists. Thus, many suppliers serving their small captive segments for a positive fee viably exist in the competitive equilibrium.

This result, outlining a peculiar relation between the number of physicians in the market and the fees they charge, has previously been described in the literature. Several pioneering econometric analyses of healthcare markets found a partial positive correlation between the physicians stock and prices (Feldstein (1970); Fuchs and Kramer (1972)). Those studies contradict the predictions of standard competitive model, opening the door for alternative explanations, one of which might be the informational route this paper proposes.

C.1. Extensions to the original model

The side of the consumers and the way they process the anecdotes sampled remains unchanged.

[21] Full proofs for this appendix are available upon request.

There are n physicians in the market, indexed by $i \in N = \{1, 2, \cdots, n\}$. The physicians compete in prices and abilities. We define the ability $\alpha_i \in [0, 1]$ as the probability for a physician i to change a patient's health state. The physicians compete in abilities and prices. The ability choice is costless.The physicians charge a fee $p_i \in (0, 1)$ for their services. We assume the marginal cost for providing healthcare services to be negligible.

All the physicians choose their abilities independently and simultaneously, before meeting the consumers. The physicians are fully rational and perfectly informed. That is, they observe the ability chosen by all the other physicians in the market once it has been chosen. Next, they simultaneously set prices to maximize their individual profits. The physicians' fees are publicly known, whereas their abilities are unknown to the consumers. The consumers estimate these abilities through small samples of anecdotal-evidence gathered from past consumers.

Not all physicians in the market are equally visible to the consumers. When sampling for anecdotal evidence a consumer has access to a limited subset of physicians. She will only be able to gather anecdotes about those physicians who have treated someone she knows. We denote $\gamma_i \in (0, 1]$ for all $i \in N = \{1, 2, \cdots, n\}$ to be Physician i's visibility, the exogenously given probability for him to be considered by any particular consumer. All visibilities are known by the physicians. The patients base their participation decisions on the sampling rule described in this paper's main duopolistic model. To be clear, a consumer draws a single anecdote for each physician she is aware of and then, if the anecdote is positive, she believes she will also be cured if she visits such physician, estimating his ability to be 1. On the other hand, she discards the idea of visiting the physician upon finding a negative anecdote, which amounts to taking his ability to be 0. Once the sampling process has taken place over all the physicians a consumer is aware of, she compares the subset for which she found positive anecdotes. The consumer believes she will be cured with probability 1 if she visits any of such physicians. Thus, she bases her decision on the fees they charge.

The timing of the game is not changed. We proceed our analysis by backwards induction. First, taking as given abilities and fees established by the n physicians present in the market, we pay attention to the decisions the consumers make by gathering anecdotal information. Next, we move to the n physicians' pricing decisions, which we describe for any given vector of abilities ($\alpha = (\alpha_1, \alpha_2, \cdots, \alpha_n)$). Finally, we consider the ability setting stage, where physicians decide the ability level with which they will partake in the market.

C.2. Consumer behavior with n Physicians

Consumers can only observe anecdotes for those physicians who have treated someone they know. We denote this her consideration set. The set of all possible consideration sets is the power set of N. The visibilities, γ_i $\forall i \in N = \{1, 2, \cdots, n\}$, define a probability distribution over this power set, which could be understood as the probability that a given consumer has each of the possible consideration sets.

Each consumer takes an independent, size-1 sample for each physician in her consideration set. Thus, for the market with n competitors we consider, the sampling process is modeled as if the consumers observe a single realization of a Bernoulli distributed random variable with a parameter equal to Physician i's ability α_i. Thus, when she samples, a consumer who is aware of Physician i observes a positive anecdote from a patient who visited him with probability α_i.

The consumers build their beliefs on the abilities of the physicians based entirely on the anecdotal evidence they find in their consideration sets. Therefore, probability α_i can also be understood as the expected proportion of consumers who observe a positive anecdote from Physician i. As a result, a consideration set is divided in subsets comprising all the physicians for whom the consumer has found a positive anecdote. We denote these as the sets of *acceptable physicians*, since all the physicians comprised in them are estimated by a consumer to be of maximal ability. If she can afford it, the consumer will visit the "cheapest" of the physicians included in her *acceptable* set.

Given the form of their utility function, among all the consumers who would in principle demand the services from a particular physician included in their respective **acceptable physicians** sets, only the ones with a high-enough willingness to pay end up visiting the physician. With thus build the demand Physician i faces, which encompasses the consumers who have any possible consideration set including Physician i, and both captive and contested segments as in the duopolistic case.

