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# Thesis Draft

## Master in Economics

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# 1 Introduction

The question of sickness at work presents us with a principal-agent problem: though in cases of true sickness it is best for the employee’s personal wellbeing and indeed even firm productivity [Chunyu et al. \(2024\)](#) that they should stay home, it would also be possible to call in sick without any affliction, skipping work undetected.

The common solution to this problem is third-party certification, a specialized professional to attest to the condition and allow for or even demand of the employer that sick leave be granted. And who else to carry out this evaluation than physicians themselves—knowledgeable on the subject as they are—making diagnosis, treatment referral and certification of sickness a one-stop-shop for the patients.

The problem with this oversized, multi-faceted role physicians play in healthcare systems is that it causes conflict of interests. In cases where sick leave calls (and insurance claims) call for state-subsidized payments to be issued, we can speak of a second principal-agent problem between the physician, exercising the role of “gatekeeper”, and the taxpayer, bankrolling public healthcare and insurance.

There is evidence to the fact that even in the best of cases physicians have no incentive to place doubt on their patients claim to unobservable symptoms ([Carlsen et al.; 2020](#)), and in murkier scenarios they could be motivated to gain the reputation of being “lenient” to enjoy increased demand for their services ([Markussen and Røed; 2017](#)).

In Chile, the country of our sample, the healthcare system is bi-modal: citizens may opt for one of many private health insurers (ISAPRES) or the sole public option (FONASA), and 82% of them are affiliates of the latter. In their case, the authority behind sick leave granting is COMPIN, with the power to oversee, investigate and even sanction physicians that fall under it. A worker granted sickness absence is entitled to a work incapacity benefit (SIL), periodic payments paid in function of sick leave length.

Anecdotal evidence speaks to the presence of fraud in the system. A survey by the U. Andrés Bello Public Health Institute ([2024](#)) has it that 51% of those surveyed know someone who was granted sick leave without any sickness, 62% believe that physicians “frequently” create irregular businesses for the sale of sick leave certificates, and 56% think it would be “easy” to purchase one.

The presence of fraud is not unknown to the overseeing authority. In September 2021, COMPIN sanctioned 188 physicians who were not able to justify their unusually high issuance rate. [Oteíza \(2023\)](#) finds that this one time intervention had a spillover on non-sanctioned doctors, who on average reduced their issuance rate by at least 5.22%, on conservative estimates. This is further proof that sick leave granting is influenced by profit-seeking, and readjusted expectations of the probability of being met with punishment does influence physicians’ willingness to provide them to patients.

This paper seeks to develop a framework within which physicians’ behavior may be rationalized and modeled. It presents physician in a dual role as both medical care-takers and issuers of sick leave, and patients value both aspects separately according to population distributions. Patient strategies are the probabilities with which they’ll visit any given physician, and physician strategies is their choice of “leniency”, how willing they are to grant sick leave according to patient characteristics.

A generalized framework of patient search is laid out and contrasted with a non-search baseline, i.e. a particular kind of equilibrium in which patient strategies are set as randomized over all physicians with no distinction, that is to say, in which they’re assigned a physician with no say on the matter but whether to visit. Once patient ‘search’ comes into play, physicians take into consideration the behavior of the rest of their colleagues—and its implication on their own market share—when opting for a given level of strictness in sick leave issuance, meaning there’s a *strategic* element now involved, where physicians will be wary to lose out on too many patients to more *lenient* colleagues.

We then present two particular specifications of the ‘search’ framework: an “implicit” search model, where patient behavior takes on the form of a modified McFadden Logit<sup>1</sup>, and an “explicit” search model, akin to sequential job search models, in which patients visit physicians which render them services above their “reserve utility”.

## 2 Literature Review

It is a well established factum that taking sick leave is subject to an economic calculus on part of the workers, rather than being an orthogonal, merely health-concerned matter. Johansson and Palme (2005) begin their article with a quote by Nobel Laureate Ragnar Frisch: “Regarding the high absence rate at the Department: Acquiring minor diseases, such as colds or flu, is an act of choice”. Their paper is among many others—Paola et al. (2014), Markussen et al. (2012), Stearns and White (2018), Henrekson and Persson (2004)—which give empirical evidence of such a choice being driven by economic incentives, through an event study on exogenous institutional regime changes in the sampled nation’s public insurance system. This line of research, however, is concerned with the actions of workers themselves and their subsequent effect on macroeconomic employment variables, whereas our main focus shall be the role played by physicians.

As for the literature on physicians themselves, it has become commonplace to regard them as agents with two sources of utility: their income and their “altruistic” interest on their patients’ well-being. Empirical support for the latter can be found in experimental evidence both on medical students (Brosig-Koch et al. (2017), Hennig-Schmidt and Wiesen (2014)) as well as doctors themselves (Kesternich et al. (2015), Brosig-Koch et al. (2016)). Crea (2019) finds no evidence for this, whereas Godager

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<sup>1</sup>See McFadden (1972).

and Wiesen (2013) do, and explore its heterogeneity across physicians. The fact that physicians are also concerned with revenue, rather than being purely altruistic, is also well evidenced, see Clemens and Gottlieb (2014), Hennig-Schmidt et al. (2011), Autor et al. (2014), and also Robertson et al. (2012) for a review on the matter. Therein lies the dilemma with giving physicians the status of gatekeepers for different services and certifications, like disability insurance (as in autor). As Markussen and Røed (2017, p. 1) put it: “In essence, the GPs [general practitioners] have been assigned the task of protecting the public (or private) insurer’s purse against the customers who form the basis for their own livelihood”.

Both factors being well established in the literature on physicians, one strand of it would seek to design an optimal contract for medical care in the presence of such an economic calculus, see Choné and Ma (2011) or Gaynor et al. (2023); another, more in line with our approach, would evaluate the effects increased competition among doctors has on their rendered services. In general, Currie et al. (2023) propose that increased competition would lead to physicians offering more services that please the clients yet relatively hurt their own utility (like drug prescriptions), and less services which bring them, physicians, more utility, at the expense of patient utility (like unwanted, expensive surgical procedures). Iversen and Lurås (2000) and Iversen (2004) provide empirical evidence that somewhat supports it: physicians with a shortage of customers will provide more services, thus obtaining more income *per customer*. This line of work is more in line with our own approach, as the altruistic motivations of physicians are set momentarily aside and they’re modeled as purely profit-seeking. This reasoning applies to scenarios like ours, where the issuance of sick leaves—particularly for short-term absences, as is the case in most situations<sup>2</sup>—does not have a significant impact on client health.

To our knowledge, the only article dealing specifically with sick leave certificate granting as a function of competition among physicians is Markussen and Røed (2017). Carlsen et al. (2020) deal with sick leave as well, but make only the narrower point that in a Bayesian context doctors have almost no incentive to distrust patients’ self-reported, unverifiable symptoms. Markussen and Røed’s methodology is similar to our own: after performing “raw” regression analysis, they set-up a model of patient choice as a McFadden Logit over observables  $X_i$ , including physician leniency (assumed to be observable for prospective patients), and as such can estimate the role leniency plays in demand for their services. They then perform a series of exercises, some of their findings include: physicians with variable wage (i.e. dependent on clientele) certify 7% more absence days per month than fixed wage physicians; half of this difference has a causal interpretation, as observed from within-physician responses to market conditions; in general, more lenient gatekeeping gives the GP (physician) more customers, and more customers make the GP less lenient. Most of these stylized facts are taken up in our equilibrium models, in which patients take into account both sick leave “leniency” ( $\bar{\kappa}_j$ ) as well as physician quality ( $V_j$ ), such that physicians which

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<sup>2</sup>For cases where sickness leave is medically required we introduced the upper limit  $\bar{\kappa}_{\max}$ , such that physicians would never be so strict as to be negligent.

offer better medical attention and thus enjoy higher demand can afford to be “stricter”, and those who don’t will have the incentive to gain clientele through leniency. Not captured is the physician fixed effect, the idiosyncratic motive to leniency: we assume leniency as merely a strategic choice based on expected demand, where prior to choosing leniency physicians only differ in “quality” ( $V_j$ ) and visit revenue/cost of visit to the patient ( $r_j, \tau_j$ ).

Despite the different subject matter, the main source of inspiration for this paper is Schnell (2022), such that ours can be seen as an attempt to replicate her model and framework, initially devised for opioid markets, to the market for sick leaves. Schnell seeks to model the market scenario for the opioid crisis, with a primary market composed of physician prescriptions and a secondary black market. The presence of the latter, she concludes, makes unilateral interventions ineffective: curbing both excessive physician prescriptions as well as black market sales is required to make more than a dent on the number of opioids consumed in America.

Her paper includes four benchmark for the patient-physician market, building up to her main model including patient search, such that patients with a hire taste for opioids are assortatively matched with physicians more willing to prescribe them, and a secondary market. In our model we keep the former but not the latter, as the “black market” for sick leaves falls *within* the primary market of physicians, composed of those willing to knowingly issue fraudulent sickness certificates. Search was repurposed to fit a two-dimensional frame of physicians, characterized both by their strictness as well as their service quality. What we call the “explicit” search model is in the vein of Schnell’s sequential patient search, though more fleshed out in its dynamic programming framework for the reason just mentioned. Then there’s the “implicit” model, which defines patient behavior according to a modified McFadden Logit. We show in the Appendix A.2 that such a framework wouldn’t have altered Schnell’s main conclusions.

Our model differs from Schnell’s chiefly in the fact that physicians take into account *other* physicians’ behavior when selecting their own strategy, such that market equilibrium requires a Nash equilibrium in physician strategies. We discuss in the Appendix A.1 that the source of this feature, not present in Schnell’s model, is the lack of additive separability across patients in the physician’s utility function, such that her optimal behavior takes into account *aggregate* patient demand as well as *marginal*.

### 3 Model

We now present the model itself before proceeding with further discussion. We consider  $i = 1, \dots, I$  patients and  $j = 1, \dots, J$  physicians.<sup>3</sup>

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<sup>3</sup>Note on language: For ease of reference, we refer to any patient as “he”, and to any physician as “she” (s we have done already). At this point it shall be noted that the first person plural (we) employed over the course of this article is to be read as including the reader or perhaps as a royal *we*.

Patients are characterized by their “medical need”  $\kappa_i \in \mathbb{R}_0^+$  and their “taste for sick leave”  $\gamma_i \in \mathbb{R}_0^+$ , respectively following the ex-ante cumulative distributions  $F(\kappa)$  and  $G(\gamma)$ , which are public knowledge. Physicians are described by their “service quality”  $V_j \in \mathbb{R}^+$ , also known both to all patients and other physicians.

