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Who benefits from quality competition in health care?

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Abstract: We study how competition between physicians affects the provision of medical care. In our theoretical model physicians are faced with a heterogeneous patient population, in which patients systematically vary with regard to both, their responsiveness to the provided quality of care and their state of health. We test the behavioral predictions derived from this model in a controlled laboratory experiment. In line with the model, we observe that competition significantly improves patient benefits as long as patients are able to respond to the quality provided. For those patients, who are not able to choose a physician, competition even decreases the patient benefit compared to a situation without competition. This decrease is in contrast to our theoretical prediction implying no change in benefits for passive patients. Deviations from patient-optimal treatment are highest for passive patients in need of a low quantity of medical services. With repetition, both, the positive effects of competition for active patients as well as the negative effects of competition for passive patients become more pronounced. Our results imply that competition can not only improve but also worsen patient outcome and that patients' responsiveness to quality is decisive.

Keywords: physician competition, patient characteristics, heterogeneity in quality responses, fee-for-service, laboratory experiment

JEL Classifications: I11, D43, C91

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1 Introduction

Over the last decade, an increasing number of countries (e.g., UK, Netherlands, Norway, France) have expanded the scope for patient choice and competition amongst GPs to strengthen the role of market mechanisms and to improve quality (Brekke *et al.*, 2014; Siciliani *et al.*, 2017). Economic theory predicts that competition between providers can generally be beneficial to quality when prices are regulated and the price is above the marginal cost (Gaynor and Vogt, 2003). If prices are regulated, as in most European countries, providers then compete on the quality dimension. Accordingly, the more sensitive the demand side responds to quality differences, the stronger the positive effects of competition. However, competition often does not work because patients do not respond sufficiently to differences in quality.[1]

In this study, we develop a theoretical model to investigate how competing physicians respond to a heterogeneous patient population, in which patients vary by their responsiveness to the quality of medical treatment and their state of health. We then test the behavioral predictions derived from this model in a controlled laboratory experiment. Regarding patient responsiveness, we differentiate between two extreme patient types. *Passive* patients are not able to choose their physician and, consequently, are always treated by the same physician. This patient type does not only represent those, who are immobile or have no information about the quality provided, but also typifies those patients, who are not interested in choosing a physician (see, e.g., Harris, 2003; Schwartz *et al.*, 2005). *Active* patients are mobile and fully informed and choose the physician offering the highest quality of medical care. This patient type covers not only situations where a patient chooses a physician largely based on observable quality dimensions (e.g., Dranove and Jin, 2010), but also situations where the patient is informed by an expert (e.g., Brekke *et al.*, 2007; Beukers *et al.*, 2014). Besides the heterogeneity in responsiveness, patients in our set-up vary regarding their state of health. Again, we differentiate between two extreme patient types – patients, who are in need of a low number of medical services, and patients, who are in need of a high number of medical services. In our set-up physicians are paid by a fee for each service provided. We abstract away from budgetary constraints that might restrict the physician in the number of patients treated or in the number of services provided per patient as our focus is on potentially discriminating effects due to the heterogeneity of patient types.

Using an experimental approach to study physician competition offers several advantages. The most important advantage is that it allows implementing ceteris paribus changes of parameters. In our experiment, we can *exogeneously* vary the number of competitors from no competition to competition, the composition of the patient population, and the patients' responsiveness to quality changes. This allows identifying causal effects and, thus, directly testing the predictions of our theoretical model. By appropriately defining the set-up, we can not only avoid endogeneity problems that often restrain analyses based on field data, but also have full knowledge about the patients' health status, their responsiveness to the

[1] Potential reasons for that may be various, e.g., patients have not enough information about the quality of medical treatment, they only have limited mobility (e.g., due to physical restrictions or due to caring responsibilities), or they have higher travel costs or have to travel long distances. Survey evidence also suggests that patients rarely use publicly reported information and simply do not look for alternatives, even if it is in their best interest to do so (Glenngård *et al.*, 2011), or they search for basic information rather than making decisions based on clinical quality (Hoffstedt *et al.*, 2021).

quality of care, physicians' monetary incentives as well as the optimal medical treatment for each patient. Of course, implementing ceteris paribus conditions in an experiment necessarily implies abstracting from other real-world complexities.[2] But our results help to understand the behavioral effects of competition and contribute to the debate of whether quality competition among providers should be encouraged given that patients are differently responsive to the quality of medical treatment.

The results of our study provide some support for the view that competition may have positive effects on the quality of medical care, but it does so for active patients only. In contrast to the theoretical prediction, physician competition can even worsen the health outcomes of passive patients compared to a monopoly set-up. The observed effects are also sensitive to the patients' state of health: health outcomes are particularly bad for passive patients with a low severity of illness.

The remainder of the paper is organized as follows. Section 2 embeds our study in the literature. Sections 3 and 4 present the experimental set-up and the theoretical predictions, respectively. Section 5 summarizes our results and Section 6 concludes.

