Appendix B. Analysis of the case where ability choice has a positive cost [19]

In this appendix we examine to what extent the results presented in our main model are driven by the assumption of a costless ability. Particularly the equilibrium where all physicians choose the maximum ability level despite the heterogeneity in their visibilities and the limited information available to the consumers. We introduce a convex cost for the abilities in order to capture the investment physicians make when setting a high ability level. Aside from expanding our main model, this separates us from preceding works which either did not consider the abilities as a strategic variable or took it as a costless choice.

We find that the two physicians differentiate in abilities for any combination of visibilities in the support. That is, while in the costless case they both set the same ability level as long as at least one of their visibilities was small enough, here the relatively-dominant physician will always choose a higher equilibrium ability, no matter the specific size of the visibilities.

The relatively-dominant physician is defined as the one who has a superior visibility. In the equilibrium the relatively-dominant player is in an advantageous situation with respect to his competitor, for he charges a higher fee, serves a bigger demand, and obtains more profits than the rival.

Both physicians' equilibrium abilities decrease in the cost. Thus, the costlier it is for a physician to offer a high-quality service, the further down the overall market standard is pushed. This feature might potentially interest a planner.

The difference between the equilibrium abilities diminishes as the non-dominant physician's visibility increases, thus reducing the dominant player's advantage. Again, a relevant feature policy-wise, for it would entail that more information could lead to a higher average ability in the market. That said, since abilities are exogenous in our model, the implications for a planner are not immediate.

B.1. Extensions to the original model

The main setting and timing remain the same except for the addition of a costly ability.

The ability choice cost for Physician i is described by the following function:
$C(\alpha_i) = \frac{1}{2}c\alpha_i^2$, where $c > 0$.

Providing the healthcare service is otherwise costless for the physicians.

B.2. Analysis of the equilibrium with costly abilities

The price competition stage of the game is unchanged. The physicians face the same demands as in the costless case, each comprising captive and contested segments. When competing in abilities, the physicians maximize their profits knowing that they will next compete in prices. Thus, more generally speaking, the maximization problem Physician i faces if he is the relatively-dominant player is the following:

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

$$
\begin{aligned}
\max_{\alpha_i} \quad & \frac{\alpha_i\gamma_i(1-\alpha_j\gamma_j)}{4} - \frac{1}{2}c\alpha_i^2 \\
\text{st.} \quad & \alpha_i \geq \frac{\gamma_j}{\gamma_i}\alpha_j,
\end{aligned}
$$

where $i, j \in \{1, 2\} : i \neq j$. Physician j's maximization problem is only different in that his demand is a function of his own ability and visibility, not the rival's, as described in the main model.

The convex cost function $C(\alpha_i) = \frac{1}{2}c\alpha_i^2$ captures the fact that a physician's incentives to set a high ability, so that he is able to attract many consumers from both the captive and contested demand segments, are counterbalanced by how costly it is for him to increase his ability level. If in the costless ability choice setting we modeled the diagnose technology or professional preparation a physician decided to acquire before entering the market, when this decision is costly we move closer to a setting where the physician decides his performance standards during a specific market period.

From solving the respective maximization problems we find that there are two possible equilibria in the ability competition stage, which will be adopted by the physicians depending on the relative size of their visibilities. We denote these equilibria as follows:

$$
\begin{aligned}
(\widetilde{\alpha_1}, \widetilde{\alpha_2}) &= \left(\frac{\gamma_1(4c+\gamma_2^2)}{8c(2c+\gamma_2^2)}, \frac{\gamma_2}{4c+2\gamma_2^2}\right), \quad \text{and} \\
(\widetilde{\alpha_1}', \widetilde{\alpha_2}') &= \left(\frac{\gamma_1}{4c+2\gamma_1^2}, \frac{\gamma_2(4c+\gamma_1^2)}{8c(2c+\gamma_1^2)}\right).
\end{aligned}
$$

In which case either of these will be the equilibrium strategy played by the physicians is determined by the following visibility levels:

$$
\gamma_1^A(\gamma_2) \equiv \frac{2\gamma_2\sqrt{2c(2c+\gamma_2^2)}}{4c+\gamma_2^2} \quad \text{and} \quad \gamma_1^B(\gamma_2) \equiv \sqrt{\frac{4c\gamma_2^2}{2(c+\sqrt{c(c+\gamma_2^2)}) - \gamma_2^2}},
$$

where $\gamma_1^B(\gamma_2) > \gamma_2 > \gamma_1^A(\gamma_2)$. These cut-off levels define three regions in the physicians' visibility space. In these regions the equilibrium decisions of the physicians will either be $(\widetilde{\alpha_1}, \widetilde{\alpha_2})$, $(\widetilde{\alpha_1}', \widetilde{\alpha_2}')$ or both.