A patient  $i$  can visit a physician for treatment and may be also granted sick leave. After the patient is assigned a physician  $j$ , his utility function—implicitly dependent on his characteristic  $(\kappa_i, \gamma_i)$  tuple—is defined piecewise as follows:

$$U_i(V_j) = \begin{cases} \gamma_i + V_j \kappa_i - \tau_j & \text{if he's granted sick leave,} \\ V_j \kappa_i - \tau_j & \text{if he only visits the physician,} \\ 0 & \text{if no visit takes place} \end{cases}$$

As we see, there are three components to patient utility: an interaction between the patient’s medical need  $\kappa_i$  and the physician’s service quality  $V_j$  which implies their complementarity, his “taste” for sick leave  $\gamma_i$  in the case he’s granted one, and  $\tau_j$ , which we define as the cost of visit for physician  $j$ . As well as being complementary,  $\kappa_j$  as multiplied by  $V_j$  would give it the interpretation of being the marginal willingness to pay for physician quality.<sup>4</sup>

Whereas patients may visit at most one physician, a physician may see several patients. We define  $Q_j$  as the expected number of patients for physician  $j$ , the demand for her services. We say ‘expected’ because, as we’ll see later on, patients may opt for a mixed strategy, assigning a certain *probability* to visiting  $j$ , and we define  $Q_j$  as the sum of the ex-ante probability of visit of all patients, not their ex-post realization.

As physician  $j$  has the option to issue sick leave to a given patient  $i$  which visits her, we likewise define  $X_j$  as the *expected* number of sick leaves granted by physician  $j$ , given her ex-ante patient demand and how many of them would be granted one.

We define the physician’s utility function as follows:

$$U_j(Q_j, X_j) = R_j(Q_j) - P(X_j)$$

where  $R_j(\cdot)$  is an individual, concave *revenue* function defined over expected total clients, and  $P(\cdot)$  is a convex *punishment* function on  $X_j$ , composed of the probability of being fined for a certain number of sick leaves issued and the magnitude of the fine. The implication is that after a given number of patients, the disutility of an additional (expected) sick leave issued would outweigh physician  $j$ ’s financial incentive for further clientele. The  $j$  subindex indicates that we will allow  $R_j(\cdot)$  (revenue by visit) to vary across physicians. We assume both  $R_j(\cdot)$  and  $P(\cdot)$  to be twice differentiable.

We stress again that we define physician utility in terms of the *expected* realization of patient demand and granted sick leaves, as befits the logic of this game, where doctors take action before patients (we will specify the timing of our game below).

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<sup>4</sup>Conceptually, willingness to pay would also depend on patient  $i$ ’s wealth level  $w_i$ . To steer away from discussions on wealth disparity, we interpret  $\kappa_i$  as the *average* willingness to pay for  $V_j$ .

Following Schnell (2022), we focus on *threshold equilibria*, wherein each physician's strategy is the choice of a value  $\bar{\kappa}_j \in \mathbb{R}_0^+$ , such that of the patients who visit  $j$ , those with a  $\kappa_i$  value above or at that threshold will be granted sick leave, and those strictly under it won't. As a result of this, each physician will be identified by their given 'service quality', revenue function, cost of visit to the patient and choice of threshold:  $\{V_j, R_j(\cdot), \tau_j, \bar{\kappa}_j\}$ . The set  $\{\bar{\kappa}_j\}_{j=1}^J$  will be known to patients when deciding on their behavior strategy.

Our models are different iterations of a general game with the following timing:

- First stage: Physicians simultaneously choose  $\bar{\kappa}_j$ .
- Second stage: Observing  $\{V_j, R_j(\cdot), \tau_j, \bar{\kappa}_j\}$ . The set  $\{\bar{\kappa}_j\}_{j=1}^J$ , each patient chooses (or is assigned to) some doctor  $j$ .
- Third stage: Each patient can choose to see their physician and incur a visit cost  $\tau_j$ , or refrain from doing so.

Conditional upon his visit (as not to visit renders null utility), the utility of patient  $i$  from seeing physician  $j$  is:

$$U_i(V_j, \bar{\kappa}_j) = \begin{cases} \gamma_i + V_j \kappa_i - \tau_j & \text{if } \kappa_i \geq \bar{\kappa}_j, \\ V_j \kappa_i - \tau_j & \text{if } \kappa_i < \bar{\kappa}_j \end{cases}$$

We will usually use  $u_{ij}$  as a shorthand.

### 3.1 Non-search Equilibrium

For illustration purposes, we first devote attention to a non-search baseline, where each patient is randomly assigned to a physician, with an equal probability of being matched to any of the  $J$  physicians. Their only say in the matter is whether they'll then visit physician  $j$ , i.e. the second stage of the game is out of their hands, and they only make choices in the third stage after assignment.

A patient won't visit his assigned physician if his expected utility from such a visit is negative, we call this a *free disposal* requirement. As such, a doctor  $j$ 's expected client demand, as a function of  $\bar{\kappa}_j$  and given the parameter  $V_j$ , will be the following:

$$Q_j(\bar{\kappa}_j) = \frac{I}{J} \left[ \int_{\tau/V_j}^{\infty} dF(k) + \int_{\min\{\bar{\kappa}_j, \tau/V_j\}}^{\tau/V_j} \int_{\tilde{\gamma}(k)}^{\infty} dG(\gamma) dF(k) \right] \quad (\text{N.1})$$

where the left term consists of the mass of patients who just by virtue of doctor  $j$ 's service quality  $V_j$  would be willing to pay a visit (i.e.  $\kappa_i \geq \tau/V_j$ ), and the right term would be patients who only see doctor  $j$  out of the expectation of getting sick leave ( $\kappa_i \geq \bar{\kappa}_j$  &  $\gamma_i \geq \tau - V_j \kappa_i$ ), but wouldn't visit otherwise. We define  $\tilde{\gamma}(k) := \tau - V_j k$  as the lower limit of the inner integral.

Given that each patient with a  $\kappa_i$  higher or equal to  $\bar{\kappa}_j$  is granted a sick leave certificate, the expected total number of such certificates granted by  $j$ , as a function of  $\bar{\kappa}_j$ , is:



$$X_j(\bar{\kappa}_j) = \frac{I}{J} \int_{\bar{\kappa}_j}^{\infty} \int_{\bar{\gamma}(k)}^{\infty} dG(\gamma) dF(k) \quad (\text{N.2})$$

Given (N.1) and (N.2), each physician solves for the following unconstrained optimization:

$$\bar{\kappa}_j^* \equiv \arg \max_{\bar{\kappa}_j} R_j(Q_j) - P_j(X_j) \quad (\text{N.3})$$

We now SEE LATER

**Lemma 3.1.** *No value in  $(\frac{\tau}{V_j}, \infty)$  can be the optimal solution of (N.3).*

PROOF: APPENDIX

**Lemma 3.2.** *When  $\bar{\kappa}_j \in [0, \frac{\tau}{V_j}]$ ,*

$$\frac{\partial Q_j}{\partial \bar{\kappa}_j} = \frac{\partial X_j}{\partial \bar{\kappa}_j}$$

PROOF: APPENDIX

This proposition implies that when  $\bar{\kappa}_j$  is low enough that the marginal patient is indifferent, any new clients gained by doctor  $j$  are those she entices through the expectation of getting a certificate, meaning that in the vicinity of  $\bar{\kappa}_j$  the change in expected patients  $\Delta Q_j / \Delta \bar{\kappa}_j$  through a variation in  $\bar{\kappa}_j$  is the same as the change in expected certificates granted  $\Delta X_j / \Delta \bar{\kappa}_j$ .

Given Proposition 3.2, the following equation, which is the FOC of (N.3):

$$R'_j(Q_j) \frac{\partial Q_j}{\partial \bar{\kappa}_j} - P'_j(X_j) \frac{\partial X_j}{\partial \bar{\kappa}_j} = 0$$

may be simplified into

$$R'(Q_j) = P'(X_j) \quad (\text{N.4})$$

We can see that (N.3) offers three possibilities by way of solution: a *corner* solution towards  $\infty$ , where doctor  $j$  is content with her “captured” clientele (those who would visit her even without expecting sick leave), and offers no certificates at all<sup>5</sup>; the corner solution  $\bar{\kappa}_j = 0$ , maximum leniency; and an *inner* solution in  $[0, \frac{\tau}{V_j}]$  fulfilling equation (N.4) and thus the FOC of (N.3). We formalize equilibrium below.

**Equilibrium in non-search models.** *Given a doctor-patient market specified by  $\{(\kappa_i, \gamma_i)\}_{i=1}^I, \{(V_j, R_j(\cdot), P_j(\cdot))\}_{j=1}^J$ , we define an equilibrium as a set of physician thresholds  $\{\bar{\kappa}_j\}_{j=1}^J$  satisfying (N.3) and their corresponding equilibrium (expected) patient demand and granted sick leave certificates  $\{(Q_j, X_j)\}_{j=1}^J$  as described by (N.1), (N.2), respectively.*

<sup>5</sup>We may rationalize this by interpreting it as physician  $j$  being as strict as is medically responsible. We could have written this as  $\bar{\kappa}_j$  having an upper bound  $\kappa_{\max}$ , where any physician would be obliged to grant sick leave to a patient with  $\kappa_i > \kappa_{\max}$ .

## 3.2 Search Equilibria

### a Introducing search

We introduce patient “search” as a general framework in which patients can choose freely among all physicians.

We define for each patient  $i$  a vector  $S_i \in \Delta(\mathcal{J})$ , where  $\mathcal{J}$  is the  $1 \times J$  vector composed of all  $1, \dots, J$  physicians.  $S_i$  will be his *strategy* for this game, representing his probabilistic choice of visit for each doctor  $j$ , such that each component  $s_{i1}, \dots, s_{iJ}$  of  $S_i$  stands for the probability that he’ll visit doctors  $1, \dots, J$  respectively.

In order to describe a proper probability distribution, the following criteria must be met:

- i.  $\forall j, s_{ij} \geq 0$
- ii.  $\sum_{i=1}^J s_{ij} \leq 1$

We will allow the sum of all components to be less than one, implying the presence of an *outside option* for patients, that is, to not visit any doctors. Such an option is important, as patient rationality in our models will include “*free disposal*”, meaning that a patient will never visit a doctor if his expected utility from such a visit is less than 0, i.e.  $s_{ij} = 0$  if  $U_i(V_j, \bar{\kappa}_j) = 0$ . This makes the third stage trivial, as under free choice, patient  $i$  will only be assigned with positive probability to doctors he will be willing to visit.

We can re-interpret the non-search model as each patient being made to play by the strategy  $\{S_i : s_{i1} = s_{i2} \dots = s_{iJ} = \frac{1}{J}\}$ , and it’s the lack of a free choice which makes the third stage non-trivial.

