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# Market conditions and general practitioners' referrals

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**Abstract** We study how market conditions influence referrals of patients by general practitioners (GPs). We set up a model of GP referral for the Norwegian health care system, where a GP receives capitation payment based on the number of patients in his practice, as well as fee-for-service reimbursements. A GP may accept new patients or close the practice to new patients. We model GPs as partially altruistic, and compete for patients. We show that a GP operating in a more competitive market has a higher referral rate. To compete for patients and to retain them, a GP satisfies patients' requests for referrals. Furthermore, a GP who faces a patient shortage will refer more often than a GP who does not. Tests with Norwegian GP radiology referral data support our theory.

**Keywords** Physician · Service motive · Profit motive · Referral · Radiology

**JEL Classification** D22 · H42 · I10 · I11 · I18

## Introduction

Nonprice rationing is common in health care delivery systems. Managed care and gatekeeping are common forms of rationing. In private health insurance markets in the United States, primary care physicians or general practitioners (GPs) often coordinate care for patients, and

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specialty care is available only with referrals. The United States, comprehensive health care reform will promote primary care, and it is likely that gatekeeping will become the standard responsibility for GPs. In many European countries, gatekeeping is also common. In this article, we model a GP's referral decision, and assess its empirical significance.

We focus on GPs' radiology and imaging referrals. These services are diagnostic in nature, and yield valuable information to the GP. Often a radiology referral is the beginning of a medical treatment by a specialist. Radiology referrals by GPs are therefore key in cost control because specialty care uses more resources.

We study the factors that affect a GP's radiology referral decisions. Naturally, one expects that variations in patient characteristics would be correlated to the likelihood of referrals. Nevertheless, it is well-known that these variations do not fully explain referrals. In this article, we study how physician characteristics and local physician market conditions affect a GPs' radiology referrals.

Our model is adapted for the Norwegian GP market. Since 2001, each inhabitant in Norway is listed with a GP. The size of a GP's practice is determined by a matching mechanism, and it is quite possible that a GP may want more patients than he currently has in the practice. A GP facing a patient shortage may leave his practice open so that new patients may join. When the local physician market is competitive, more GPs will have their practices open to new patients. We use the number of GPs with open practice per 1,000 inhabitants in a municipality as a measure of the intensity of competition. Furthermore, we use the information of whether a GP faces a patient shortage to explain the GP's radiology referrals.

A GP is paid according to a capitation fee per patient in the practice and fee-for-service reimbursements. A GP does not directly benefit from referring a patient to radiology services. Our understanding is that Norwegian GPs have no financial stake in radiology laboratories. A GP may gain indirectly because he may provide more treatments to a patient after the radiology referral. Furthermore, radiology referrals may increase patient satisfaction. This may help the GP to retain patients and to attract new patients.

A GP's preferences are a weighted sum of profits and patient benefit. These preferences are the key linkage between the theoretical model and the empirical implementation. We hypothesize that these weights are influenced by market conditions. When the physician market is more competitive, the weight on patient benefit is assumed to be higher. A GP who has to compete against more rival GPs has a more liberal referral rule.

We consider, as well, the effect of a patient shortage on referrals. A GP who faces a patient shortage will have a higher referral rate than a GP who does not. This result is simply due to cost consideration. If marginal costs are increasing, a GP with enough patients in his practice will reduce radiology referrals because the marginal cost of a referral is higher than if he had experienced a shortage of patients.

We test the predictions of the model with data on Norwegian GPs' referrals to diagnostic radiology. We have monthly radiology referral data at the individual physician level from 2004 to 2007. Our (unbalanced) panel consists of over 4,200 GPs, and over 165,000 monthly observations of referral rates. The data set is unique since it includes information on all GPs in the Norwegian Health Insurance system. We merge the referral data with data of physicians, so we have information about physicians and their practices. Having information on practice size, we can use a standardized dependent variable of referral rate per 1,000 patients.

Since each GP is likely to have his own practice style, observations of an individual GP are correlated over time. We estimate the contributions of potential explanatory variables by panel data methods, and control for unobserved heterogeneity by fixed effects.

First, we confirm that market conditions have the expected effects on radiology referrals. In a municipality with more open GP practices, a GP tends to refer more patients for radiology services. Second, we confirm that a GP who faces a patient shortage more often refers. Third, our empirical findings are consistent with common expectations: the referral rate declines with the distance between a GP and a radiology laboratory, and GPs who have more female and elderly patients in their practices have higher referral rates.

GP characteristics and market conditions contribute to the referral rate. The magnitude, though statistically significant, does not seem to be large. Suppose we compare two municipalities, one with 0 open GP practice, and one with about 0.72 open practice per 1,000 inhabitants, which corresponds roughly to the 75th percentile in ranking of municipalities with open practices. According to our estimates, the difference is 0.45 referral per 1,000 patients per month, a 3.8% increase from the mean referral rate.

An on-going health policy debate concerns the substitution of secondary care providers by primary care providers. This is usually regarded as a cost-saving strategy. By increasing the number of GPs, policy makers hope to reduce the use of more expensive specialists. The results here do not lend support to the cost-saving goal. When there are more GPs, competition becomes more intense, and increases radiology referrals, usually the gateway to specialty care. Our study concerns radiology referrals only, so it may not offer a comprehensive evaluation of the cost-saving argument.

Many papers in the health economics literature are on the relationship between financial incentives and such aspects of the health market as outcomes, costs, quantities and qualities. Physicians' responses against policy changes have been studied extensively (McGuire 2000; Leger 2008). Our article here is on the relationship between gatekeeping and financial incentives, and the literature is smaller. Our study does not involve a policy implementation of new financial incentives. Rather, it follows a panel of physicians over a period of 4 years.

In a recent article, Fang and Rizzo (2009) address the effect of competition on physician-enabled demands, those health care services initiated by consumer requests. They have found that physicians' perception of competition would impact their decision to approve care or medicine requested by patients. This impact is positive when the patient's care is reimbursed by fee-for-service, but negative when reimbursement is through managed care. Our results are in line with those in Fang and Rizzo: competition does have an impact on medical service provision. Our article, however, has several differences. First, we have available market data on competition, so do not have to rely on physicians' perceptions. Second, the distinction between payment mechanisms is irrelevant in our setting. Third, we focus on imaging referrals, while Fang and Rizzo look at whether any service has been provided due to physician-enabled demand.

Gatekeeping by primary care physicians has been shown to be responsive to financial incentives. Dusheiko et al. (2006) study the United Kingdom fundholding natural experiment. Between 1991 and 1999, UK GPs who opted for a fundholding scheme were paid according to capitation, and were responsible for their patients' elective surgery charges. These GPs have an incentive to avoid referring patients for such services.[1] Dusheiko et al. show that the abolition of fund holding has increased elective surgery admission rates between 3.5 and 5.1%.

Croxson et al. (2001) show that UK GPs have inflated costs for the time period before they become fundholders under capitation. Rochaix (1993) presents evidence for Quebec GPs

[1] In an experiment, Earwicker and Whynes (1998) show that GPs' referral rates are more responsive to specialist interests and waiting time than to costs. Because the study consists of a questionnaire survey, GPs do not actually have to bear any costs.

responding to a price freeze during a 15-month period by adjusting quantities. Generally, the evidence that physicians respond to financial incentives is widely accepted.