The size of the captive and contested demand depend not only on a Physician's own ability and exogenously set visibility, but also on those of his rivals. For example, if $n = 4$ the demand for Physician 1 would be the following:

$$\begin{aligned} D_1 =& \gamma_1\alpha_1 [\gamma_2\gamma_3\gamma_4(1-\alpha_2F_2(p_1))(1-\alpha_3F_3(p_1))(1-\alpha_4F_4(p_1))+ \\ & \gamma_2\gamma_3(1-\gamma_4)(1-\alpha_2F_2(p_1))(1-\alpha_3F_3(p_1))+ \\ & \gamma_2(1-\gamma_3)\gamma_4(1-\alpha_2F_2(p_1))(1-\alpha_4F_4(p_1))+ \\ & (1-\gamma_2)\gamma_3\gamma_4(1-\alpha_3F_3(p_1))(1-\alpha_4F_4(p_1))+ \\ & \gamma_2(1-\gamma_3)(1-\gamma_4)(1-\alpha_2F_2(p_1))+ \\ & (1-\gamma_2)\gamma_3(1-\gamma_4)(1-\alpha_3F_3(p_1))+ \\ & (1-\gamma_2)(1-\gamma_3)\gamma_4(1-\alpha_4F_4(p_1))+ \\ & (1-\gamma_2)(1-\gamma_3)(1-\gamma_4)]\,(1-p_1)\,, \end{aligned}$$

Where $F_j(p)$ represents the cumulative distribution of probabilities physician j assigns to prices in the pricing domain up to price p. We use this as a way to represent the possible mixed pricing strategies of physicians.

When rewritten, this expression reduces to:

$$D_1(p) = \gamma_1\alpha_1(1-\alpha_2\gamma_2F_2(p))(1-\alpha_3\gamma_3F_3(p))(1-\alpha_4\gamma_4F_4(p))\,(1-p_1)$$

Using similar arguments for the n-physicians case, the demand a Physician i faces where $i \in N$, is:

$$D_i = \gamma_i\alpha_i \prod_{j\neq i}(1-\alpha_j\gamma_jF_j(p_i))\,(1-p_i)$$

C.3. Price competition with n Physicians

For the sake of expositional clarity in the analysis of the physicians' pricing strategies, and *without loss of generality*, we assume that $\gamma_n\alpha_n \geq \gamma_{n-1}\alpha_{n-1} \geq \cdots \geq \gamma_1\alpha_1 > 0$.

We also assume $1 > \gamma_n \alpha_n$. These assumptions entail three main implications: First, that no matter how low a physician's ability is, a non-zero portion of the consumers will observe him. Second, some of the patients who have been treated by a given physician in the past will be cured irrespective of the physician's ability level. Third, there may be physicians who are dominant in a combination of visibility and ability. We loosely denote this interaction as a proxy for the information available on a physician. That is, it is easier to find anecdotes for a physician with a superior $\gamma_i \alpha_i$, particularly positive ones.

As in the duopolistic case, there is no Nash Equilibrium in pure strategies for the game we solve. This happens because, regardless of the rivals' pricing strategies, a physician will always serve a positive portion of the demand even if being undercut by a competitor. We have assumed the cost of providing the service to be negligible. Setting a price equal to the marginal cost would yield zero profits for a physician, and he would rather set any positive price and derive profits from his captive segment, irrespective of the rivals' pricing strategies. This is only possible because $\alpha_i \gamma_i > 0$ and $\alpha_i \gamma_i < 1$ for all i; one of the implications derived from the assumption opening this section.

Carrying this analysis into the backwards-induction solution of the pricing stage of the game, we find an asymmetric Nash Equilibrium in mixed strategies for price competition.

The mixed strategy equilibrium is such that every physician randomizes over some of the pure strategies available. In particular, every physician in the market randomizes over some price interval between zero and one-half. The price interval supporting a physician's strategies is defined by the relative size of his combined ability and visibility with respect to those of his rivals.

In the mixed strategy Nash Equilibrium we set forth below, physicians mix over different price intervals. Every physician i mixes over a strategy support $[p^L, p_i^H]$. Given the abilities $\alpha_i \in (0,1] \quad \forall i \in N$, and exogenous probabilities of being considered $\gamma_i \in (0,1] \quad \forall i \in N$. We define a sequence of prices $\{p_1^H, p_2^H, \cdots, p_n^H\}$ with $p_1^H \leq p_2^H \leq \cdots \leq p_n^H$, where:

$$p_j^H = \frac{1 - \sqrt{1 - \frac{\prod_{h=j+1}^{n-1}(1-\alpha_h\gamma_h)}{(1-\alpha_j\gamma_j)^{(n-j-1)}}}}{2}$$

for $j \in N \setminus \{n-1, n\}$ and $p_n^H = p_{n-1}^H = \frac{1}{2}$

The following figure illustrates what the strategy supports will typically look like.