Thus, the equilibria found when the physicians compete in abilities depends on the region their visibilities fall into. We formally describe the result in the following proposition.

Proposition 4. *In the ability competition stage of the game, with two physicians active in the market and given the visibilities $\gamma_i \in (0, 1)$ for $i \in \{1, 2\}$, the set of Nash Equilibria is the following:*

a. $\{(\widetilde{\alpha_1}, \widetilde{\alpha_2})\}$ *if* $\gamma_1 > \gamma_1^B(\gamma_2)$.

b. $\{(\widetilde{\alpha_1}, \widetilde{\alpha_2}), (\widetilde{\alpha_1}', \widetilde{\alpha_2}')\}$ *if* $\gamma_1 \in [\gamma_1^A(\gamma_2), \gamma_1^B(\gamma_2)]$.

c. $\{(\widetilde{\alpha_1}', \widetilde{\alpha_2}')\}$ *if* $\gamma_1 < \gamma_1^A(\gamma_2)$.

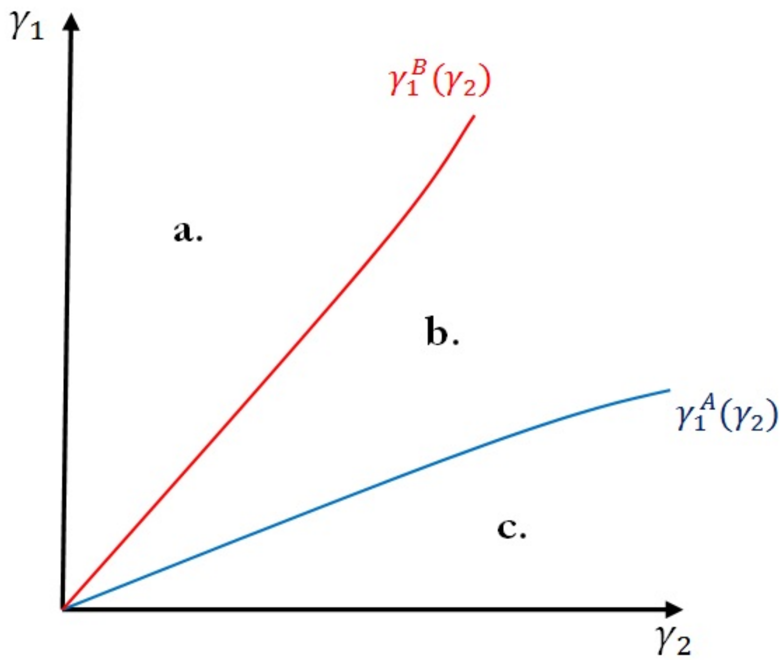
We can see that a unique Nash Equilibrium in abilities is found when the physician's visibilities are such that they fall either in regions $a.$ or $c.$ On the other hand, if the visibilities are in region $b.$, there are two Nash Equilibria in abilities. In region $b.$, Physician 1 either sets a high or low ability level, with $\widetilde{\alpha_1}$ being the superior ability if $\gamma_1 \in [\gamma_2, \gamma_1^B]$. For the rival, $\widetilde{\alpha_2}'$ is the superior ability when $\gamma_1 \in [\gamma_1^A, \gamma_2]$. However, $\widetilde{\alpha_1}'$ and $\widetilde{\alpha_2}$ are also equilibrium strategies in the region.

In the case where γ_1 falls in regions $a.$ or $c.$ the relatively-dominant physician always sets the highest ability level. Thus, Physician 1 is the relatively-dominant player in region $a.$ and Physician 2 in region $c.$

The equilibrium abilities in the three regions are functions of the physicians' visibilities and the cost. Regardless of who is the dominant player, the relative size of the visibilities largely affect the ability levels observed in the equilibrium.

In the following graph we present the three equilibria described and the visibility combinations determining the regions where they will be found. Each region is denoted with the corresponding equilibria set, as detailed in the Proposition.