The financial incentives in Dusheiko et al. and Croxson et al. come directly from service capitation. In Rochaix (1993) GPs' reimbursement rates have been restrained. All three studies, as most in the literature, use a natural experiment, a policy change, to identify physicians' responses to changes in financial incentives. Any changes in market conditions then occur simultaneously with policy changes. By contrast, in our study, all GPs in the panel are subject to a common and time-invariant payment and capitation policy. The panel structure allows us to use exogenous changes in market conditions to identify GPs' responses.

The theoretic GP referral and gatekeeping literature in health economics has studied such issues as cream skimming (Barros and Olivella 2005), quality (Brekke et al. 2007), GP reputation and human capital investment (Gonzalez 2004), efficient use of information (Gonzalez 2010), and dual job incentives (Biglaiser and Ma 2007). The managed care literature (Glied 2000) has also considered the gatekeeping and referral role of GPs (Malcomson 2004), and diagnostic information and incentives (Allard et al. 2011). These studies assume a fixed set of market conditions, with the exception of Brekke et al. (2007) in which competition among specialists is studied in a model of referral under incomplete information. In our article, market conditions vary exogenously, but we let GPs respond to market conditions by their referral decisions.

Radiology referral can be interpreted as a quality attribute of GP services. Spence (1975) first points out the inefficiency under market provision, due to the divergence between consumers' marginal and average quality valuations. The theoretical literature has tended to take a normative approach to consider how the inefficiency can be remedied by regulating price, quality, or both; see, for example, Barros and Martinez-Giralt (2002), and Ma and McGuire (2002). We do not address welfare or regulation issues here.

Our empirical implementation uses Norwegian GP data. Iversen and Lurås (2000) model a GP who decides on the number of patients in his practice and referrals of patients to specialists. For four Norwegians municipalities, a 1993 trial replaced a GP's practice allowance by a capitation based on the practice size. Iversen and Lurås (2000) predict that this payment change would lead to a higher referral rate due to GPs shifting treatment costs to specialists. Norwegian data for one municipality before and after the introduction of capitation support the predictions.

Structured focus group interviews with Norwegian GPs by Carlsen and Norheim (2003) corroborate with the statistical results in Iversen and Lurås (2000). The GPs generally perceived themselves as less concerned with the gatekeeper role under a (partial) capitation scheme, and felt it more important to provide better services and keep patients satisfied. Lurås (2007) analyzes a survey of a representative sample of Norwegians on their satisfaction with their GPs. The satisfaction indexes include a GP's interpersonal skills, medical skills, referral practices, and consultation lengths. Lurås finds that patients listed with GPs with a patient shortage were less satisfied in all these dimensions than those listed with GPs with enough patients. Our article complements these studies on the Norwegian health care system.

The rest of the article is organized as follows. The next section describes parts of the Norwegian health care system relevant to our study. Sect. "A Model of Referral and Patient List" presents a model of GP patient lists and referrals, as well as its predictions. Sect. "Descriptive statistics" describes the data and summary statistics. The main regression results and robustness checks are in the "Empirical analysis and results" section. The last section draws some conclusions.

**Study setting**

Norway provides health care to its 4.5 million citizens by a national health service. Primary care physicians are mostly private practitioners, while hospitals are publicly owned with salaried physicians. The Regular General Practitioner Scheme implemented in 2001 requested that each inhabitant of Norway be listed with a General Practitioner (GP), a primary care physician. Over 95% of the population complied with the request. In a nonemergency episode of illness, a patient's initial medical services are provided by the GP. Secondary and specialty services require a GP's referral. Thus, besides providing medical services, the GP is a gatekeeper.[2]

About 90% of GPs are self-employed and contract with municipalities, and the remaining GPs are directly employed by municipalities. The GP-list system was established by the Regular General Practitioner Scheme in 2001. A GP would indicate the maximum number of patients he would like. Simultaneously, each inhabitant would submit up to three preferred physicians to National Health Insurance. A matching algorithm respecting GP and patient preferences would form the list for each GP. A GP may have a list that has less patients than his stated maximum. In our empirical work, we say that a GP experiences *a patient shortage* if he has at least 100 patients less than his stated maximum.

In 2004, a GP, on average, had between 1,250 and 1,300 patients listed in his or her practice. In any year, a patient may switch GPs up to two times. A GP can announce whether his practice is open to new patients or not. A GP who already has the maximum number of patients may close his practice to new patients. The information on whether practices are open or closed to new patients is publicly available through the internet, or from the municipality.

In terms of out-of-pocket expenses, in 2011, a patient's copayments for an outpatient visit with a primary care physician and a specialist are respectively about (1 US$ is approximately 5.5 Norwegian Kroner) US$30 and US$55. If within a year a patient's copayment exceeds US$340, National Health Insurance pays for the excess copayment. For a radiology consult, in addition to a copayment of US$40, a patient will incur both time and unreimbursed transportation costs. In major cities, there may be many laboratories or hospitals where radiology and imaging facilities are available. In remote areas, however, there are fewer facilities, and consumers may have to incur higher travel costs to fulfill a radiology referral.

A primary care physician earns three sources of income. First, from the municipality a GP receives a capitation payment for each patient listed with him. The capitation payment is not subject to risk adjustments. Second, a GP receives fee-for-service payments from National Health Insurance. Third, a GP receives patients' copayments. Each of the three components makes up about one third of a GP's practice income.

Radiology and imaging services in Norway are provided by public and private laboratories. Public laboratories are service departments of public hospitals. Private laboratories are for-profit companies. In either case, radiologists or trained medical personnel perform the procedures, and radiology reports are sent to the referring physicians. As far as we are aware, GPs in Norway do not have financial stakes or ownership in private radiology laboratories, although there is no legal restriction on partnership or joint ownership. Neither do we know of any contracts that specify payments from laboratories to GPs based on their radiology and imaging referrals.

Private laboratories charge patients copayments, and bill National Health Insurance for fees. With a referral a patient pays the same copayment whether he uses a public or private

[2] A patient may be able to obtain second opinions from a provider other than his or her own GP. In some cases, for example, when the patient is unable to get an appointment from the listed GP due to vacations or long waits, the patient can obtain services from another GP.

laboratory. A private laboratory must have a contract with a Regional Health Authority to bill National Health Insurance. The contract specifies the volume a Regional Health Authority is prepared to pay for, and a payment amount. This revenue for a private laboratory is in addition to fees from National Health Insurance and patient copayment. If a laboratory provides services in excess of the contracted volume with a Regional Health Authority, no extra payment will be received from the Regional Health Authority, although the laboratory still receives reimbursement from National Health Insurance and patient copayment.

Many public and private radiology laboratories operate in major urban centers. The density of public laboratories in major cities is comparable to that of private laboratories. In rural areas, public hospitals are often the only facilities where imaging referrals can be served. A GP has the choice of referring a patient to a public laboratory or a private laboratory that has a contract with an Regional Health Authority. In major cities, private laboratories are often more convenient to patients because of shorter waiting and travel times, as well as longer operating hours. Some public laboratories ration their services and do not accept ordinary referrals from primary care physicians. Nevertheless, for patients with more complicated or uncommon imaging and radiology procedures, laboratories in public hospitals may be more suitable. In many cases, the typical referral seems more likely to be one for a private laboratory, and variations in market conditions for GPs will affect variations in referral rates to private laboratories.