Given the collection of all patients’ strategies  $(\{S_i\}_{i=1}^I)$ , each with a respective  $s_{ij}$  for doctor  $j$ , we can formulate expected clientele and granted sick leaves for  $j$  in a manner very much alike the previous section (indeed, as a generalization):

$$Q_j(\bar{\kappa}_j, \bar{\kappa}_{-j}) = \int_{\tau/V_j}^{\infty} s_{ij} dF(k) + \int_{\min\{\bar{\kappa}_j, \tau/V_j\}}^{\tau/V_j} \int_{\bar{\gamma}(k)}^{\infty} s_{ij} dG(\gamma) dF(k) \quad (\text{S.1})$$

$$X_j(\bar{\kappa}_j, \bar{\kappa}_{-j}) = \int_{\bar{\kappa}_j}^{\infty} \int_{\bar{\gamma}(k)}^{\infty} s_{ij} dG(\gamma) dF(k) \quad (\text{S.2})$$

As before, the left term in equation (S.1) includes patients who would visit  $j$  even without sick leave, whereas the right term those who only do so because they expect one.

Notice that we now present  $Q_j$  and  $X_j$  not only in terms of the threshold  $\bar{\kappa}_j$  chosen by doctor  $j$ , but also in terms of the thresholds of the other  $J - 1$  doctors, which

we abbreviate as  $\bar{\kappa}_{-j}$ . Whereas before doctors were simply allotted a given number of patients, now they will *compete* for them, as patients'  $S_i$  strategy will consider the whole of  $(\{\bar{\kappa}_j\}_{j=1}^J)$  when considering which physician(s) they will visit with positive probability.

## b Some analytic results

We shall further specify the form  $S_i$  will take. Consider now a  $1 \times J$  vector  $U_i$ , where each component  $u_{i1}, \dots, u_{iJ}$  indicates the utility patient  $i$  expects from a visit to doctors  $1, \dots, J$  respectively, corresponding to  $U_i(V_j, \bar{\kappa}_j)$  for each doctor  $j$ . As a shorthand, we shall write  $u_{i,-j}$  to indicate the  $J - 1$  components of  $U_i$  excluding  $u_{ij}$ .

In the models considered, each component  $s_{ij}$  of  $S_i$  will be defined as:

$$s_{ij} \equiv g_i(u_{ij}, u_{i,-j})$$

where  $g_i(\cdot)$  is a continuous function weakly increasing in the first argument  $u_{ij}$ , and weakly decreasing in the remaining arguments given by  $u_{i,-j}$ . Our model specifications will consist in giving this function  $g_i(u_{ij}, u_{i,-j})$  a specific form.

As we show in the APPENDIX, such prerequisites over  $s_{ij}$  are enough to prove most of the qualitative relations we expect to see regarding equilibrium aggregates and doctor strategies, but not enough to prove that  $\bar{\kappa}_j$  and  $\bar{\kappa}_{-j}$  are strategic complements – i.e., that for any  $l \neq j$ ,  $\frac{\partial^2 U_j}{\partial \bar{\kappa}_j \partial \bar{\kappa}_l} \geq 0$

## c The “implicit” search model

The “implicit” search model is a McFadden Logit choice model modified to give null probability visits to doctors which afford patient  $i$  non-positive utility, that way the free disposal requirement is fulfilled.

We call it the “implicit” search model because strictly speaking patient search is not formally included, yet one arrives at result qualitatively similar to specifications that do (like our own). The choice strategy noisily assigns positive probability to physicians who render  $i$  high utility, and the higher this  $u_{ij}$  expected utility is, the higher the probability of visit.

Instead of *explicitly* defining search and subsequent choice, probability of visit depends upon expected utility from doctor  $j$ ,  $u_{ij}$ , and a weighing parameter  $\lambda$ . The lower the value of  $\lambda$ , the noisier patient “search” is: they give high assignment probability to sub-optimal –yet feasible– physician choices.

We define the components  $s_{ij}$  of the patient's strategy vector  $S_i$  as follows:

$$s_{ij} = \frac{\alpha_{ij}}{\sum_{k=1}^J \alpha_{ik}}, \text{ where } \alpha_{ij} = \begin{cases} e^{\lambda u_{ij}}, & \text{if } u_{ij} > 0 \\ 0, & \text{if } u_{ij} = 0 \end{cases} \quad (\text{S})$$

Unlike the “explicit” search model, the probability that patient  $i$  visits doctor  $j$  is *strictly* growing in  $\kappa_i$ , rather than being a piece-wise constant function with different levels. There is a discrete jump in probability at  $\bar{\kappa}_j$ , but elsewhere above 0 the function is smoothly increasing, rewarding physicians with high  $V_j$ .

The same lemmas as in the non-search model still hold.

**Lemma 3.3.** *No value in  $(\frac{\tau}{V_j}, \infty)$  can be the optimal solution of (N.3).*

PROOF: APPENDIX

**Lemma 3.4.** *When  $\bar{\kappa}_j \in [0, \frac{\tau}{V_j}]$ ,*

$$\frac{\partial Q_j}{\partial \bar{\kappa}_j} = \frac{\partial X_j}{\partial \bar{\kappa}_j}$$

PROOF: APPENDIX

Thus, the possible solutions for (N.3) remain threefold: the corner solutions 0 and  $\infty$ , and an inner solution where the simplified FOC  $R'(Q_j) = P'(X_j)$  holds.

Equilibrium is achieved in a similar fashion, though now taking into account the patients’  $S_i$  strategies.

**Equilibrium in “implicit” search.** *Given a doctor-patient market specified by  $(\{(\kappa_i, \gamma_i)\}_{i=1}^I, \{(V_j, R_j(\cdot), P_j(\cdot))\}_{j=1}^J)$ , we define an equilibrium as a set of physician thresholds  $\{\bar{\kappa}_j\}_{j=1}^J$  satisfying (N.3) and patient strategies  $\{S_i\}_{i=1}^I$  as defined by (S), with their corresponding equilibrium (expected) patient demand and granted sick leave certificates  $\{(Q_j, X_j)\}_{j=1}^J$  as described by (S.1), (S.2), respectively.*

#### d The “explicit” search model

What we call the “explicit” model is in which patient strategy  $S_i$  is explicitly the result of a sequential search algorithm on part of the patients. This is in line with [Schnell \(2022\)](#), though made trickier by the fact that our model allows for physician services apart from contingent “prescriptions” (in our case, sick leave certificates). In our model some patients *are* willing to visit physicians who don’t intend to grant them sick leave, given a high enough benefit from the medical service proper,  $V_j \kappa_i$ .

FURTHER EXPLANATION REQUIRED, TO BE CONTINUED

## 4 Computation

### 4.1 Algorithms for Model Computation

Given a set of physicians  $\{(V_j, R_j(\cdot), \tau_j)\}_{j=1}^J$ , punishment function  $P(\cdot)$ , distribution functions for patient parameters  $F(\kappa)$  and  $G(\gamma)$ , and one search model parameter  $z$ ,

which is  $\lambda$  in the Logit model,  $\beta$  in the sequential model, we develop an algorithm to compute market equilibrium.

Equilibrium aggregates are computed on the basis of Monte-Carlo matrix calculus. Set  $J$  as the number of physicians,<sup>6</sup>  $I$  as the size of the sample drawn randomly from  $F(\kappa)$  and  $G(\gamma)$ . For both models we define a class which can output a matrix  $S$  where each column is a patient's strategy vector  $S_i$  following that model, when given as input the arrayed set of physicians' quality and visit cost  $\{(V_j, \tau_j)\}_{j=1}^J$ , an arrayed set of patients  $\{(\kappa_i, \gamma_i)\}_{i=1}^I$ , the model parameter  $z$  and a given vector of physician strategies  $\{\bar{\kappa}_j\}_{j=1}^J$ .

We input as "patients" our  $I$  samples from  $F(\kappa)$  and  $G(\gamma)$ , then a  $J \times I$  matrix  $U$  is computed, where each component  $u_{ji}$  corresponds to the utility the sampled patient  $i$  would get from a visit to physician  $j$ .<sup>7</sup> This step is the same for both classes.

What differs between both models is the computation of the matrix  $S$  of patient strategies out of the utility matrix  $U$ :

- **Implicit search model (Logit):** First, an ' $\alpha$ -matrix' is calculated over matrix  $U$ , where each  $\alpha_{ji}$  is  $e^{\lambda u_{ji}}$  if  $u_{ji} > 0$  and 0 if not. Then, for each patient  $i$ , that is, for each column, each component  $s_{ji}$  of the  $S$  matrix takes on the values  $s_{ji} = \alpha_{ji} / \sum_{k=1}^J \alpha_{ki}$ .
- **Explicit search model (Sequential):** Recall equation (NUMBER) characterizing patient thresholds. We first compute the  $I$ -dimensional vector of the sampled patients' respective  $\bar{U}_i$ . Define  $U_i$  as the set  $\{u_{ji}\}_{j=1}^J$  of utility patient  $i$  receives from a visit to each physician. In matrix terms  $U_i$  would be the  $i$ th column of the  $J \times I$  matrix  $U$ . The operation to compute each  $\bar{U}_i$  is the following:

$$\bar{U}_i \equiv \arg \min_{x \in U_i} \left\| x - \frac{\beta}{1 - \beta} \sum_{j=1}^J \left\{ \frac{\mathbb{I}[u_{ji} \geq x] \cdot (u_{ji} - x)}{\mathbb{I}[u_{ji} \geq x]} \right\} \right\|$$

where the norm  $\|\cdot\|$  is defined in  $\mathbb{R}$  as simply the absolute value  $|\cdot|$ . This is to say, for each sampled patient  $i$  we evaluate  $x$  for each  $u_{ji}$  in  $U_i$ . In plain words, if patient  $i$  were to say: "I will only visit physicians which grant me at least as much utility as physician  $j$ ", the optimal choice of  $j$  and its respective  $u_{ji}$  would be the minimal in  $U_i$  for the evaluation of the absolute value in the left-hand side of (4.1). This is computationally less intensive than seeking to compute the exact root of (NUMBER), which would be a redundant exercise, because there's a discrete number of physicians above that mark, and selecting instead to use

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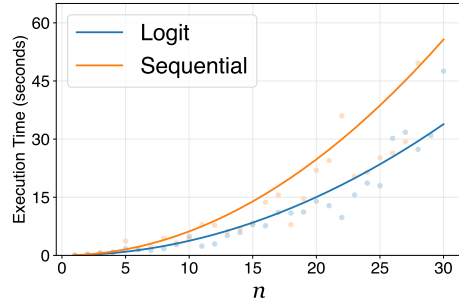
<sup>6</sup>Or, as we'll later interpret it, as the number of bins, where each bin  $j$  is a unique combination of  $(V_j, \tau_j, R_j(\cdot), P_j(\cdot))$ .