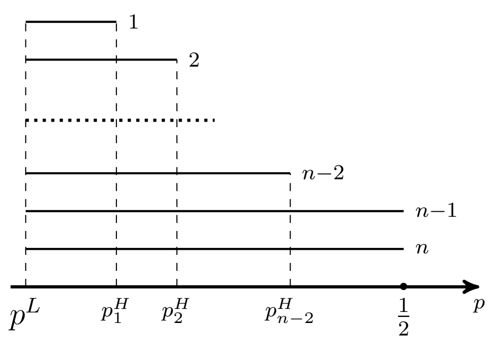

Figure C2: Strategy supports

From a game-theoretical point of view, the asymmetry in equilibrium pricing strategies comes from the very definition of mixed strategy Nash Equilibrium. Such an equilibrium requires that, for a physician to randomly choose from any two available prices, the profits associated with them to be the same, thereby making him indifferent. If this were not the case, the physician would choose the price that yields the higher profits to him instead of randomizing. In our setting this strategic thinking derives in an asymmetric mixed strategy Nash Equilibrium in which dominated ability-visibility physicians price more aggressively. That is, physicians for whom information is less plentiful set lower prices.

Positive anecdotes for dominated physicians, conditional on being observed, are harder for consumers to come by. Hence, in order to be more competitive, such physicians need to be found less expensive than their dominant rivals. A lower price allows them to attract demand from their contested segment with a higher probability, given the relatively small captive segments they hold. This leads to an equilibrium in which the more dominant a physician is, the larger his pricing interval and the higher his average price.

In principle, this is a counterintuitive result. A dominant physician would be expected to price more aggressively, if only due to his contested demand segment being larger. This is not the case in the equilibrium we find, where dominated physicians set low prices with higher probability. Moreover, the fact that physicians whose information is more plentiful choose to set higher prices and focus on deriving profits from their captive segments, resonates with the duopolistic setting described in the duopolistic setting explored in this paper's main model.

All things being equal, a higher ability level allows a physician for a larger pricing support and a higher expected price in the equilibrium. Proposition 5, presented below, formally describes the equilibrium strategies.

Proposition 5. *In the price competition stage of the game, with n physicians active in the market, there is a Nash equilibrium in mixed strategies characterized by the following c.d.f.:*

$$F_i(p) = \frac{1}{\alpha_i \gamma_i} \left[1 - \left(\frac{\prod_{h=j}^{n-1} (1 - \alpha_h \gamma_h)}{4p(1-p)} \right)^{\frac{1}{n-j}} \right] \quad \textit{for } \; p \in [p_{j-1}^H, p_j^H] \subset (p^L, p_i^H]$$

for $j < i$ with $F_i(p) = 0$ for all $p < p^L$ where $p^L = \frac{1 - \sqrt{1 - \prod_{\kappa \neq n} (1 - \alpha_\kappa \gamma_\kappa)}}{2}$ and $F_i(p) = 1$ for all $p \geq p_i^H$.

We believe such equilibrium to provide some interesting intuitions. First, a dominant physician (one with a higher visibility and superior care-provision capabilities) is more likely to set a high price than less popular and less able competitors. In some sense, ability-visibility dominance provides physicians with superior market power which allows them to price highly and obtain higher equilibrium profits from both of the. To some extent, the asymmetry in equilibrium pricing strategies mimics the asymmetry we assumed in the ability-visibility combination.

In this section we presented a first glance at the incentives for ability differentiation between physicians, as they derive from the demand structure and the second-order effects operating between the physician's profits functions and the abilities and visibilities of their rivals. We continue to solve the game by backwards induction, moving now to the stage where the physicians choose their ability level.

C.4. Ability competition with n Physicians

Generally speaking, a high-ability physician whose past-patients are hard to find will likely have a smaller captive segment than a well-known competitor with a lower ability level. The reverse argument is not necessarily true in a market with many competitors. A physician with a large visibility will be included in a large number of patients' consideration sets. However, a low ability could avoid him from being included in the *acceptable set* if the anecdote found for him were a negative one, therefore rendering his innate visibility-advantage irrelevant in the market.

Proposition 6 shows that for a given set of visibilities there is a unique Nash equilibrium in this stage of the game.