## A model of referral and patient list

In this section we set up a model of radiology referral and patient list. The model will adopt many of the institutional features in the Norwegian general practitioner (GP) market. According to National Health Insurance, 99% of Norwegian residents are listed with GPs. The GP is also a gatekeeper; secondary services require a GP's referral. We proceed in two steps. First, we analyze a GP's referral decision given the number of patients he has in the practice. Second, given the optimal referral decisions, we study the GP's choice of practice size.

We normalize the demand for radiology services and assume that each patient in the GP's practice potentially requires a referral. In an initial visit, the GP obtains some information about a patient's medical conditions. In many cases, radiology services will not be needed. This happens when the patient's severity is low, the diagnosis clear, or both. In other cases, diagnostic radiology may have to be considered. Information from radiology may help the GP and the patient to formulate the next steps in the treatment episode. Upon learning radiology test results, the GP may stop treatment, continue treating the patient, or refer the patient to specialties. At the time when the radiology test is being considered, the GP should take into account these possibilities. Furthermore, the GP should consider costs to the patient due to radiology, such as copayment, time and travel cost, etc.

To capture the possible treatment continuations upon a radiology test, we use a parameter $\beta$ to represent the expected benefit from a treatment episode beginning with a radiology referral. Expected benefits vary across patients, so we let $\beta$ be random and follow the distribution $F$ with density $f$ on an interval, which will be defined shortly.

To the GP, a referral yields an expected net revenue $S$, and we allow this to depend on the patient's expected benefit $\beta$. The expected net revenue $S(\beta)$ summarizes potential patient copayments and fee-for-service reimbursements from National Health Insurance, and the GP's costs from the continuing treatment episode after the radiology referral. Our comparative static results below do not rely on assumptions on the function $S$, but this function likely follows an inverted U-shape. For low expected patient net benefits, the intensity of treatment may be low, and the GP expects to have a low net monetary return. For high expected patient net benefits, the GP may have to refer the patient to a specialist, and again, the net monetary return to the GP will be low. For medium values of expected patient net benefits, the GP will likely continue to provide treatments, and the net monetary return will be high.

Suppose that there are $n$ patients in the GP's practice. Each patient's expected net benefit from a referral $\beta$ is drawn independently from $F$. After an initial visit, the patient and the GP both learn the realization of $\beta$. Then the GP may suggest a referral and the patient will decide whether to follow through. We assume that the patient will accept a referral only if the net expected benefit is positive. We model the GP's referral decision by a net benefit threshold $\widehat{\beta}$: he recommends a referral if and only if $\beta \geq \widehat{\beta}$. Because of the patient's reaction, we let $\widehat{\beta}$ be nonnegative. The total number of referrals is $n(1 - F(\widehat{\beta}))$. There is therefore no loss of generality if we let $\beta$ vary on the interval [0, 1]; any negative realization of $\beta$ would not lead to a radiology consult.

The GP incurs monetary and time costs from referrals. These costs are due to the time and effort needed to read reports and communicate with radiologists, etc. We call this the effort cost due to referrals. Given that there are $n$ patients who demand referrals and the referral threshold $\widehat{\beta}$, the effort cost is $C(n(1 - F(\widehat{\beta})))$, where $C$ is a positive, strictly increasing and strictly convex function.

The GP's expected payoff is

$$n \int_{\widehat{\beta}}^{1} S(\beta)\, f(\beta)\, \mathrm{d}\beta - C(n(1 - F(\widehat{\beta})));$$

the first term is the monetary revenue, whereas the second term is the effort cost. We, however, model the physician's behavior as guided by the utility function

$$U(\widehat{\beta}; n, S, \theta) \equiv n \int_{\widehat{\beta}}^{1} S(\beta)\, f(\beta)\, \mathrm{d}\beta - C(n(1 - F(\widehat{\beta}))) + n\theta \int_{\widehat{\beta}}^{1} \beta f(\beta) \mathrm{d}\beta. \quad (1)$$

Besides the GP's revenue and effort, expression (1) includes a product of the patient's expected net surplus and a parameter $\theta$.

How do we interpret the utility function in (1)? We hypothesize that the GP's referral threshold is affected by market conditions. One can think of market conditions determining a bargaining outcome between physicians and patients, given by the maximization of a weighted sum of the GP's payoff and the patient's surplus. Market conditions influence the weight on patient surplus. In a more competitive market, a GP will have less bargaining power because the patient may switch to another GP, and therefore the value of $\theta$ tends to be higher. In our empirical work, we use market conditions to identify $\theta$.

The GP's optimal choice of the referral threshold $\widehat{\beta}$ can be characterized as follows. The first-order derivative of (1) is

$$\left[-S(\widehat{\beta}) - \theta\widehat{\beta} + C'(n(1 - F(\widehat{\beta})))\right] f(\widehat{\beta})n.$$

At an interior solution, the value of $\widehat{\beta}$ is set where the weighted sum of the GP's and the patient's marginal benefits, $S(\widehat{\beta}) + \theta\widehat{\beta}$, is equal to the marginal effort cost $C'(n(1 - F(\widehat{\beta})))$. At a corner solution, $\widehat{\beta}$ is set at 0 so that all patients with positive expected benefits will receive a referral.

How does the threshold $\widehat{\beta}$ change with respect to the number of patients in the practice $n$ and the market-condition parameter $\theta$? Applying the implicit function theorem on the first-order condition (at the interior solution),[3] we obtain the following:

- A GP decreases radiology referrals when the number of patients in his practice increases; $\partial\widehat{\beta}/\partial n > 0$.
- A GP increases radiology referrals when the weight on patient benefit increases: $\partial\widehat{\beta}/\partial\theta < 0$.

These results follow directly from benefit and cost considerations. A higher $\theta$ increases the concern for patient benefit, and induces the GP to lower the referral threshold, raising the number of referrals. When $n$ increases, the GP's marginal cost increases, which reduces referrals.

Next, we turn to the GP's decision on the optimal practice size. We begin by defining the optimized value of (1):

$$V(n) = \max_{\widehat{\beta}} \; n \int_{\widehat{\beta}}^{1} S(\beta)\, f(\beta)\, \mathrm{d}\beta - C(n(1 - F(\widehat{\beta}))) + n\theta \int_{\widehat{\beta}}^{1} \beta f(\beta) \mathrm{d}\beta. \tag{2}$$

The value function $V(n)$ is the GP's payoff from having $n$ patients in his practice when he chooses the optimal referral threshold. In the Norwegian system, the GP receives a capitation fee for each patient in the practice. Let $R$ denote the capitation fee. If the GP has $n$ patients, his total payoff is $V(n) + nR$, which we assume is strictly quasi-concave.

If the GP were able to choose the practice size, he would choose it to maximize $V(n)+nR$. In the Norwegian system, however, the GP is only able to specify the desired practice size. Patients specify their preferences on GPs to National Health Insurance, and a central matching mechanism allocates patients to each GP. A GP may be assigned more or less than his desired number of patients. We assume that if a GP is assigned more than the desired number of patients for his practice, he rejects the excess number of patients. If he is assigned less than his desired number, then that becomes his practice size; we call this case *patient shortage.*

In the short run, a GP may not be able to influence the demand from patients who want to be listed with him. For a GP, we model patients' demand for listing with him as a random variable. Let $N$ be a random variable with support on the positive real numbers, and distribution $G$ and density $g$. The number of patients who want to be listed with a GP is a realization of $N$. Suppose that the GP chooses a desired practice size, $\widehat{N}$, which is the limit of his practice size. If $N < \widehat{N}$, the GP's practice size is $N$. If $N > \widehat{N}$, the GP's practice size is $\widehat{N}$.