Figure B1: **Nash Equilibria in the Ability Competition Stage**



It is easy to identify the relatively dominant player in the regions where only one Nash Equilibrium exists. In region $a.$, Physician 1 is the relatively-dominant player, setting a higher ability level and serving a bigger demand. On the other hand, Physician 2 is the relatively dominant player in region $c.$

Both regions $a.$ and $c.$ expand when the ability choice becomes more costly. Naturally, a costlier ability choice makes it less attractive for a non-dominant physician to set a high ability level in the equilibrium. For instance, if the cost c is high and $\gamma_1 \in [\gamma_1^B, 1]$, Physician 1 is more likely to choose $\widetilde{\alpha_1}$ in the equilibrium. That is, the region where $\widetilde{\alpha_1}$

and $\widetilde{\alpha_1}'$ are equilibria for him, becomes smaller. In Figure 1 this would amount to region $b.$ becoming smaller as the ability cost rises.

All things equal, a higher ability allows the relatively-dominant physician to charge a higher fee since his captive demand segment enlarges. A higher equilibrium fee is an evident reply to a higher ability cost. Region $a.$ also expands in γ_2, which means that when the relatively-dominant physician's advantage becomes less strong, he has incentives to set a high ability in the equilibrium, provided the cost is not too high. If the mass point included in his equilibrium pricing strategies' $C.D.F.$ becomes smaller, then the dominant physician's captive demand segment is diminished. Hence, the physician has incentives to be more competitive over the contested demand segment and the way for him to do this is through a high ability level. In other words, the two responses the relatively-dominant physician has to counter an increase in the rival's visibility is to set a high ability level or lower his fee.

We discuss the comparative statics of these abilities in the following corollary.

Corollary 1. *In any of the Nash Equilibria presented in Proposition 4 the physicians' abilities increase in their own visibilities and decrease in that of the rival's. Both physicians' equilibrium abilities negatively depend on the ability cost.*

As expected, the physicians' abilities in the three regions decrease as the cost rises. Unlike the main model's results with a costless ability, here any small but positive cost would imply a lower average equilibrium level in abilities for similarly low visibility values. This, however, does not imply an increase in the difference between the two abilities. The average ability is lower the higher the cost gets, but $\widetilde{\alpha_1}$ and $\widetilde{\alpha_2}'$ continue to be superior to the rival's in regions $a.$ and $c.$ That is, both abilities decrease in the cost but none more so than the other, neither to the point where the relatively-dominant physician ceases to be so.

In terms of visibilities we find that $\widetilde{\alpha_1}$ negatively depends on Physician 2's visibility. Similarly, $\widetilde{\alpha_2}'$ decreases in γ_1. We can therefore say that the relatively-dominant physician's ability decreases in the rival's visibility. This suggests that when a physician's dominant position is weakened, he has fewer incentives to set a high ability in the equilibrium.

The equilibrium abilities for both the dominant and non-dominant physicians in regions $a.$, $b.$, and $c.$ are increasing functions of their own visibility. When more consumers are aware of a physician and can find positive anecdotes easily, such a physician not only serves a bigger demand, but also charges a higher fee for his services. As a consequence, when the rival is more visible a consumer is more likely to find two positive anecdotes simultaneously. This implies a higher probability that consumers will consider the physicians equivalent in abilities, basing their decision to visit one of them on the price. Setting a high ability level while charging a lower fee is not attractive for the relatively-dominant physician, given the negative relationship between $\widetilde{\alpha_1}$ and γ_2, and $\widetilde{\alpha_2}'$ and γ_1.

Therefore, more information becoming available to the consumers in the form of easier-to-find anecdotes might lead to smaller fees but it will also lower the average ability levels in some equilibria, particularly when the relatively-dominant physician's visibility remains unchanged with respect to an increase in the rival's. This result is consistent with our findings in the case of a costless ability choice, where low average ability levels appeared when the two physicians' visibilities were above $\frac{1}{2}$. On the contrary, if both visibilities increase simultaneously, with the dominant physician's advantage being only narrowly affected, both physicians might have incentives to increase their ability level if the marginal cost of doing so is small enough. That is, a low cost and low visibilities might lead to higher equilibrium abilities in our model than high visibilities and a low cost.