2 Related literature

Our paper is related to two streams of the literature. First, we add to the literature on physician payment incentives. Second, we contribute to literature that investigates physician competition.

In health economics, an extensive literature has investigated how physician incentive schemes like capitation and fee-for-service payment lead to deviations from patient-optimal treatment (e.g., Ellis and McGuire, 1986, 1990; Ellis, 1998; Iversen and Lurås, 2012). Theoretical and empirical evidence on the relationship between physician remuneration and the quality of medical care suggests that capitation entails an incentive for underprovision, while fee-for-service can induce overprovision (see, e.g., Ellis and McGuire, 1986; Gaynor and Gertler, 1995; Gosden *et al.*, 2000; Patcharanarumol *et al.*, 2018). Experimental research provides similar evidence (e.g., Hennig-Schmidt *et al.*, 2011; Green, 2014; Brosig-Koch *et al.*, 2016, 2017b,c; Lagarde and Blaauw, 2017; Di Guida *et al.*, 2019; Martinsson and Persson, 2019; Reif *et al.*, 2020).

While physician payment schemes and their consequences for medical treatment decisions are well studied, other factors might also be decisive for the quality of medical care a patient receives. One widely discussed factor is the introduction of competition between physicians. Yet, we know very little about how the level of competition between physicians affects the quality of healthcare (Gaynor and Town, 2011). The existing theoretical literature mostly admits that competition between physicians can reduce the distortions occurring under traditional incentive schemes under certain conditions (e.g., Gravelle and Masiero, 2000; Karlsson, 2007; Allard *et al.*, 2009; Gaynor and Town, 2011; Brekke *et al.*, 2014).

A large and growing body of literature has investigated the effects of competition on quality for hospitals (e.g., Cooper *et al.*, 2011; Bloom *et al.*, 2015; Moscelli *et al.*, 2018). For (local) physician markets, field

[2] See also the debate by, e.g., Herbst and Mas (2015) and Levitt and List (2007) on the extent to which insights from the laboratory can be generalized to the field.

evidence is scarce and rather mixed, however (Gaynor and Vogt, 2003). From the existing empirical studies, primary care competition is associated with higher patient satisfaction rather than increased (clinical) quality (e.g., Gravelle *et al.*, 2019; Dietrichson *et al.*, 2020). Dackehag and Ellegård (2019) analyze whether Swedish public primary care providers react to increased competition from private providers. They find that providers in markets with increasing competition registered more diagnoses. Using Norwegian data of GP radiology referrals, Iversen and Ma (2011) find that competition leads to a higher number of referrals. Dunn and Shapiro (2018), who consider the impact of competition on the quantity and type of health services provided by US cardiologists, observe that – with fee-for-service payment – a higher market concentration increases the use of cardiac catheterization, but decreases the probability of less invasive diagnostic tests being performed. According to their results, a higher concentration, signaling stronger competition, leads to improved quality of care in terms of fewer readmissions, but does not affect mortality. Koch *et al.* (2018) find that less competition due to an increase in consolidation among cardiology practices leads to increases in negative health outcomes for the patients, e.g., mortality. Studying the effect of competition on GPs' service provision in Norway, Brekke *et al.* (2019) conclude that GPs are more likely to certify sick leave to patients that visit them at their own practice (competitive environment) than at the emergency center (non-competitive environment). Evidence for competition among physicians in England, where the price is regulated, also find a positive relationship of competition and quality. Greater competition (increased number of rival practitioners) is associated with an increase in clinical quality and patient satisfaction, though the magnitudes of the effects are small (Gravelle *et al.*, 2019).

There is also some contradicting evidence, though. Godager *et al.* (2015) reexamine the effect of competition on GP referrals in Norway. When including some additional controls, competition has no or only a small positive effect on the number of referrals and, thus, the quality of medical care. Gravelle *et al.* (2016), too, find no effect of physician competition on the quality of medical care, measured by average consultation length in Australia. Analyzing the quality of medical care in terms of management of chronic diseases and length of consultation in Australia, Johar *et al.* (2014) report that competition does even lower the quality of care a patient receives. Finally, Pekola *et al.* (2017a,b) find that competition has slightly negative effects on quality in the market for physiotherapists, who are – similarly to physicians – organised and regulated by the Social Insurance Institution of Finland (Kela).

There is very limited evidence focusing directly on the heterogeneous effects of competition. Scott *et al.* (2022) reveal heterogeneous effects of competition on the provision of low-value health care by GPs. Although the authors find no impact of competition on antibiotic prescribing, they do find an impact on the number of imaging procedures for back pain or uncomplicated acute bronchitis. To the best of our knowledge, no previous study has explored how physician competition affects the quality of care for heterogeneous patient populations in which patients systematically differ with respect to their state of health and their responsiveness to the quality of care.