Given the demand specification, for a given desired practice size $\widehat{N}$, the GP's expected payoff is

$$\int_{0}^{\widehat{N}} [V(N) + NR]\, g(N) \mathrm{d}N + \int_{\widehat{N}}^{\infty} \left[V(\widehat{N}) + \widehat{N}R\right] g(N) \mathrm{d}N. \tag{3}$$

The first-order derivative of (3) is

$$\begin{aligned}&\left[V(\widehat{N}) + \widehat{N}R\right] g(\widehat{N}) - \left[V(\widehat{N}) + \widehat{N}R\right] g(\widehat{N}) + \left[V'(\widehat{N}) + R\right] (1 - G(\widehat{N}))\\ &\quad = \left[V'(\widehat{N}) + R\right] (1 - G(\widehat{N})).\end{aligned} \tag{4}$$

[3] The sign of the derivative of the optimal referral threshold $\widehat{\beta}$ with respect to a parameter ($n$ and $\theta$) is the same as the sign of the cross-partial derivative of the objective function (1) with respect to $\widehat{\beta}$ and the parameter. Generally, if $x(\theta) = \mathrm{argmax}_x f(x;\theta)$, then, by the implicit function theorem, $x'(\theta) = -f_{x\theta}/f_{xx}$, and the sign of $x'(\theta)$ is the same as the sign of $f_{x\theta}(x;\theta)$, by the second-order necessary condition for a maximum.

The value of (4) vanishes if and only if $\widehat{N} = \text{argmax}_N V(N) + NR \equiv N^*$. The optimal practice-size limit is one that the GP would have chosen if he was able to pick the practice size freely.

The result captures the following intuition. Suppose that the GP sets a practice-size limit $\widehat{N}$ below $N^*$. There are two possibilities. If $N$ turns out to be less than $\widehat{N}$, the payoff would not be affected by any small change in the practice limit. If $N$ is more than $\widehat{N}$, the GP would have increased his payoff by a small increase in $\widehat{N}$. Setting $\widehat{N}$ below $N^*$ is suboptimal. Now suppose that the GP sets a practice size limit $\widehat{N}$ above $N^*$. If $N$ is below $\widehat{N}$, the GP's payoff is unaffected by any small change in $\widehat{N}$. If $N$ is above $\widehat{N}$, the GP would have increased his payoff by a small decrease in $\widehat{N}$. It is indeed optimal for the GP to report truthfully his desired practice size. We summarize the result here:

- A GP optimally sets his desired practice size to the level he would have chosen if he were able to choose the practice-size without any demand constraint; $\widehat{N} = N^* \equiv \text{argmax}_N V(N) + NR$. The optimal practice size limit is independent of the distribution of demand $G$.

Market conditions may affect how likely it is that a GP may face a patient shortage. When the density of GPs in a geographical market is high, the GP may likely be rationed. According to the comparative static results above, he would recommend more radiology referrals than a GP who does not face a patient shortage. Furthermore, in a more competitive market, a GP may have less bargaining power, so that the value of $\theta$ tends to be higher. Both factors tend to raise a GP's equilibrium referral rates. We summarize the predictions of the model. Given a cost function $C$, and distributions of referral benefits and demand, respectively $F$ and $G$, we have:

**Prediction 1:** A GP who faces a patient shortage has a higher referral rate than a GP who does not.

**Prediction 2:** In a more competitive market, a GP has a higher referral rate due to lower bargaining power.

We now discuss the robustness of our model. We have studied the model in two steps: referral decisions and then maximum practice-size decisions. We use monthly data in the empirical work. Within this time frame, a GP can reasonably expect the size of his practice to be given. This then corresponds to the first step of referral decision making. Furthermore, when the practice size is given, the event of a patient shortage can be regarded as predetermined, so can be used as an explanatory variable.

We have focused on radiology referrals; our data are on such services. Including many services and referrals in the model would not involve any new conceptual issue. We can imagine that these other services or referral decisions are at their respective optimal levels. Then we can apply the comparative static results above. Furthermore, differences in patients' health conditions can be captured by altering the benefit distribution function $F$. Differences across municipalities and, hence, the overall demand for GPs, can be captured by altering patient distributions $G$.

We do not distinguish between referrals to public and those to private laboratories, but the model can be adapted for this distinction. Public laboratories are usually more appropriate for some medical conditions or when travel distances to private laboratories are too big. We can let the GP's referral decision be made in two steps. First, the GP decides how the patient may benefit from a diagnostic imaging test. In this first step, based on the patient's medical condition and location, the GP will have to consider whether a public laboratory or a private laboratory is more appropriate. Second, after the assessment of the benefit in the first step, he has to decide whether to make the referral, based on his utility (which is partially determined by the patient's benefit). For some medical conditions, public laboratories may be the only appropriate choice; this may also be true for some remote locations. Otherwise, the GP may have more flexibility in choosing between referrals to public and private laboratories. In our empirical analysis, we study separately referrals to private and public laboratories.

We have used a model with symmetric information. At the referral stage, the GP and the patient share the same information. The basic incentives in the model remain the same when there is asymmetric information. When the GP has more information, demand inducement becomes relevant. A patient may infer the benefit or cost of a referral from that recommendation. Nevertheless, along an equilibrium path, the patient's inference must be consistent with the GP's private information. Because our comparative results are based on simple utility maximization principles, we expect that the model predictions will continue to hold in a more complex environment with some asymmetric information.

We have assumed that a GP's demand is random. This is a natural assumption in the short run, say, within a year or two. In the long run, a GP likely has a higher demand if he has a good reputation, so we do expect that a GP will attempt to build reputation. By being more relaxed towards radiology referrals, a GP may raise patient satisfaction, which, in turn, enhances his reputation. Furthermore, in a more competitive environment, reputation should be more important. These considerations reinforce our results. We expect that in the long run, more referrals will be associated with a more competitive GP market.

## Descriptive statistics

Data for this study are from Norwegian National Health Insurance. Claims data from private and public radiology laboratories are merged with information of referring physicians and characteristics of the physicians' municipalities. Only referrals from primary care physicians are included. Monthly numbers of referrals by a physician are available for the 4 years between 2004 and 2007. The referrals are classified according to four modalities: X-ray, ultrasound, magnetic resonance imaging (MRI), and computerized axial tomography (CAT scan). Because we are primarily interested in incentives of private GPs, we exclude salaried GPs employed by municipalities; this has led to a 7% reduction in the number of observations. Salaried GPs are mostly located in remote municipalities. Hence, even if we were interested in comparing private GPs with salaried GPs, it would be difficult to separate location and incentive effects.

Because we use claims data from the laboratories to National Health Insurance, referrals refused by patients are unavailable. We are interested in referrals due to competitive pressures and patients' demands, so we do not consider this omission to be problematic. Although we have information about physicians and their practices, we do not have information about patients' medical conditions.