<sup>7</sup>As we have defined our matrices  $J \times I$  for ease of visualization, we will refer to matrix components as  $x_{ji}$  in this section rather than  $x_{ij}$  as we do elsewhere in the paper.

“the lowest  $u_{ji}$  above the root of (NUMBER)” as threshold instead of the root proper would result in the same vector of strategies  $S_i$  for each patient.<sup>8</sup>

Once having computed our  $I$ -dimensional vector of patients’  $\bar{U}_i$ , we evaluate column-wise the binary operator  $\mathbb{1}\{u_{ji} \geq \bar{U}_i\}$  over matrix  $U$ , and the  $J \times I$  matrix  $S$  of patient strategies takes on the values  $s_{ji} = \mathbb{1}\{u_{ji} \geq \bar{U}_i\} / \sum_{k=1}^J \mathbb{1}\{u_{ki} \geq \bar{U}_i\}$ .

The  $S$  matrix in both cases is computed in linear time,  $\mathcal{O}(n)$  in big-O notation, where input size  $n$  is the number of physicians  $J$ . Both consist of a series of ufunc or vectorized operations, where the inclusion of one more physician introduces a new row with  $I$  elements on which operations are performed at each stage. The additional step of calculating the  $\bar{U}_i$  vector makes the execution of the ‘explicit’ search model relatively slower (see Figure 1a).



(a) Linear polynomial fit of execution time for  $S$  matrix in both models

(b) Quadratic polynomial fit of execution time for  $\bar{\kappa}^*$  vector in both models

Figure 1: Execution time comparison between the *implicit* and *explicit* search models

The steps following the computation of the  $S$  matrix are the same for both models. The  $J$ -dimensional vector  $Q$  of each physician’s expected demand  $Q_j$  is achieved through the row-wise summation of all patient’s demand for  $j$ , i.e. performing  $\sum_{i=1}^I s_{ji}$  for each  $j$ . The vector  $X$  of each physician’s expected sick leaves issued  $X_j$  performs that same summation, conditional on the patients’  $\kappa_i$  being above or at physician  $j$ ’s chosen threshold  $\bar{\kappa}_j$ , that is,  $\sum_{i=1}^I \mathbb{1}[\kappa_i \geq \bar{\kappa}_j] s_{ji}$ . Both sums are normalized to fit the actual number of patients in the physician-patient market.

For a given vector  $\bar{\kappa}$ , computing patient strategies, physician aggregates and then physicians’ utility—defined as  $\{R_j(Q_j) - P(X_j)\}$ —entails a sequence of calculations done in linear time. However, the calculation of the *equilibrium* vector  $\bar{\kappa}^*$  is performed in quadratic time  $\mathcal{O}(n^2)$ , as it requires each of the aforementioned steps to be done

<sup>8</sup>Granted, this is not strictly true, as in our formulation a ‘ $u_{ji}$ ’ may be selected as threshold which is actually below the root proper in  $\mathbb{R}$ , but closer to it than the nearest one above it. The effect of this “estimation noise” on our overall results is negligible.

some  $x$  number of times *per* physician, such that the inclusion of an additional physician increases the number of operations required *per* physician as well as the amount of physicians whose  $\bar{\kappa}_j$  needs to be computed. See Figure 1b.

The algorithm to find the equilibrium  $J$ -vector  $\bar{\kappa}^*$  of physician strategies is as follows:

- i Input an initial guess  $\bar{\kappa}^0$  for physician thresholds.
- ii For each physician, we fix the value of  $\bar{\kappa}_{-j}$ , the threshold values of the other  $J - 1$  physicians, and compute equilibrium aggregates and physician  $j$ 's utility for different choices of  $\bar{\kappa}_j$  across a grid. In particular,  $U_j(\bar{\kappa}_j, \bar{\kappa}_{-j})$  is computed for each decimal step between 0 and  $\bar{\kappa}_{\max}$ , the maximum threshold physicians may choose.
- iii The choice of threshold  $k_j$  which rendered  $j$  the most utility in the previous step is selected, and a grid is set-up spanning the 19 centesimal values in  $[k_j - 0.05, k_j + 0.05]$ ,<sup>9</sup> each value therein input as physician  $j$ 's threshold  $\bar{\kappa}_j$  to compute  $U_j$  again, and the value within the grid which maximizes utility is chosen as  $\bar{\kappa}_j^1$ .
- iv Having performed the previous step for all  $J$  physicians, we input as a new guess the vector  $\bar{\kappa}^1 = \{\bar{\kappa}_1^1, \dots, \bar{\kappa}_J^1\}$  to run steps ii and iii again. This defines an equilibrium-searching loop  $\bar{\kappa}^n = \Phi(\bar{\kappa}^{n-1})$ , and the loop is concluded when a fixed point is found, that is, the vector  $\bar{\kappa}^*$  such that  $\bar{\kappa}^* = \Phi(\bar{\kappa}^*)$ .
- v Optionally, having found a two decimals fixed point  $\bar{\kappa}^*$ , there's an algorithm in place to find an  $x$ -decimal fixed point  $\bar{\kappa}^{*x}$ . It starts by running a modified version of step iii on the two-decimal solution, setting up a grid of the 19 *millesimal* values in  $[\bar{\kappa}_j^* - 0.005, \bar{\kappa}_j^* + 0.005]$  for each physician  $j$ ,<sup>10</sup> selecting that which renders highest utility for each, and inputting this new vector as guess to run this step again, and so on until the fixed point  $\bar{\kappa}^{*3} = \Phi(\bar{\kappa}^{*3})$  is found.

This goes on like this, calculating the  $t$  decimals solution out of the  $t - 1$  decimals solution by setting up  $10^{-(t-1)}$ -sized grids for each physician in each iteration, until the specified amount of decimals wanted from the solution vector  $\bar{\kappa}^{*x}$  is reached.

On the one hand, having to perform several operations *per* physician is quite computationally intensive and runs the cost of quadratic execution time. On the other hand, although each iteration takes some time, for the right parameters the algorithm is quite efficient in the number of iterations needed for convergence, usually taking between 2 and 5. The option to find fixed points to  $n + 1$  decimal places incurs progressively smaller execution time costs compared to  $n$  decimals, as the initial guess for  $n + 1$  decimals becomes increasingly accurate. See Figure 2.

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<sup>9</sup>If  $k_j$  is 0 (or  $\bar{\kappa}_{\max}$ ), only the 10 centesimal values above (below) and at  $k_j$  are computed.

<sup>10</sup>For  $\bar{\kappa}_j^* = 0$  or  $\bar{\kappa}_{\max}$  a similar logic to the footnote above follows.

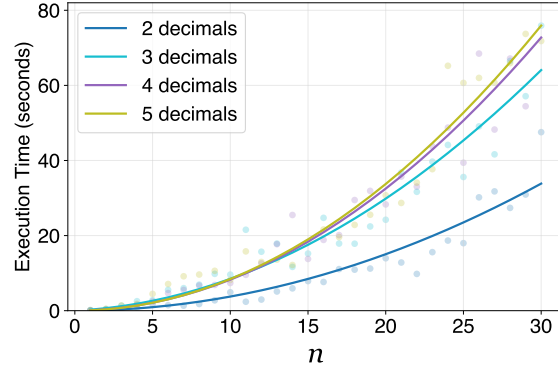
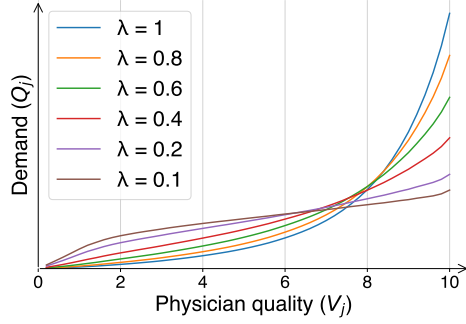


Figure 2: Quadratic polynomial fit of execution time of  $\bar{\kappa}_j^*$  for different decimal approximations in Logit model

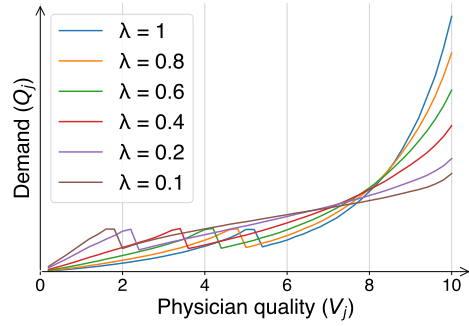
Once the equilibrium vector  $\bar{\kappa}_j^*$  is calculated, it may be used to compute the equilibrium aggregates  $Q_j$  and  $X_j$  for all physicians, as well as physician utility.



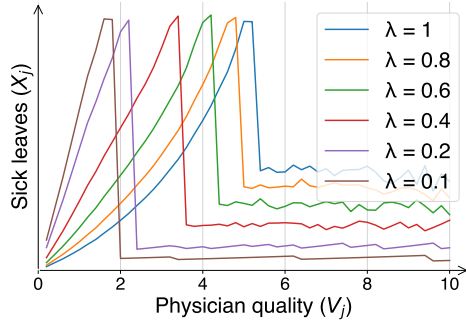
## 4.2 Illustrative Examples



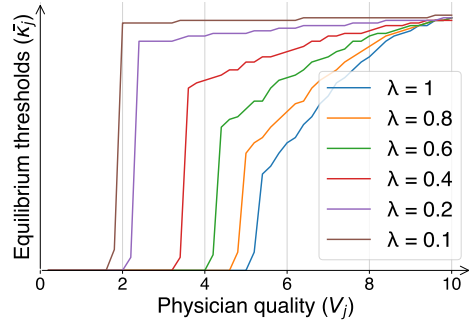
(a) Patient demand  $Q_j$  by physician quality,  $\bar{\kappa} = \vec{0}$



(b) Patient demand  $Q_j$  by physician quality, equilibrium  $\bar{\kappa}^*$



(c) Sick leaves issued  $X_j$  by physician quality, equilibrium  $\bar{\kappa}^*$



(d) Equilibrium  $\bar{\kappa}_j^*$  by physician quality

Figure 3: Physician aggregates and strategies for different values of  $\lambda$  in the *implicit* search model