In all cases, a Physician's profit levels increase in his visibility. That is, he is able to attract more consumers, has incentives to set a higher ability level, and can charge a higher fee. This is true for both the dominant and the non-dominant players, though the effect is somewhat amplified for the dominant physician. On the other hand, a costlier ability diminishes the profits level for the physicians. A higher cost causes the physicians' captive demands to shrink, forcing them to compete in prices.

The total profits obtained by the two physicians are always higher when the relatively dominant physician chooses a high ability. That is $\widetilde{\Pi_1} + \widetilde{\Pi_2} \geq \widetilde{\Pi_1}' + \widetilde{\Pi_2}'$ in region $a.$, where Physician 1 is the relatively-dominant player, but also in the portion of region $b.$ where $\gamma_1 \in \left[\gamma_2, \gamma_1^B\right]$. The same argument applies for Physician 2 and the region determined by $\gamma_1 \in (0, \gamma_2)$.

Given the equilibrium allocations found, we know that both physicians will always choose different ability levels leading to one leader and a follower.

Following a Pareto-efficiency argument in terms of the total industry profits we can say that Physician 1 will be the relatively-dominant player when $\gamma_1 \geq \gamma_2$, with the physicians setting the equilibrium abilities corresponding to Proposition 4's region a. Physician 2 is the relatively-dominant player when $\gamma_2 > \gamma_1$ and the equilibrium is the one defined in Proposition 4's region c. Under this frame of analysis, where a total efficiency argument would take precedence, the dominant physician would always be the one who has the higher visibility level.[20]

The ability cost is what ultimately determines whether the non-dominant physician will set a higher equilibrium ability the more visible he is. That is, both physicians' ability choices decrease in the cost. However, if this cost is high enough the non-dominant physician may have incentives to set a higher ability in the equilibrium the higher his visibility is. The rationale for this being that the non-dominant physician can catch-up quickly to his rival, since both the ability cost and the increase in the non-dominant physician's visibility undermine the dominant player's advantage.

A higher ability increases the non-dominant player's competitiveness and his potential demand. On the other hand, if the ability cost is low or very close to zero, the non-dominant physician's equilibrium ability decreases in his visibility. This happens because the non-dominant physician decides to focus on his captive demand, charging a higher fee. The low ability cost also means that the dominant physician will choose a high ability, becoming a tougher competitor over the contested segment of the demand. This outcome is very close to what we found when the ability choice was costless. Moreover, high visibility levels and a low ability cost would lead to an outcome where the differentiation is maximum, as found in the main model.

[20]This hints at the importance of family sagas and inherited advantages as captured by the visibilities in our model, a particularly interesting implication in the analysis of a dynamic setting. That said, the existence of more than one Nash Equilibria in one portion of the visibility space somewhat complicates this analysis.

B.3. Concluding remarks

When we extend the paper's main model to include a costly ability choice, we find that the relative size of the physicians' visibilities will determine their abilities in the equilibrium. They differentiate when the difference in visibilities is large, with the relatively-dominant player setting a higher ability level than his rival. Moreover, in many cases the relatively-dominant physician is also the one who has a higher visibility. On the other hand, if the visibility levels are not too far apart, two robust equilibria in abilities are found. In each of them, one of the physicians sets a higher ability than the competitor, though the relationship between the visibility level and the equilibrium ability of each one is not as clear.

The total healthcare profits are bigger when the relatively-dominant physician is the one who sets the highest ability in the equilibrium. The dominant player serves the largest demand and charges the higher fee for his services, obtaining the most profits as well. These results align with the ones discussed in the costless case, although there are many other important differences that deserve to be mentioned. First, when the ability is costly there is no equilibrium where the two physicians set the maximum ability. Neither is there one where the competitors choose the same ability level. The two physicians differentiate in abilities for all visibilities as long as the choice carries a cost. Furthermore, the costlier the ability decision is, the lower the equilibrium average ability in the market.

The two physicians' abilities increase in their visibilities, with the dominant player's position becoming stronger as his visibility increases. The easier it is for a consumer to find an anecdote for a given physician, the more incentives he has to set a high ability. This result somewhat contradicts our findings in the costless ability case, since here the equilibrium where both visibilities are equal to one does not lead to the maximum differentiation in abilities. That is, when both physicians are equally visible, their costly ability choice facing boundedly-rational patients is not trivial. This suggests several questions regarding which we hope to explore in the near future.