The population distribution in Norway is scattered. There are a number of fairly densely populated urban areas (such as Bergen, Oslo, and Trondheim), and many remote areas where long distances separate centers of municipalities. Patients referred to radiology examinations experience considerable variations of travel times depending on their locations. Since travel cost can be high, both in terms of transportation and time, GPs should be sensitive to patients' travel distances to their nearest radiology providers. Ideally, we should measure the travel distances from a patient's home to the nearest public or private laboratories. This information is unavailable to us, so we proxy the patient's travel time (inversely) by the distance between the referring GP's municipality and the nearest laboratory's municipality. Since most patients

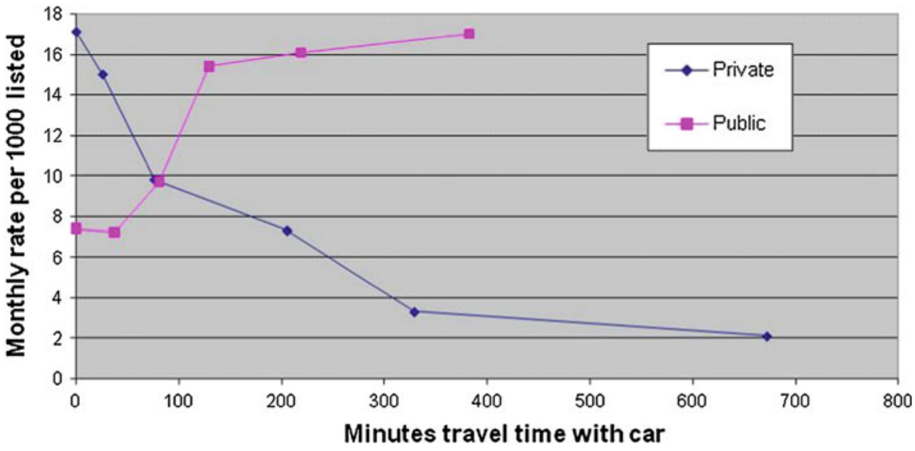


**Fig. 1** Travel time and referral rates

**Table 1** Monthly referral rates per 1,000 listed patients, by years and laboratory types (# obs. in parenthesis)

| | Year | | | |
|---|---|---|---|---|
| | 2004 (39,735) | 2005 (41,552) | 2006 (41,836) | 2007 (42,638) |
| Private | 11.1 | 11.6 | 12.1 | 13.1 |
| Public | 2.8 | 7.6 | 8.4 | 8.9 |
| Total | 13.9 | 19.2 | 20.5 | 22 |

are listed with a GP in their home municipality, this approximation is acceptable. We use travel times to both private and public laboratories. Travel time is measured by the driving time in hours with a small private car. A matrix that describes the travel times between Norwegian municipalities in 2002 is provided by the private firm InfoMap Norge AS.

We define a GP's monthly normalized referral rate as the number of radiology referrals per 1,000 listed patients. Figure 1 shows GPs' average monthly referral rates to public and private radiology laboratories. The maximum travel time by car to a public laboratory is 6 h and 20 min, while the longest travel time by car to a private laboratory is 18.5 h. Private laboratories likely offer more flexible hours and better amenities than public laboratories. More important, waiting times for procedures at private laboratories are likely to be shorter. These conveniences tend to be more important if they are comparable to the travel time and cost, so when travel time is short, private laboratories are more attractive. Conversely, when travel time is long, these conveniences do not figure significantly. This consideration is borne out in Fig. 1: private laboratory referrals dominate public when travel time is low, but the opposite is true when travel time is high. The plots of referral rates to private and public laboratories intersect at a travel time of 90 min.

Table 1 reports the time trend of GPs' monthly rates of referral to public and private laboratories. Both have increased over our data period. Data for 2004 are believed to be somewhat incomplete, especially for laboratories in public hospitals. Even disregarding 2004, we find a 13% increase in referrals to private radiology and a 17% increase in referrals to public radiology from 2005 to 2007. These increases are somewhat higher than average services in the health sector. In the empirical analyses, we control for trend effects by year dummies.

**Table 2** Monthly referral rates per 1,000 listed patients, by percentiles of open practices, open practices per 1,000 inhabitants, vacancies and vacancies per 1,000 inhabitants in municipality (# obs. = 165,425)

| | Median | 50–75th% | 75–90th% | Over 90th% |
|---|---|---|---|---|
| By open practices | | | | |
| Private | 12 | 12.3 | 15 | 20.6 |
| Public | 7 | 7.3 | 3.1 | 0.8 |
| Total | 19 | 19.6 | 18.1 | 21.4 |
| By open practices per 1,000 inhabitants | | | | |
| Private | 11.2 | 13.3 | 15.3 | 7.5 |
| Public | 6.9 | 6.8 | 5.2 | 11.1 |
| Total | 18.1 | 20.1 | 20.5 | 18.6 |
| By no. of vacancies | | | | |
| Private | 9.4 | 11.6 | 15.0 | 20.5 |
| Public | 9.3 | 6.9 | 4.1 | 0.8 |
| Total | 18.7 | 15.5 | 19.1 | 21.3 |
| By no. of vacancies per 1,000 inhabitants | | | | |
| Private | 10.8 | 12.7 | 16.5 | 10.0 |
| Public | 7.6 | 6.7 | 3.7 | 9.7 |
| Total | 18.4 | 19.4 | 20.2 | 19.7 |

There are some seasonal effects in our data. For example, GPs' referral rates in July may be 60% lower than in November (likely due to summer vacations). We will explain how we have handled the seasonal components at the end of Sect. "Empirical analysis and results".

We use administrative borders to define market boundaries. In Norway, primary care is the municipalities' responsibilities, and almost the entire population is listed with GPs in their residential municipality. Therefore, administrative borders are appropriate for our study. As an alternative, we could count the number of GPs with open lists who are within a certain distance from a GP, and use that as the extent of competition faced by the GP. This measure would be parallel to Propper et al. (2004), who define a hospital's catchment area by a radius of 30 min of travel time, and measure the extent of competition by the number of hospitals in the catchment area.

Table 2 presents the distributions of GPs' referral rates according to the number of open practices, as well as to the number of open practices per 1,000 inhabitants in the municipality. The number of open practices and the per-capita counterpart measure the degree of competition; patients dissatisfied with their current GPs can only switch to GPs who accept new patients. The per-capita measure takes into account municipality sizes. Table 2 also contains referral rates according to vacancies in a municipality (defined as the sum of maximum list sizes less the sum of actual list sizes) and vacancies per 1,000 inhabitants in the municipality. Vacancies measure the competitiveness of GP supply.

From Table 2, GPs' private laboratory referral rates are positively correlated with the number of open practices, but GPs' referral rates to public laboratories exhibit the opposite correlation. The total referral rate increases by 12.6% as the number of open practices moves from the median to the over-90th percentile. For the number of open practices per 1,000 inhabitants, the private and public laboratory referral rates exhibit different patterns. There, the private referral rate actually drops for municipalities in the over-90th percentile,

**Table 3** Monthly referral rates per 1,000 listed patients, by patient shortage (# obs. in parenthesis)

| | Enough patients (125,922) | Shortage of patients (39,839) |
|---|---|---|
| Private | 11.8 | 12.6 |
| Public | 7.2 | 6.3 |
| Total | 19 | 18.8 |

but the corresponding public laboratory referral rate rises, while the total referral rate follows an inverted U-shape. Similar corresponding correlation patterns apply to vacancies and vacancies per 1,000 inhabitants.