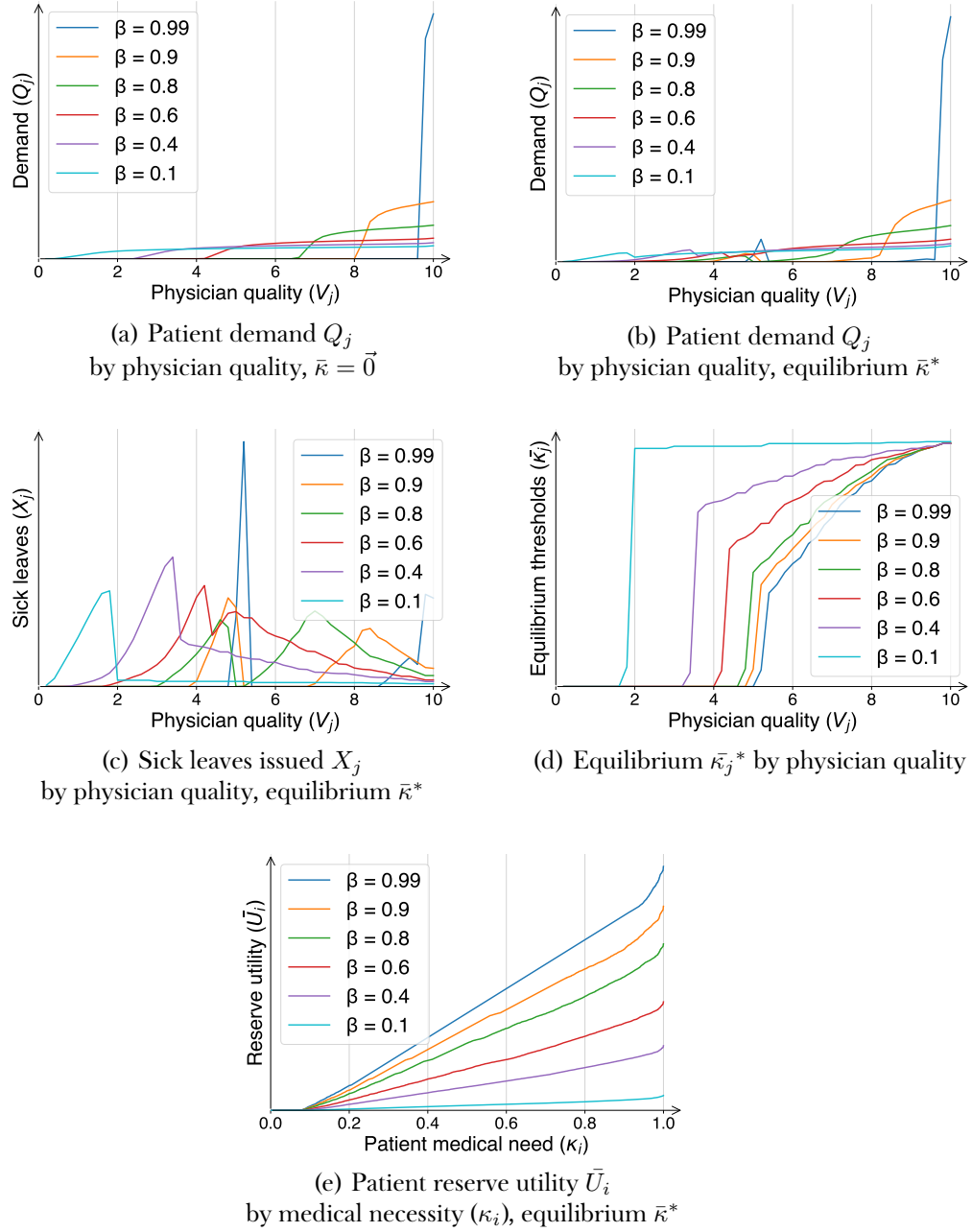


Figure 4: Physician aggregates and strategies for different values of  $\beta$  in the *explicit* search model

## 5 Data

We use administrative data provided by FONASA from all sick leaves issued from January 2018 to October 2022 in the public health system.

Overall totals by patients and physicians in the sampled period have the following descriptive statistics.

Statistic	Physicians	Patients
Mean	88	3
Std	199	3
Min	1	1
Max	8,743	73
Percentiles		
10th	2	1
50th	24	2
90th	216	7
99th	1007	14
Count	48,611	1,445,696

Table 1: Summary Statistics for Physicians and Patients

## 6 Calibration

The first step required in calibration is to divy up the physicians into bins. The way this is achieved is by setting up a three part 'quality' score, composed of the physician's percentile in three categories: average days of sickness leave granted, percentage of sick leaves issued over 30 days, amount of sick leaves issued over 30 days.

The logic behind these categories can be surmised in the models section. As physician quality ( $V_j$ ) increases, so too their choice of threshold ( $\bar{\kappa}_j$ ) in order to avoid excessive patient demand. As a result, the composition of their patient-base tends to a higher average  $\kappa_i$ , including a higher percentage of  $\kappa_i \geq \bar{\kappa}_{\max}$ . Sickness leave of  $\geq 30$  days is subject to higher scrutiny and requires special approval, as well as being indicative of serious illness/injury. As such, issuances of  $\geq 30$  days, composing close to 21% of our sample, are taken to be such given to patients whose  $\kappa_i \geq \bar{\kappa}_{\max}$ , and a higher percentage of those in  $Q_j$  taken to be indicative of higher  $V_j$ .

Taking the average percentile in the three categories mentioned above, we set up four bins of physician quality, with the following frequency in the sample

	%
$V_{high}$	39.65
$V_{mid-high}$	21.69
$V_{mid-low}$	20.00
$V_{low}$	18.66

Table 2: Frequency of physician quality  $V_j$  bins

We perform calibration of the Logit model. We perform GMM on 9 sample moments as can be seen below. We use the subsample of day sick leaves because it allows for linear independence from the parameters determining  $G(\gamma)$ , as a patient with  $\kappa_i \geq \bar{\kappa}_{\max}$  will be granted sick leave by any physician, such that:

$$s_{ij} = \frac{\alpha_{ij}}{\sum_{k=1}^J \alpha_{ik}} = \frac{e^{\lambda u_{ij}}}{\sum_{k=1}^J e^{\lambda u_{ik}}} = \frac{e^{\lambda\{V_j\kappa_i + \cancel{\gamma_i} - \tau_j\}}}{\sum_{k=1}^J e^{\lambda\{V_k\kappa_i + \cancel{\gamma_i} - \tau_k\}}} = \frac{e^{\lambda\{V_j\kappa_i + -\tau_j\}}}{\sum_{k=1}^J e^{\lambda\{V_k\kappa_i + -\tau_k\}}}$$

We assume  $F(\kappa)$  to be an exponential function where we normalize the shape parameter  $\lambda_F$  (subscript F, subscript S for the model one) to 1.  $G(\gamma)$  is a normal distribution whose parameters we'll seek to shape. We also look to calibrate the value of each of the four bins, and finally the value of  $\kappa_{\max}$ . We perform a separate GMM prior to the main one to get the parameters determining  $P(\cdot) = \text{fine} * \Pr[\text{fine}|X_j] = t * (\theta X_j)^2$ .

Parameter	Value	Source
Quality bins		
$V_{high}$	-	2nd GMM
$V_{mid-high}$	-	2nd GMM
$V_{mid-low}$	-	2nd GMM
$V_{low}$	-	2nd GMM
Punishment function		
$t$	-	1st GMM
$\theta$	-	1st GMM
Medical need distribution $F(\kappa)$		
$\lambda_F$	-	Normalization
Taste distribution $G(\gamma)$		
$\mu$	-	2nd GMM
$\sigma$	-	2nd GMM
Maximum threshold level		
$\bar{\kappa}_{\max}$	-	2nd GMM
Logit model parameter		
$\lambda_s$	-	2nd GMM
Revenue/cost of visit		
$r_j$	-	Data
$\tau_j$	-	Data

Table 3: Model parameters

Data calibration relies on nine moments: sick leaves issued by bin, sick leaves over 30 days by bin, proportion of  $\geq 30$  in total.

Moment	Data	Simulated
Total sick leaves issued		
$V_{high}$	967,956	-
$V_{mid-high}$	1,055,544	-
$V_{mid-low}$	1,068,364	-
$V_{low}$	1,481,964	-
Sick leaves issued of $\geq 30$ days		
$V_{high}$	656,920	-
$V_{mid-high}$	239,168	-
$V_{mid-low}$	53,270	-
$V_{low}$	4,832	-
Proportion of $\geq 30$ days sick leaves over total	2,086	-

Table 4: Model parameters

## 7 Counterfactuals & Comments

PENDING.

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## Appendix

### A.1 The cause of the “strategic effect”

The main difference between our equilibrium and that of [Schnell \(2022\)](#) is the presence of a “strategic effect”, wherein doctor  $j$  takes into account the behavior of other doctors in the selection of her own  $\bar{\kappa}_j$ . Of the different modifications we made to her framework, we’ll argue it’s the absence of *additive separability* across patients in physician utility  $U_j(\cdot)$  which accounts for this.

In our context of unbounded maximization by doctor  $j$ , the absence of additive separability implies she can’t consider each patient individually when it comes to whether she’s willing to allow (or induce) their visit, as such a decision is no longer independent of other patients’ visits; the marginal utility of an additional patient is dependent on the aggregate of clients up to that point, both in terms of the visit itself as well as in the number of sick leave certificates granted up to that point.

Let’s illustrate this point. Consider for a moment a finite number of patients  $1, \dots, k$ , where each patient is inputted directly as an argument in our doctor  $j$ ’s  $U_j(\cdot)$ , like so:  $U_j(1, \dots, k)$ . If  $U_j(\cdot)$  has the property of additive separability, this means it may be reformulated like so:

$$U_j(1, \dots, k) = v_{j1}(1) + \dots + v_{jk}(k) = \sum_{i=1}^k v_{ji}(i)$$

Unconstrained optimization in this context implies she’s willing to see any patient whose  $v_{ji}(i)$  is non-negative, such that her optimal level of utility is:

$$U_j^*(1, \dots, k) = \sum_{i: v_{ji}(i) \geq 0} v_{ji}(i)$$

In the context of our doctor-patient model, where physician utility is increasing in  $\kappa_i$ , selection is achieved by the doctor by choosing a  $\kappa_j^*$  which excludes all patients  $i$  whose  $\kappa_i < \kappa_j^*$ . Supposing our patients are well-ordered in  $\kappa_i$ , the choice of such a  $\kappa_j^*$  would be one where the marginal consumer  $i$  affords a non-negative  $v_{ji}(i)$ , and the inframarginal consumer  $i + 1$  fulfills  $v_{j,i+1}(i + 1) < 0$ . Ignoring for a moment that patients themselves have a *choice* of visiting – depending upon a second dimension  $\gamma$  –, we would then have:

$$U_j^*(1, \dots, k) = \sum_{i: \kappa_i \geq \kappa_j^*} v_{ji}(i)$$

If instead of a discrete set we consider a mass of consumers  $\mathcal{I}$  characterized by their level of  $\kappa_i$ , and we make the simplifying assumption that  $v_{ji}$  takes on the same form  $v_j$  for every  $i \in \mathcal{I}$ , our  $U_j(\cdot)$  could be expressed as:

$$U_j^*(\mathcal{I}) = \int_{\kappa_j^*}^{\infty} v_j(k) dF(k)$$



$U_j^*(\mathcal{I})$  represents the optimal value of  $U_j(\mathcal{I})$ , where doctor  $j$  only sees patients who provide her with non-negative marginal utility, i.e. such that  $\kappa_i \geq \kappa_j^*$ . We can find this optimal value  $\kappa_j^*$  by looking at *threshold* equilibria, where doctor utility is also dependent on the threshold  $\bar{\kappa}_j$  over which she's willing to see patients:

$$U_j(\mathcal{I}, \bar{\kappa}_j) = \int_{\bar{\kappa}_j}^{\infty} v_j(k) dF(k)$$

The optimal value of threshold  $\bar{\kappa}_j$  is  $\kappa_j^*$ . Assuming  $U_j(\cdot)$  is twice differentiable and concave in  $\bar{\kappa}_j$ , such a solution may be arrived at through the FCO:

$$\frac{\partial U_j(\mathcal{I})}{\partial \bar{\kappa}_j} \equiv -v_j(\bar{\kappa}_j)f(\bar{\kappa}_j) = 0$$

Solving for this would yield  $\bar{\kappa}_j = \kappa_j^*$ .