Proposition 6. *In the ability choice stage of the game and given exogenous physicians' visibilities such that $\gamma_n \geq \gamma_i \; \forall i \in N$, the equilibrium abilities are:*

$$\alpha_i^* = \begin{cases} \frac{1}{2\gamma_1} & if\ \gamma_i > \frac{1}{2} \\ 1 & if\ \gamma_i \leq \frac{1}{2} \end{cases} \quad for \quad i < n$$

and

$$\alpha_n^* = 1$$

The main implication of this equilibrium is that the better-known physician always chooses the maximum ability level. That is, the physician who is included in the most number of consideration sets is also the one who most often appears in the consumers' *acceptable* sets. One interpretation for this behavior might be that the physician whose past patients are more numerous, hence being more visible, has incentives to consolidate his innate competitive advantage by choosing a high ability level. Since the ability choice is assumed to be costless in our model, it is natural for the equilibrium decision of such physician to be the maximal ability value.

Every non-dominant physician i maximizes his profits by choosing his ability level such that the ability-visibility combination is $\alpha_i \gamma_i = \frac{1}{2}$ whenever possible. However, when the physician's visibility is below one half he is unable to reach this ability-visibility combination level. Thus, he chooses the maximum level of ability available to him, which is $\alpha_i = 1$.

This results in non-dominant physicians following either of two strategies, depending on the size of their visibility. If a physician's visibility is below $\frac{1}{2}$ he chooses the maximum ability level. Otherwise, the physician sets a lower ability level as a function of his own visibility. Therefore, differentiation in abilities is observed between the portion of physicians who have a visibility level of at least $\frac{1}{2}$ and those whose value for γ_j falls below such threshold.

These equilibrium strategies carry several interesting implications. First, in terms of the ability, the relatively-dominant physician is pooled with those who have lower visibilities. Thus, by choosing a high ability the physician increases the mass of consumers who could potentially demand his services. In practical terms, if a consumer has the relatively dominant physician and another with visibility below $\frac{1}{2}$ in her *acceptable* set, the two physicians are deemed to be identical in abilities for her, competing exclusively in terms of their fees. The fact that the ability is costless allows for such an equilibrium to arise.

The truly peculiar market outcome appears in the segment of physicians whose visibility is above $\frac{1}{2}$, thus closer to that of the relatively dominant one. These physicians, a priori in lesser of an informational disadvantage than the physicians with visibilities below the threshold, settle for a lower ability. This result extends into a competitive environment what we found in the duopolistic setting presented in the present paper.

Indeed, we find that more plentiful information leads to more differentiation in abilities even when there are many physicians in the market. Moreover, the less visible a physician is, the more his equilibrium ability converges to the maximal level. Thus, the physician who per our hypothesis on the sizes of the visibilities, could be considered immediately behind the relatively dominant player, sets an ability nearly half the value of the equilibrium ability set by the dominant one. Hence, if information on all the physicians were abundant and thus led to high visibilities across the market, the average equilibrium abilities would decrease with respect to a scenario were visibilities were below $\frac{1}{2}$.

This result leads to a puzzling situation for a planner. Intuition would suggest that releasing more information in healhcare markets should be beneficial for the patients in the sense that it could correct some of the distortions generated by the patient-physician informational asymmetry. We find that not to be the case, particularly with boundedly-rational patients. If the goal of a planner is to increase the mass of high-ability providers, which would indeed lower the equilibrium prices as well, he would have to decrease the physicians' visibilities.

C.5. Concluding remarks

When extending the duopolistic market analyzed in this paper to a competitive one, we identify three types of physicians per their equilibrium ability choices: the relatively dominant one, those who are very visible and set a low ability, and those who are not very visible and set a high ability.

In the equilibrium the market will comprise: a very visible physician who charges a high fee but offers a high-quality service, a few physicians who are quite visible but not as much as the relatively-dominant player and charge a smaller fee for a service of relatively lesser quality, and a mass of smaller and hardly visible physicians who compete for patients in prices and offer a service of quality comparable to that of the relatively dominant provider.

A planner might affect the composition of such market by controlling the physicians visibilities. Higher visibility values lead to lower average equilibrium abilities. Moreover, if all visibilities were equal to one – all physicians being universally visible –, we get an analogue of Spiegler (2006) and Szech (2011) results, in what could be called maximal ability differentiation, with one of the physicians setting an ability level of one and the other choosing one half. This is also in line with the results presented in the duopolistic scenario. That is, more ability differentiation is observed when information on the physicians is more readily available.