Table 3 shows GPs' monthly referral rates according to whether or not they experience a shortage of patients. A GP is said to experience a patient shortage if his actual list size is less than the maximum he has reported to National Health Insurance by at least 100. In our data, an average of 24% of GPs have experienced a patient shortage. The percentage of GPs with a patient shortage is smaller in 2007 (21.9%) than in 2004 (25.7%). This reduction results from a drop in the reported maximum list sizes and an increase in the number of listed patients for some GPs. From Table 3, GPs who experience a patient shortage refer more patients to private laboratories than those who have enough patients, but refer less patients to public laboratories. Nevertheless, the total referral rates are almost the same whether or not GPs experience patient shortage.[4]

Table 4 shows some characteristics of GP practices and their municipalities. Our data consist of a panel of GPs over a period of 48 months, so we include between-GP and within-GP variations as well as the usual descriptives.[5] The monthly total number of referrals is 19.0 per 1,000 patients. From the columns that display between and within standard deviations, there are considerable variations both across individuals and periods. The average list size is 1,235 people. On average, 11% of the people listed are over 70 years old. About 70% of the GPs are male and the mean age of Norwegian GPs is 48 years.

The mean travel time by car to the nearest private laboratory is 1 h and 3 min. The longest travel time is more than 18 h. The mean travel time to a public laboratory is 24 min with a maximum of 6 h and 22 min.[6] Only gender is a time–invariant variable, and the within variation equals to zero. Travel time comes out with some within variation due to 13 GPs having moved practices between municipalities during our data period. The patient composition variable shows variations over time.

The variable for testing Prediction 1 is *Short,* which indicates whether a GP faces a patient shortage. The key variables for testing Prediction 2 are *#Open*, *#Open/capita*, *#Vacancy* , and *#Vacancy/capita*. The variable *#Open* is the number of GPs in a municipality accepting new patients; the variable *#Open/capita* is *#Open* divided by the municipality population (in units of thousands).[7] The variable *#Vacancy* is the sum of GPs' maximum list sizes in a

4 We have also verified that our results are robust when patient shortage is defined as 50 and 200 patients less than the stated maximum, or when shortage is defined simply as the difference between the maximum and actual list sizes. These robustness checks are available from the authors.

5 Because our panel is unbalanced, the within and between standard deviations do not sum to the overall standard deviation.

6 In Table 4, there are less observations for *PrTravel* and *PuTravel* than other variables. The reason is that InfoMap Norge AS provided the travel time information for 2002, but since then a number of municipalities merged, so the software could not provide information for new municipalities.

7 We define *#Open* as the number of GPs in a municipality with open lists minus one if the GP's practice is open; otherwise, it is equal to the number of GPs with open lists.

**Table 4** Variable definitions and descriptives

| Variable | Definition | Mean | SD | SD between | SD within | Min | Max |
|---|---|---|---|---|---|---|---|
| Referral | No. referrals in a month per 1,000 listed patients | 19 | 12.5 | 9.1 | 9.1 | 0 | 500 |
| PrReferral | No. referrals in a month per 1,000 listed patients to private provider | 12 | 10.1 | 8.4 | 6.1 | 0 | 500 |
| PuReferral | No. referrals in a month per 1,000 listed patients to public provider | 7 | 9.9 | 7.8 | 6.4 | 0 | 249 |
| List | Practice size in units of 1,000 patients | 1.235 | 0.39 | 0.399 | 0.081 | 0.09 | 2.712 |
| Propold | Proportion of persons in the list aged 70 and older | 0.11 | 0.06 | 0.06 | 0.009 | 0.001 | 0.68 |
| Propfem | Proportion of females in the list | 0.51 | 0.1 | 0.1 | 0.012 | 0.09 | 0.9 |
| Male | Dummy variable equal to one if the physician is male | 0.7 | 0.46 | 0.46 | 0 | 0 | 1 |
| Age | GP's age in years in 2001 | 48 | 9.41 | 10.2 | 1.13 | 26 | 75 |
| Short | Dummy variable equal to one for GPs with (preferred—actual list) $\geq 100$ | 0.24 | 0.43 | 0.4 | 0.21 | 0 | 1 |
| #Open | No. GPs in municipality who accept new patients | 74.5 | 129.4 | 124.5 | 7.8 | 0 | 422 |
| #Open/capita | No. GPs who accept new patients per 1,000 inhabitants | 0.62 | 0.18 | 0.17 | 0.08 | 0 | 3.75 |
| #Vacancy | Total no. of vacancies on lists | 11,249 | 23,489 | 22,125 | 4,403 | −2,530 | 85,274 |
| #Vacancy/capita | Total no. of vacancies on lists per 1,000 inhabitants | 88.40 | 128.84 | 137.17 | 49.05 | −1,000 | 268.85 |
| PrTravel | Travel time in hours by car from GP's municipality to nearest private laboratory's municipality | 1.04 | 2 | 2.21 | 0.17 | 0 | 18.42 |
| PuTravel | Travel time in hours by car from GP's municipality to nearest public laboratory's municipality | 0.4 | 0.71 | 0.82 | 0.09 | 0 | 6.37 |

There are 165,425 observations for each variable, except the last two. There are 165,283 observations for each of PrTravel and PuTravel municipality less the sum of their actual list sizes; the variable *#Vacancy/capita* is *#Vacancy* divided by the municipality population (in units of thousands). We use these four variables to identify the effects of market conditions on referral rates. More discussions follow shortly.

On average, more than 74 practices accept new patients in the municipalities; this corresponds to a mean of 81% of open lists. On average 0.62 GP per 1,000 inhabitants accepts new patients. The average vacancy is 11,249 vacancies, and the average vacancy per 1,000 inhabitants is 88.4.

## Empirical analysis and results

We now use data described in Sect. "Descriptive statistics" to test the predictions from the model in "A model of referral and patient list" section. For econometric analysis, the Norwegian list-patient system has several advantages. There is almost complete patient and GP participation under Norwegian National Health Insurance. Self-selection into the system is unlikely to be a problem. We also know a GP's practice size. This allows us to standardize a GP's practice, so that comparing the number of referrals of GPs with different practice sizes is meaningful. Physicians' fees from National Health Insurance and patient copayments are outcomes of negotiation between the state and the Norwegian Medical Association, and uniform among all GPs. Therefore, at the municipality level, market conditions do not influence a GP's fees.

Our data consist of radiology referrals made by a panel of doctors over a period of 48 months. Unobserved heterogeneity among GPs is likely because our data cannot possibly include all relevant factors that influence referral decisions. Unobserved heterogeneity violates the assumptions of ordinary least squares regression because error terms of different periods may be correlated for a GP.

Using the index $i$ to refer to GP, and $t$ to refer to time period (a month), we fit a standard model:

$$y_{it} = \alpha_i + x_{it}\beta + z_i\gamma + \epsilon_{it} \qquad (i = 1, \ldots., 4265; \qquad t = 1, \ldots., 48).$$

The dependent variable $y_{it}$ is the $i$-th GP's radiology referral rate in the $t$-th period. The independent variable $x_{it}$ is a vector of GP and time-varying explanatory variables, while $z_i$ is a vector of GP-specific, time–invariant variables. The vectors of coefficients to be estimated are $\beta$ and $\gamma$. To allow for GP heterogeneity, we let $\alpha_i + \epsilon_{it}$ be a stochastic error term. The stochastic variable $\alpha_i$ is the GP-specific random variable capturing unobserved heterogeneity. It differs among GPs, but is constant for a GP over time. We assume

$$\begin{array}{lll} \mathrm{E}(\epsilon_{it}) = 0 & \mathrm{Var}(\epsilon_{it}) = \sigma_\epsilon^2 & \mathrm{Cov}(\epsilon_{it}, \epsilon_{is}) = 0 \\ \mathrm{E}(\alpha_i) = 0 & \mathrm{Var}(\alpha_i) = \sigma_\alpha^2 & \mathrm{Cov}(\alpha_i, \epsilon_{it}) = 0 \end{array}$$

We use fixed effects models, since the Hausman test often rejects the assumption that $\alpha_i$ is uncorrelated with either $x_{it}$ or $z_i$.