**Schnell (2022)** is an example of just such a treatment, which specifies the physician's additive utility by patient in the following manner:

$$v_{ji}(\kappa_i) \equiv R_j + \beta_j h(\kappa_i)$$

where  $R_j$  is a parameter standing for revenue by visit, and  $\beta_j h(\kappa_i)$  represents the physician's "altruistic" utility over the health impact of a prescription drug to a patient with "pain level"  $\kappa_i$ .

The optimal threshold  $\kappa_j^*$  is then obtained out of the maximization<sup>11</sup>:

$$\max_{\bar{\kappa}_j} \int_{\bar{\kappa}_j}^{\infty} R_j + \beta_j h(k) dF(k)$$

Which gives out the following FOC:

$$R_j = -\beta_j h'(\bar{\kappa}_j)$$

which, as is immediately apparent, doesn't depend upon the behavior of other doctors—more specifically, *their* choice of  $\bar{\kappa}_j$ . It merely establishes that, at the threshold, marginal benefit by patient—revenue  $R_j$ —must equal marginal "cost"—altruistic "cost"  $\beta_j h(\bar{\kappa}_j)$ —. A way to interpret this is that doctors will be willing to see any and all patients which render them positive marginal utility, unconcerned with their total market share, and thus, what other physicians may do to take away clientele.

Such a treatment is rendered inviable by our choice of utility function. Schnell's parameter of revenue would in our model imply the linearity of our revenue *function*  $R_j(\cdot)$  and our  $P(\cdot)$  function over *aggregate* licenses granted. Strict convexity of  $P(\cdot)$  would forestall its formulation as Schnell-like  $\beta_j h'(\bar{\kappa}_j)$  terms for each patient,

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<sup>11</sup>Once again, ignoring patient choice and  $\gamma_i$ . We're presenting a *simplified* version for illustrative purposes.

because the impact on doctor  $j$ 's utility in granting patient  $i$  a license would no longer independent from the granting of licenses of other patients. Likewise, strict concavity of  $R_j(\cdot)$  belies a simple “ $r$ ” parameter such that  $R'_j(Q_j) = rQ_j$ .

More formally, when  $U_j(1, \dots, k)$  *isn't* additively separable across patients, the value  $\kappa_j^*$  such that if  $\kappa_i \geq \kappa_j^*$  patient  $i$  provides positive marginal utility, isn't independent of current clientele, because what before was a properly defined object, marginal utility by patient  $i$ ,  $v_j(\kappa_i)$ , can no longer be so identified. The marginal utility  $i$  provides to  $j$  as the  $k$ th client (assuming some order over clients) is not necessarily the same he'd provide as the  $k + 1$ th client, and so, as the  $k$ th client he could provide 0 utility, implying  $\kappa_i = \kappa_j^*$ , whereas as the  $k + 1$ th he could be inframarginal, such that  $\kappa_i < \kappa_j^*$ .

$\kappa_j^*$  is not longer independent of clientele mass  $\mathcal{I}$  as before, but a function of it,  $\kappa_j^*(\mathcal{I})$ . More specifically, in the models we consider it will depend on the *cardinality* of current clientele,  $|\mathcal{I}|$ , such that our physician's choice of marginal consumer will depend on her aggregate level of patient demand, where before it didn't. This effect is introduced through the *strict non-linearity* of our physician utility function  $U_j(\cdot)$ , either through the strict concavity of  $R_j(\cdot)$  over expected patient demand  $Q_j$ , or the strict convexity of  $P_j(\cdot)$  over total expected sick leaves granted.

When either of those is the case, *aggregate* levels enter into the equation and form part of the optimality condition. Our general FOC reflects this:

$$R'_j(Q_j) \frac{\partial Q_j}{\partial \kappa_j} = P'_j(X_j) \frac{\partial X_j}{\partial \kappa_j} \quad (1)$$

where either or both of  $R'_j(\cdot)$  and  $P'_j(\cdot)$  are a non-constant function over aggregates.

When such aggregates, either  $Q_j$  or  $X_j$ , come into play, physicians come to consider their *market share*, which doesn't depend exclusively on their own choice of  $\bar{\kappa}_j$ . Each patient's strategy  $S_i$  is constructed taking into account the whole of  $\{(V_j, \bar{\kappa}_j)\}_{i=1}^J$ .

Imagine equation (1) holds for some doctor  $j$ , and some doctor  $l \neq j$  decides to lower her  $\bar{\kappa}_l$ , enough that it changes the value of  $s_{ij}$  for some mass of clients. The value of  $Q_j$  would then change, and therefore that of  $R'_j(Q_j)$ . If  $P'_j(X_j)$  didn't vary by the same amount, (1) would no longer be an equality, leading  $j$  to modify her choice of  $\bar{\kappa}_j$  to make equality hold.

This intelligible line of reasoning links the presence of a “strategic effect” to the non-additive separability of  $U_j(\cdot)$ : doctor  $j$  takes into account other physicians' strategy in her own choice of  $\bar{\kappa}_j$  because of the present of *aggregate* amounts of clientele in her optimality conditions, which is so because utility isn't additively separable across clients.

## A.2 Schnell (2022) with Logit choice

To prove our point that it is additive separability which accounts for a possible strategic effect, we reformulate Schnell (2022) in the manner of a McFadden Logit – with some quirks.

The way in which Schnell devises her physician's utility formula is implicitly Bernoulli-like:

$$\int_{\kappa} \int_{\gamma} u(\kappa, \gamma) \cdot p(\kappa, \gamma) dG(\gamma) dF(\kappa)$$

where  $u(\kappa, \gamma)$  is the utility function of the physician from patients characterised by a given  $(\kappa, \gamma)$  tuple, and  $p(\kappa, \gamma)$  stands for the proportion of clients atomized in such a tuple the physician expects to have visit her.

$u(\kappa, \gamma)$  we'll leave as Schnell defined it:  $\beta_j h(\kappa) + R_j \cdot p(\kappa, \gamma)$  lends itself nicely as the  $s_{ij}$  we have been using thus far, which implicitly depends on the  $(\kappa_i, \gamma_i)$  tuple which characterizes patient  $i$ :

$$\int_{\kappa} \int_{\gamma} [\beta_j h(\kappa) + R_j] \cdot s_{ij}(\kappa, \gamma) dG(\gamma) dF(\kappa)$$

In our modeling section, our "implicit" search model was a left-censored Logit choice model, which gave null probability of assignment to physicians from which patient  $i$  expected non-positive utility. It was defined as:

$$s_{ij} = \frac{\alpha_{ij}}{\sum_{k=1}^J \alpha_{ik}}, \text{ where } \alpha_{ij} = \begin{cases} e^{\lambda u_{ij}}, & \text{if } u_{ij} > 0 \\ 0, & \text{if } u_{ij} = 0 \end{cases}$$

Schnell's opioid-focused physician model provides an additional simplification: patients which aren't given a drug prescription, i.e. those such that  $\kappa_i < \bar{\kappa}_j$ , don't garner positive utility from a visit. As such, in the original model as in this reformulation, patients "below"  $\bar{\kappa}_j$  have a null probability of visit, such that the inferior limit of integration for  $\kappa$  is  $\bar{\kappa}_j$ .

As for  $\gamma$ , the limit of the inner integral remains the same as in Schnell in the absence of a secondary market, a value of  $\gamma_i$  such that  $u_{ij} = 0$ , i.e.  $h(\kappa_i) + \gamma_i - \tau^d - \tau^o = 0$ .<sup>12</sup>

The double-integral maximized as physician utility is then as follows:

$$\max_{\bar{\kappa}_j} \int_{\bar{\kappa}_j}^{\infty} \int_{\tau^d - \tau^o - h(\kappa)}^{\infty} [\beta_j h(\kappa) + R_j] \cdot \frac{e^{\lambda u_{ij}}}{\sum_{k: u_{ik} > 0} e^{\lambda u_{ik}}} dG(\gamma) dF(\kappa)$$

The FOC of such an equation is:

$$[\beta_j h(\bar{\kappa}_j) + R_j] \int_{\tau^d - \tau^o - h(\bar{\kappa}_j)}^{\infty} \frac{e^{\lambda u_{ij} | \bar{\kappa}_j}}{\sum_{k: u_{ik} > 0 | \bar{\kappa}_j} e^{\lambda u_{ik}}} dG(\gamma) f(\bar{\kappa}_j) = 0 \quad (2)$$

Where we use " $| \bar{\kappa}_j$ " to clumsily indicate that we integrate  $\gamma$  over patients where  $\kappa_i = \bar{\kappa}_j$ . As an integral over a strictly positive value and the atom of a density function,

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<sup>12</sup>Schnell splits the costs a patient will face into costs of visit ( $\tau^d$ ), cost of purchase ( $\tau^o$ ) and search cost ( $\tau^s$ )

respectively, the factors B and C in the equation are non-negative. For this reason, the only way for (2) to be fulfilled is the following condition:

$$R_j = -\beta_j h(\bar{\kappa}_j) \quad (3)$$

This is the same result as in the original model in ?? in the absence of a secondary market, a condition which stipulates that marginal utility in  $\bar{\kappa}_j$  must be 0, i.e. that revenue ( $R_j$ ) must equal "altruistic" loss ( $\beta_j h(\bar{\kappa}_j)$ ), which pre-supposes that the marginal patient granted prescription opioids suffers a net loss in utility (the negative externalities outweigh its medical benefit as a palliative).

Condition (3) means a value  $\kappa_j$  is chosen irrespective of the strategies employed by other doctors, it quite literally doesn't enter into the equation. As we have argued, additive separability over clients means the *total* demand for physician  $j$ 's services doesn't influence marginal utility by a given patient  $i$ , and so has no sway in the optimality condition. Doctor  $j$  states simply that she won't grant a prescription (or sick leave, as in our case) below  $\bar{\kappa}_j$ , *come what may*. In order for her to care about *aggregate* values, like her total expected demand, making her care about her market share and thus about the strategies of other doctors, *strict non-linearity* must be introduced into her utility function.

### A.3 On the strategic complementarity of $\bar{\kappa}_j$ 's

We had defined the components  $s_{ij}$  of  $S_i$  as:

$$s_{ij} \equiv g_i(u_{ij}, u_{i,-j})$$

where  $g_i(\cdot)$  is a continuous function weakly increasing in the first argument  $u_{ij}$ . Our defining  $s_{ij}$  this way has two interlinked corollaries:

**Corollary A.1.**

$$s_{ij} \mid \kappa_i < \bar{\kappa}_j \leq s_{ij} \mid \kappa_i \geq \bar{\kappa}_j \quad (\text{with strict inequality if } \gamma_i > 0).$$

*Proof.* For a fixed value of  $V_j$  and  $\kappa_i$ , for all  $i$ , the value of  $U_i(V_j, \bar{\kappa}_j)$  is  $V_j \kappa_i - \tau_j$  if  $\kappa_i < \bar{\kappa}_j$ , and  $\gamma_i + V_j \kappa_i - \tau_j$  if  $\kappa_i \geq \bar{\kappa}_j$ , where  $\gamma_i \geq 0$ . Given that  $s_{ij}$  is weakly increasing in  $u_{ij}$ , and we see that  $u_{ij}$  is weakly higher if  $\kappa_i \geq \bar{\kappa}_j$ , the corollary follows.  $\square$

**Corollary A.2.**

$$\frac{\Delta s_{ij}}{\Delta \bar{\kappa}_j} \leq 0 \qquad \frac{\Delta s_{ij}}{\Delta \bar{\kappa}_l} \geq 0, \forall l \neq j$$

*Proof.* From the argumentation in corollary 1 follows that  $u_{ij}$  is weakly decreasing in  $\bar{\kappa}_j, \forall j$ . Take some  $l \neq j$ , then  $s_{ij}$  is defined in turn as weakly decreasing in  $u_{il}$ , which implies it is increasing in  $\bar{\kappa}_l$ .  $\square$

Both corollaries hinge upon our definition of  $U_i(\cdot)$  as a step function over  $\kappa_i$ , such that it is discontinuous at  $\kappa_i = \bar{\kappa}_j$ , where there's a discrete jump of magnitude  $\gamma_i \geq 0$ .

**Corollary A.3.**

$$\frac{\partial Q_j}{\partial \bar{\kappa}_j}, \frac{\partial X_j}{\partial \bar{\kappa}_j} \leq 0 \qquad \frac{\partial Q_j}{\partial \bar{\kappa}_l}, \frac{\partial X_j}{\partial \bar{\kappa}_l} \geq 0, \forall l \neq j$$

*Proof.* We recall our function of patient demand for physician  $j$  is:

$$Q_j(\bar{\kappa}_j, \bar{\kappa}_{-j}) = \int_0^\infty \int_0^\infty s_{ij}(k, \gamma) dG(\gamma) dF(k)$$

Were physician  $j$  to increase her threshold from  $\bar{\kappa}_j$  to  $\bar{\kappa}_j' = \bar{\kappa}_j + \epsilon, \epsilon > 0$ , for the mass of patients whose  $\kappa_i \in [\bar{\kappa}_j, \bar{\kappa}_j + \epsilon)$ , utility would weakly decrease and thus so would their  $s_{ij}$ , falling to  $s_{ij}' \leq s_{ij}$  (see first corollary, think of  $s_{ij}'$  as  $s_{ij} \mid \kappa_i < \bar{\kappa}_j$  as opposed to  $s_{ij} \mid \kappa_i \geq \bar{\kappa}_j$ ).

The difference that would make for patient demand *caeteris paribus* given the  $\bar{\kappa}_{-j}$  strategies of the other physicians (ommitted in our notation) is:<sup>13</sup>

$$\Delta Q_j = Q_j(\bar{\kappa}_j + \epsilon) - Q_j(\bar{\kappa}_j) = \int_{\bar{\kappa}_j}^{\bar{\kappa}_j + \epsilon} \int_0^\infty \{s_{ij}' - s_{ij}\} dG(\gamma) dF(k)$$

By the definition of a partial derivative:<sup>14</sup>

$$\begin{aligned} \frac{\partial Q_j}{\partial \bar{\kappa}_j} &= \lim_{\epsilon \rightarrow 0} \frac{\int_{\bar{\kappa}_j}^{\bar{\kappa}_j + \epsilon} \int_0^\infty \{s_{ij}' - s_{ij}\} dG(\gamma) dF(k)}{\epsilon} \\ &= \int_0^\infty \{s_{ij}(\bar{\kappa}_j, \gamma)' - s_{ij}(\bar{\kappa}_j, \gamma)\} dG(\gamma) f(\bar{\kappa}_j) \end{aligned}$$

where the derivative is negative if  $s_{ij}'$  is strictly lower than  $s_{ij}$ , meaning a shift in leniency would affect the utility and optimal strategy of some positive mass of patients around  $\bar{\kappa}_j$ ; or null, if  $s_{ij}' = s_{ij}$ .

In a similar vein, consider some physician  $l \neq j$  shifting her threshold from  $\bar{\kappa}_l$  to  $\bar{\kappa}_l' = \bar{\kappa}_l + \epsilon, \epsilon > 0$ . The fall in patient strategies in  $[\bar{\kappa}_j, \bar{\kappa}_j + \epsilon)$  from  $s_{il}$  to  $s_{il}^* \leq s_{il}$  could provide a windfall for  $j$  (and all other physicians), raising  $s_{ij}$  to  $s_{ij}^* \geq s_{ij}$  (see previous corollary). In that case:

$$\Delta Q_j = \int_{\bar{\kappa}_l}^{\bar{\kappa}_l + \epsilon} \int_0^\infty \{s_{ij}^* - s_{ij}\} dG(\gamma) dF(k)$$

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<sup>13</sup>Besides simplifying  $Q_j(\bar{\kappa}_j, \bar{\kappa}_{-j})$  into  $Q_j(\bar{\kappa}_j)$ , we also forego the arguments of  $s_{ij}(k, \gamma)$ , as we've done many times already, to avoid notation clutter.

<sup>14</sup>The notation for  $s_{ij}(\bar{\kappa}_j, \gamma)'$  is to be taken to mean the strategy  $s_{ij}' \leq s_{ij}$  of the mass of patients at different levels of  $\gamma$  atomized at  $\kappa_i = \bar{\kappa}_j$ .

thus rendering:

$$\begin{aligned}\frac{\partial Q_j}{\partial \bar{\kappa}_l} &= \lim_{\epsilon \rightarrow 0} \frac{\int_{\bar{\kappa}_l}^{\bar{\kappa}_l + \epsilon} \int_0^\infty \{s_{ij}' - s_{ij}\} dG(\gamma) dF(k)}{\epsilon} \\ &= \int_0^\infty \{s_{ij}(\bar{\kappa}_l, \gamma)^* - s_{ij}(\bar{\kappa}_l, \gamma)\} dG(\gamma) f(\bar{\kappa}_l)\end{aligned}$$

As for  $X_j$ , the steps taken are almost the same, only that after raising the threshold by  $\epsilon$  the amount of sick leaves granted goes around  $\bar{\kappa}_j$  goes to 0, thus giving out:

$$\frac{\partial X_j}{\partial \bar{\kappa}_j} = - \int_0^\infty s_{ij}(\bar{\kappa}_j, \gamma) dG(\gamma) f(\bar{\kappa}_j)$$

such that it is simply required that  $j$  has positive demand for the mass of patients whose  $\kappa_i = \bar{\kappa}_j$  for this derivative to be strictly negative, else it is null.

Likewise:

$$\frac{\partial X_j}{\partial \bar{\kappa}_l} = - \int_0^\infty s_{ij}(\bar{\kappa}_l, \gamma) dG(\gamma) f(\bar{\kappa}_l)$$

□

Before dealing with PROPOSITION we need one final corollary.

**Corollary A.4.**

$$\frac{\partial^2 Q_j}{\partial \bar{\kappa}_j \partial \bar{\kappa}_l} = 0 \quad \text{and} \quad \frac{\partial^2 X_j}{\partial \bar{\kappa}_j \partial \bar{\kappa}_l} = 0, \quad \forall j \text{ and } l, \bar{\kappa}_j \neq \bar{\kappa}_l$$

*Proof.* Our proof will be heuristic. Consider

$$\frac{\partial Q_j}{\partial \bar{\kappa}_j} = \int_0^\infty \{s_{ij}(\bar{\kappa}_j, \gamma)' - s_{ij}(\bar{\kappa}_j, \gamma)\} dG(\gamma) f(\bar{\kappa}_j)$$

Patient strategies  $s_{ij}$  are taken at the atom  $\kappa_i = \bar{\kappa}_j$ . For any other physician  $l$  such that  $\bar{\kappa}_l \neq \bar{\kappa}_j$ , an infinitesimally small change to  $\bar{\kappa}_l$  doesn't affect the utility of patients at  $\bar{\kappa}_j$ , who will remain above or below  $l$ 's threshold same as before. Thus their strategy  $s_{ij}$  also remains unaffected. If  $\bar{\kappa}_l$  does equal  $\bar{\kappa}_j$ , then the following limit is not properly defined:

$$\lim_{\epsilon \rightarrow 0} \frac{\frac{\partial Q_j(\kappa_l + \epsilon)}{\partial \bar{\kappa}_j} - \frac{\partial Q_j(\kappa_l)}{\partial \bar{\kappa}_j}}{\epsilon}$$

because as  $\epsilon$  approaches 0 from the right the limit is weakly positive ( $\geq 0$ ), whereas approaching from the left it's strictly 0. Meaning the derivative  $\frac{\partial^2 Q_j}{\partial \bar{\kappa}_j \partial \bar{\kappa}_l}$  doesn't exist for  $j$  and  $l \neq j$  when  $\bar{\kappa}_j = \bar{\kappa}_l$ .