Our model is on the effect of market conditions on the bargaining between GPs and patients. For consumers, we postulate that their bargaining power is higher when more GPs are available. In our data, consumers' ability to change GPs can be measured by the number of practices in a consumer's municipality that accept new patients. Accordingly, the number of GPs with open lists, the variable *#Open*, positively measures consumers' bargaining advantage against GPs. We standardize for the municipality size by the variable *#Open/capita*.

For GPs, the difference between their desired supply, as measured by the sum of maximum list sizes, and the actual supply, as measured by the sum of actual list sizes, indicates

**Table 5** Estimated effect (robust std) of practice characteristics and market conditions on the monthly number of referrals to private laboratories per 1,000 listed patients

| | | | | |
|---|---|---|---|---|
| Propfem | 10.1** (3.34) | 9.56** (3.35) | 9.98** (3.34) | 9.81** (3.33) |
| 0.042<Propold≤0.105 | 0.72* (0.32) | 0.78* (0.31) | 0.72* (0.32) | 0.68* (0.32) |
| 0.105<Propold≤0.217 | 0.91* (0.43) | 0.99* (0.42) | 0.91* (0.43) | 0.84* (0.43) |
| 0.217<Propold | 1.89* (0.80) | 1.97* (0.80) | 1.89* (0.80) | 1.79* (0.80) |
| 55≤Age | 0.09 (0.10) | 0.09 (0.19) | 0.09 (0.18) | 0.11 (0.18) |
| Short | 0.65** (0.13) | 0.64** (0.13) | 0.63** (0.13) | 0.61** (0.13) |
| #Open/capita | 0.63** (0.25) | | | |
| #Open | | 0.016* (0.007) | | |
| #Vacancy/capita | | | 0.69 (0.43) | |
| #Vacancy | | | | 0.032** (0.008) |
| PrTravel | −1.68** (0.28) | −1.55** (0.26) | −1.67** (0.29) | −1.65** (0.28) |
| PuTravel | 0.38 (0.52) | 0.58 (0.51) | 0.38 (0.52) | 0.46 (0.51) |
| Constant | 8.31** (1.80) | 7.51** (1.86) | 8.70** (1.79) | 8.56** (1.79) |
| Dummies for years | Yes | Yes | Yes | Yes |
| Adjusted $R^2$ | 0.13 | 0.20 | 0.13 | 0.16 |
| No. observations | 165,092 | | | |
| No. GPs | 4,261 | | | |
| No. observations per GP | Min: 1; Avg: 38.7; Max: 48 | | | |

Estimates with *(**) indicate that the parameter is significantly different from zero at the five (one) percent level for a two-tailed test.

the competitiveness of the GP market. This is the variable *#Vacancy*. A higher value of *#Vacancy* indicates that market conditions are less favorable to GPs, and reduce their bargaining power against consumers. Again, we standardize for the municipality size by the variable *#Vacancy/capita*. These four variables are used as proxies for the parameter $\theta$ in Sect. "A model of referral and patient list".

The variables for market conditions are predetermined. The number of GPs with open lists is arguably predetermined when referral decisions are being made. Geographical variations in the numbers of open lists are largely explained by variations in GP density prior to the introduction of the regular GP scheme in 2001. Referral decisions within a time period do not affect the number of open lists in the market within the same time period. We consider the total maximum and actual list sizes for a municipality. Neither of these can be influenced by an individual GP's referral decision.

Prediction 1 of our model is about the effect of GPs' patient shortages on referral rates, so we include the variable *Short* as defined in Table 4. Our regressions also use other controls; their inclusion is self-explanatory. GP fixed effects are used in all regressions.

Results from the estimations of factors that influence a GP's referrals to private radiology, *PrReferral*, are in Table 5. In tables on regression results, estimates significant at 5% are superscripted by *, and 1% by **. Because the proportion of elderly in a GP's practice (*Propold*) and the GP's age (*Age)* show nonlinear relationships to *PrReferral*, we convert these two variables into dummy variables. For *Propold*, groups are determined according to 10th, 50th and 95th percentiles. We also have considered alternative groupings, but these have not changed regression results. *Age* is grouped according to the 75th percentile.

There are four sets of regression results in Table 5. Each regression uses a different measure of competition: *#Open/capita*, *#Open*, *#Vacancy/capita*, and *#Vacancy*. The other covariates are common in all regressions. Signs of estimates of covariates are as one would naturally expect. The referral rate increases with a patient's age and with the proportion of females in a GP's practice. Longer travel times from the GP to private laboratories tend to reduce referrals, but the travel times to public laboratories have insignificant effects on referrals to private laboratories. These estimates are stable across the four regressions.

The four estimates of the effect of patient shortage on referrals to private laboratories range from 0.61 to 0.65, are significant at 1%, and stable across the regressions. If we take the average of these four estimates, then GPs with patient shortage have a referral rate 0.63 per 1,000 listed patients higher than GPs with enough patients. Since the mean referral rate per 1,000 listed patients is 11.8 per 1,000 patients for GPs with enough patients, patient shortage contributes to a 5.3% increase in the referral rate The results support Prediction 1 in Sect. "A model of referral and patient list".

To support Prediction 2, the estimate of the market conditions on referral rates should be positive. We have used four variables to proxy market conditions: *#Open/capita*, *#Open*, *#Vacancy/capita*, and *#Vacancy*. In each of the four regressions in Table 5, this coefficient is positive. The coefficient for *#Vacancy/capita* is insignificant; the other three are significant.[8] Our results support Prediction 2 in Sect. "A model of referral and patient list". In fact, from the regression with *#Open/capita* as the market-condition proxy, we can get a sense of the magnitude of the effect by the following: the estimated magnitude of the effect of *#Open/capita* is 0.63. If we raise the *#Open/capita* from 0 to 0.72, which is the 75th percentile, we will add 0.45 to the referral rate, which is a 3.8% increase compared to the mean referral rate.

We check the robustness of the basic model by alternative estimation methods. We will only use *#Open/capita* as the market-condition variable in the robustness checks. We consider *#Open/capita* to be the most relevant since it indicates a patient's choice set, taking into account municipality population density. Our first robustness check concerns location effects. GPs are clustered in municipalities, and GPs in the same municipality may develop their own professional culture of radiology referrals. This unobserved heterogeneity can be modeled in two ways. In the first specification, we introduce a dummy for each municipality. In the second specification, we introduce the municipality level as a third level with the random intercepts for municipalities. We assume that the random intercept for a municipality has a zero expectation and a constant variance. In addition, we assume that the random intercepts and residual errors are mutually independent. From Table 6, signs and magnitudes of the estimated coefficients of *Short* and *#Open/capita* are similar to those in the main regression in Table 5. In addition, we have found a statistically significant municipality random effect.

Second, we divide our data according to four radiology modalities, and estimate each individually. The results are in Table 7. The estimated coefficients of *Short* are all positive and statistically significant at 1%. The estimated coefficients of *#Open/capita* are positive and significant at 5% for X-ray and ultrasound. The absolute effect of *#Open/capita* is larger for X-ray than for ultrasound. As expected, the coefficients become smaller than when all four modalities are put together. The absolute effect of *Short* is larger for X-ray. Evaluated at the mean referral rate of each modality, the relative effect of *Short* is about 5% for each modality, except for CAT scan which is 7%.