□

## PROOF OF PROPOSITION

Consider some two physicians  $j, l$ , such that  $\bar{\kappa}_j \neq \bar{\kappa}_l$ . If we breakdown the mixed partial derivative of  $U_j$  over  $\bar{\kappa}_j$  and  $\bar{\kappa}_l$ , we get:

$$\begin{aligned}
\frac{\partial^2 U_j}{\partial \bar{\kappa}_j \partial \bar{\kappa}_l} &= \underbrace{R''(Q_j(\bar{\kappa}_j, \bar{\kappa}_{-j}))}_{\leq 0} \cdot \underbrace{\frac{\partial Q_j}{\partial \bar{\kappa}_l}}_{\geq 0} \cdot \underbrace{\frac{\partial Q_j}{\partial \bar{\kappa}_j}}_{\leq 0} + \underbrace{R'(Q_j(\bar{\kappa}_j, \bar{\kappa}_{-j}))}_{\geq 0} \underbrace{\frac{\partial^2 Q_j}{\partial \bar{\kappa}_j \partial \bar{\kappa}_l}}_{=0} \\
&\quad - \underbrace{P''(X_j(\bar{\kappa}_j, \bar{\kappa}_{-j}))}_{\geq 0} \cdot \underbrace{\frac{\partial X_j}{\partial \bar{\kappa}_l}}_{\geq 0} \cdot \underbrace{\frac{\partial X_j}{\partial \bar{\kappa}_j}}_{\leq 0} - \underbrace{P'(X_j(\bar{\kappa}_j, \bar{\kappa}_{-j}))}_{\geq 0} \underbrace{\frac{\partial^2 X_j}{\partial \bar{\kappa}_j \partial \bar{\kappa}_l}}_{=0} \\
&= \underbrace{R''(Q_j(\bar{\kappa}_j, \bar{\kappa}_{-j})) \cdot \frac{\partial Q_j}{\partial \bar{\kappa}_l} \cdot \frac{\partial Q_j}{\partial \bar{\kappa}_j}}_{\geq 0} - \underbrace{P''(X_j(\bar{\kappa}_j, \bar{\kappa}_{-j})) \cdot \frac{\partial X_j}{\partial \bar{\kappa}_l} \cdot \frac{\partial X_j}{\partial \bar{\kappa}_j}}_{\leq 0} \geq 0
\end{aligned}$$

## POOSITIVE MIXED DERIVATIVE IS STRATEGIC COMPLEMENTARITY

### A.4 Proof Sequential

We follow the argument of [Ljungqvist and Sargent \(2012\)](#). Let for the moment  $\tilde{F}_i(U) = \Pr\{u_{ij} \leq U\}$  be the distribution of utility patient  $i$  receives from doctor visits, with  $\tilde{F}_i(0) = 0$ ,  $\tilde{F}_i(B) = 1$ , for  $B < \infty$ . Each period, the patient draws an 'offer'  $U$  from  $\tilde{F}_i$ , which is to say, his search lead him to a physician  $j$  such that  $u_{ij} = U$ . He may either accept and have physician  $j$  assigned to him, receiving utility  $U$  per period henceforth, or look for a new physician next period.

Let  $u_t$  be the patient's utility for period  $t$ , where it's 0 if he doesn't visit a physician and  $U$  if he has accepted an assigned physician which renders him utility  $u_{ij} = U$ . This patient will seek to maximize  $\mathbb{E}[\sum_{t=0}^{\infty} \beta^t u_t]$ , where  $0 < \beta < 1$  is his discount factor.

Let  $V(U)$  be the expected value of  $\sum_{t=0}^{\infty} \beta^t u_t$  of a patient with an offer  $U$  in hand. Assuming no recall, under optimal behavior the value function  $V(U)$  satisfies the Bellman equation:

$$V(U) = \max \left\{ \frac{U}{1-\beta}, \beta \int V(U') d\tilde{F}_i(U') \right\} \quad (4)$$

The patient chooses an optimal value  $\bar{U}_i$ , such that offers  $U \geq \bar{U}_i$  are accepted (the visit takes place). As such, the solution takes on the following form:

$$V(U) = \begin{cases} \frac{\bar{U}_i}{1-\beta} + \beta \int V(U') d\tilde{F}_i(U') & \text{if } U \leq \bar{U}_i, \\ \frac{U}{1-\beta} & \text{if } U \geq \bar{U}_i. \end{cases} \quad (5)$$

Using equation (5), we can convert the functional equation (4) into an ordinary equation in the reservation utility  $\bar{U}_i$ . Evaluating  $V(\bar{U}_i)$  and using equation (5), we have:

$$\frac{\bar{U}_i}{1-\beta} = \beta \int_0^{\bar{U}_i} \frac{\bar{U}_i}{1-\beta} d\tilde{F}_i(U') + \beta \int_{\bar{U}_i}^B \frac{U'}{1-\beta} d\tilde{F}_i(U')$$

or

$$\begin{aligned} \frac{\bar{U}_i}{1-\beta} \int_0^{\bar{U}_i} d\tilde{F}_i(U') + \frac{\bar{U}_i}{1-\beta} \int_{\bar{U}_i}^B d\tilde{F}_i(U') \\ = \beta \int_0^{\bar{U}_i} \frac{\bar{U}_i}{1-\beta} d\tilde{F}_i(U') + \beta \int_{\bar{U}_i}^B \frac{U'}{1-\beta} d\tilde{F}_i(U') \end{aligned}$$

or

$$\bar{U}_i \int_0^{\bar{U}_i} d\tilde{F}_i(U') = \frac{1}{1-\beta} \int_{\bar{U}_i}^B (\beta U' - \bar{U}_i) d\tilde{F}_i(U').$$

Adding  $\bar{U}_i \int_{\bar{U}_i}^B d\tilde{F}_i(U')$  to both sides gives

$$\bar{U}_i = \frac{\beta}{1-\beta} \int_{\bar{U}_i}^B (U' - \bar{U}_i) d\tilde{F}_i(U') \quad (6)$$

Finally, for our purposes, we discretize  $\int_{\bar{U}_i}^B (U' - \bar{U}_i) d\tilde{F}_i(U')$  as a summation over the countable set of  $J$  doctors. The discrete equivalent of equation (6) is:

$$\bar{U}_i = \frac{\beta}{1-\beta} \sum_{j=1}^J \left\{ \frac{\mathbb{1}[u_{ij} \geq \bar{U}_i] \cdot (u_{ij} - \bar{U}_i)}{\mathbb{1}[u_{ij} \geq \bar{U}_i]} \right\} \quad (7)$$

Which is the function we say characterizes patient thresholds in the explicit search model.



## A.5 Graphs

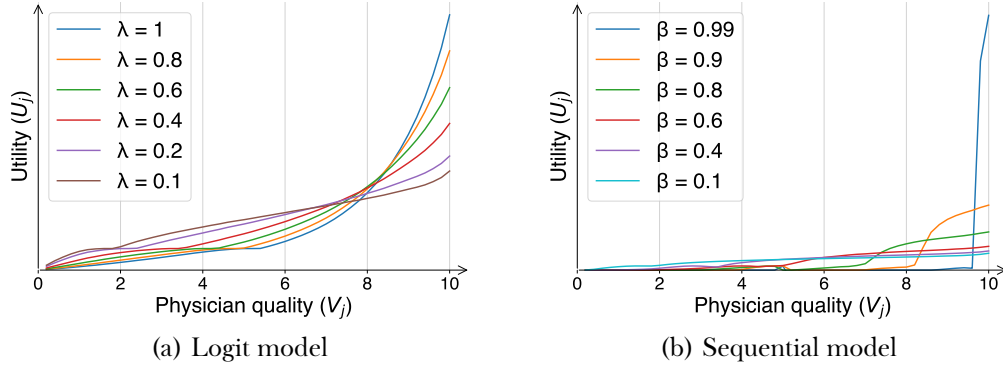


Figure 5: Equilibrium physician utility ( $U_j$ ) by quality ( $V_j$ ) for different model parameters, equilibrium  $\bar{\kappa}^*$

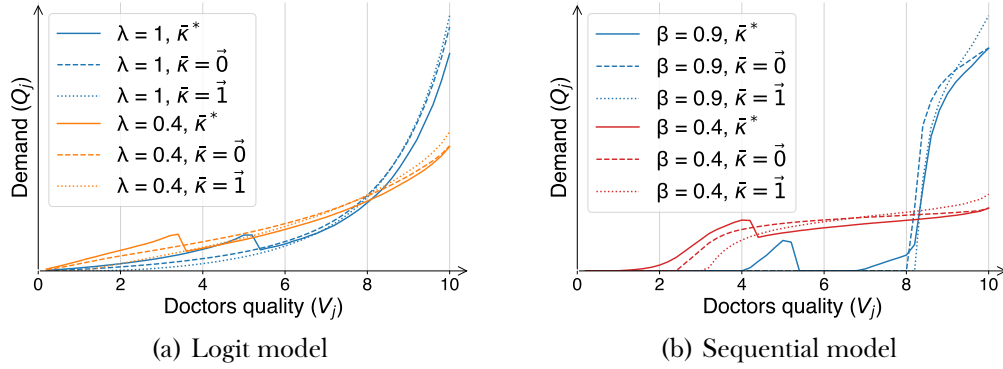


Figure 6: Comparison of patient demand ( $Q_j$ ) by physician quality ( $V_j$ ) for different model parameters and threshold vectors  $\bar{\kappa}$

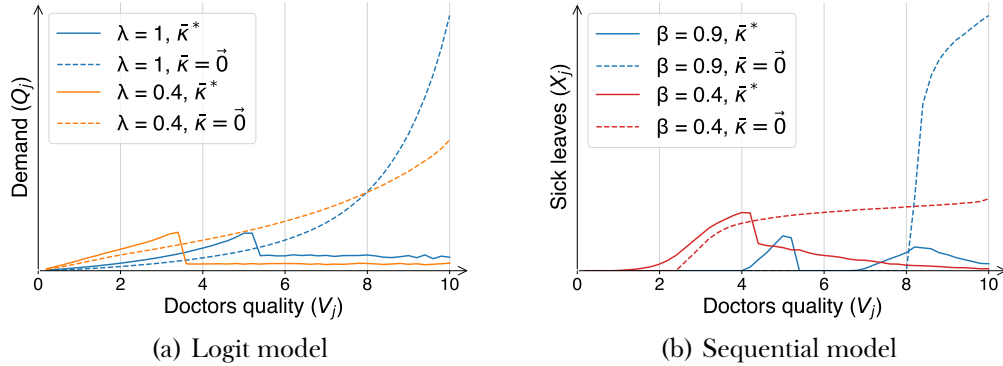


Figure 7: Comparison of sick leaves issued ( $X_j$ ) by physician quality ( $V_j$ ) for different model parameters and threshold vectors  $\bar{\kappa}$