Third, we use referrals to public laboratories and total referrals as dependent variables. These are normalized in the same way, as numbers of referrals in a month per 1,000 listed patients. From Table 8, *Short* has a positive effect on referrals to public laboratories. Similar to results in Table 5, *Short* has a positive effect on both public-laboratory and total referrals.

[8] Because the units of *#Open/capita*, *#Open*, *#Vacancy/capita*, and *#Vacancy* are very different, comparing the magnitudes of the estimates across regressions is not meaningful.

**Table 6** Estimated effect (robust std) of practice characteristics and market conditions on the monthly number of referrals to private laboratories per 1,000 listed patients adjusted for the municipality level

| | PrReferral | |
|---|---|---|
| | Municipalities as fixed effects | Municipalities as random intercept |
| Propfem | 9.43*(3.40) | 6.76**(0.88) |
| 0.042<Propold≤0.105 | 0.92** (0.28) | 0.90** (0.13) |
| 0.105<Propold≤0.217 | 1.34** (0.40) | 1.59** (0.16) |
| 0.217<Propold | 2.12** (0.75) | 2.53** (0.23) |
| Male | | 1.38** (0.21) |
| 55≤Age | 0.11 (0.18) | 0.24** (0.09) |
| Short | 0.57** (0.12) | 0.51** (0.07) |
| #Open/capita | 0.51* (0.24) | 0.60** (0.18) |
| PrTravel | −1.84** (0.45) | −1.17** (0.11) |
| PuTravel | 2.71 (2.04) | 0.19 (0.31) |
| Constant | | 5.89** (0.67) |
| Dummies for years | Yes | Yes |
| Dummies for municipalities | Yes | No, random intercept |
| Adjusted $R^2$ | 0.11 | |
| No. observations | 165092 | |
| No. GPs | 4,261 | |
| No. observations per GP | Min: 1; Avg: 38.7; Max: 48 | |

Estimates with *(**) indicate that the parameter is significantly different from zero at the five (one) percent level for a two-tailed test

**Table 7** Estimated effect (robust std) of practice characteristics and market conditions on the monthly number of referrals to private laboratories according to modalities per 1,000 listed patients

| | PrReferral | | | |
|---|---|---|---|---|
| | X-ray | Ultrasound | MRI | CAT scan |
| Short | 0.28** (0.06) | 0.07** (0.023) | 0.19** (0.05) | 0.10** (0.03) |
| #Open/capita | 0.29* (0.13) | 0.09* (0.004) | 0.17 (0.11) | 0.09 (0.05) |
| PrTravel | −0.82** (0.15) | −0.19** (0.047) | −0.46** (0.09) | −0.21** (0.05) |
| PuTravel | 0.24 (0.30) | 0.02 (0.07) | 0.16 (0.19) | 0.08 (0.09) |
| Year dummy | Yes | Yes | Yes | Yes |
| Municipality dummy | No | No | No | No |
| Adjusted $R^2$ | 0.11 | 0.07 | 0.08 | 0.18 |
| Observations | 165,092 | | | |
| GPs | 4,261 | | | |
| Observations/GP | Min: 1; Ave: 38; Max: 48 | | | |

Estimates with *(**) indicate that the parameter is significantly different from zero at the five (one) percent level for a two-tailed test

The magnitude of the effect is about a 6% increase calculated at the mean. The coefficients of *#Open/capita* are positive and significant at 1% for both public and total referrals. Predictions 1 and 2 are supported by these regressions. Longer travel times to private laboratories increase referrals to public laboratories.

**Table 8** Estimated effect (robust std) of practice characteristics and market conditions on the monthly number of referrals to public laboratories and total number of referrals per 1,000 listed patients

| | PuReferral Fixed effects | Referral Fixed effects |
|---|---|---|
| Propfem | 2.69 (4.45) | 12.79* (5.93) |
| 0.042<Propold≤0.105 | 0.80* (0.29) | 1.52** (0.45) |
| 0.105<Propold≤0.217 | 1.42** (0.40) | 2.33** (0.62) |
| 0.217<Propold | 2.27** (0.73) | 4.16** (1.16) |
| 55≤Age | 0.63* (0.28) | 0.72* (0.34) |
| Short | 0.43* (0.16) | 1.07** (0.20) |
| #Open/capita | 1.48** (0.50) | 2.11** (0.55) |
| PrTravel | 1.72** (0.40) | 0.04 (0.39) |
| PuTravel | −0.88 (0.78) | −0.49 (0.84) |
| Constant | 3.66 (2.27) | 11.98** (3.04) |
| Dummies for years | Yes | Yes |
| Adjusted $R^2$ | 0.18 | 0.07 |
| No. observations | 165,092 | |
| No. GPs | 4,261 | |
| No. observations per GP | Min: 1; Ave: 38.7; Max: 48 | |

Estimates with *(**) indicate that the parameter is significantly different from zero at the five (one) percent level for a two-tailed test

We run a robustness check to make sure that *Short* can be regarded as predetermined. We rerun the regressions with *Short* lagged by 12 months. We find that the effect of the lagged *Short* variable is still statistically significant, although the magnitude is reduced by a half. The effect of *#Open/capita* remains unchanged. We also run a regression without *Short* altogether. The effect of *#Open/capita* still remains unchanged.

As we have mentioned in Sect. "Descriptive statistics", GPs' referral rates do exhibit some seasonal patterns. To explore the possible bias due to seasonality, we have run all the regressions with month dummies. The signs and magnitudes of the effects of interest are hardly changed. Clearly, we do not need to remove seasonality completely by aggregating our data into annual observations. The month-dummy implementations yield no consequences, and aggregation will cause us to lose too much information.

Finally, we have considered the possibility that variation in GPs' practice styles may reverse the causality, so that a high referral rate causes a patient shortage. Some GPs spend very little time with each patient and refer many, while some GPs spend a lot of time with each patient and do not refer often. Furthermore, those GPs who spend very little time with each patient want a long list, and are more likely to experience a patient shortage. However, Godager et al. (2009) show that patient shortage is associated with more services per patient, so the data are inconsistent with this reversal of causality.

## Conclusions

Gatekeeping is an integral part of managed care. General Practitioners, being primary care physicians, are frontline gatekeepers. In this article, we examine how GPs' radiology referrals respond to market competition. When there are more available GPs in the market, a GP tends to refer more patients for diagnostic radiology tests. Using Norwegian data of GP radiology referrals, we show that the increase is statistically significant and modest. We have also shown that results are robust. Dividing our data into different modalities (X-ray, ultrasound, MRI and CAT scan), and allowing for municipality-location effects do not change our results.

Our results have important policy implications. Policy makers often state that substituting secondary care by primary care should save costs. The cost reduction due to this substitution may seem quite obvious: primary care uses less resources than specialty care. Nevertheless, increasing the number of GPs makes the primary-care market more competitive. Together with a capitation payment for a patient-list system, as in Norway, more GPs may experience a patient shortage from the more intense competition. Our theoretical model shows that this may lead to more referrals, and our empirical results support that. Against more competition, GPs reoptimize by referring patients more often, responding positively to patient requests. The cost-saving effect may be weakened by GPs' reactions.

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