The mixed field evidence on the effect of competition might be due to the fact that competition between physicians can be successful only if patients can respond to quality differences. This does not need to be the case, however. One potential reason is that patients have not enough information about the quality of medical treatment (see e.g., Brook and Kosecoff, 1988; Ginsburg and Hammons, 1988).[3] In a model on monopolistic competition, Dranove and Satterthwaite (1992) demonstrate that, holding price information constant, better information about quality raises the equilibrium level of quality. Gravelle and Sivey (2010) report similar results in a model on duopoly providers in case that the costs of producing quality are not too different across the two providers. There is also some field research pointing to the particularly positive effects of information on the quality of care in competitive health care markets. For example, Grabowski and Town (2011) study the effects of introducing publicly provided online data on the quality provided by nursing homes in the context of the Nursing Home Quality Initiative in the US. They find that nursing homes located in markets that are more competitive improve their quality more than homes facing less competition. Chou *et al.* (2014) analyse the relationship between report card ratings, hospital competition, and the quality of health services for Medicare patients in Pennsylvania. They report that, after introducing report cards, which rate the quality of Coronary Artery Bypass Graft programmes, hospitals in more competitive markets use more resources per patient and achieve lower mortality among more severely ill patients. Another reason for the limited responsiveness of patients to quality changes could be the restricted mobility of patients (e.g., due to physical restrictions or due to caring responsibilities). In line with this, travel distance has been found to be a major determinant of patients' choice of a hospital (e.g., Capps *et al.*, 2003; Gaynor and Vogt, 2003; Ho, 2006, 2009) or of a GP (e.g., Lagarde *et al.*, 2015; Santos *et al.*, 2017).

Finally, our paper is related to the experimental literature on provider competition. Huck *et al.* (2016) analyze the effects of medical insurance and physician competition in a credence goods market. They find that competition partially offsets the intensity of overprovision occurring under medical insurance. Similarly, Brosig-Koch *et al.* (2017a) report that the distortionary impact of payment schemes like capitation and fee-for-service can be reduced when physicians compete over the treatment of patients. In contrast to our study, they focus on medical service provision, which applies to all patients treated by a physician (like an investment in medical equipment as new technologies or in the development of new skills) and on patient populations, which are homogeneous in the state of health. Conducting a field experiment, Gottschalk *et al.* (2020) find that competition intensity measured by dentist density has no significant influence on overtreatment recommendations. Other experimental studies do not explicitly focus on the effects of physician competition as such, but examine individual elements in health care markets. For example, for credence goods markets, Angerer *et al.* (2021b) and Angerer *et al.* (2021a) look at the impact of monitoring and feedback platforms on market efficiency, and Greiner *et al.* (2017) focuses on the effects of separation of diagnosis and treatment. Han *et al.* (2017) investigate the quality provision behaviour of competing hospitals before and after hospital mergers.

[3] For a more general discussion, see Stiglitz (2000).

3 Experimental set-up

3.1 Design

In our laboratory experiment, subjects face a medically framed decision situation. This situation captures main features and incentives characterizing physician medical service provision in the field but abstracts away from its complexity. Using such a controlled decision environment has the advantage that we are able to identify and test causal relationships, which are implied by our theoretical framework, but which are difficult to detect in the field. We implement two different types of conditions in our experiment – four conditions with competition (with 41 statistically independent observations) and two conditions without competition (with 45 statistically independent observations).[4] The observations made in the latter two conditions mainly serve as a reference for the four conditions with competition. We use a between-subject design, i.e., subjects participate in exactly one condition. In all conditions, subjects decide in the role of a physician in each of a total of 20 rounds.

In the *conditions with competition*, subjects are randomly and anonymously matched in pairs, which remain fixed over the 20 rounds. Each pair of subjects faces a patient population consisting of four patients. Patients differ in their responsiveness to the quality of medical treatment (active vs passive patients) and in their state of health (low vs high severity of illness).[5] Two of the four patients in the population are passive and are always treated by the same subject, while the other two patients are active. An active patient is treated by the subject, who provides the highest quality of medical treatment, i.e., the highest patient benefit for him or her. As a result, each of the two subjects treats one passive patient and, depending on the quality of care provided for the two active patients, also treats zero, one, or two active patients.

In each round, each of the two subjects i in each pair simultaneously decides on the quantity of medical services, $q_i \in Q \coloneqq \{0, 1, \ldots, 10\}$ for each of the three patients (one passive and two active patients). For any patient, a subject's quantity choice q_i has three effects: First, it determines the health benefit of the patient, $B(q_i)$, and, thus, the quality of care for this patient if he or she is treated by i. Second, it determines the subject's profit earned from this patient, $\pi(q_i)$, if he or she is treated by i. Third, together with the other subject's quantity choice, it affects which of the two subjects treats the patient, given that this patient is an active patient. Accordingly, depending on the quantity choices made by the two subjects, a physician treats at least one and at most three patients. In case both subjects provide an identical patient benefit, active patients split up evenly.

To identify the effect of competition, we also employ two conditions without competition. In these conditions, each subject independently chooses a quantity of medical services, $q_i \in Q \coloneqq \{0, 1, \ldots, 10\}$ for one passive patient in each of the 20 rounds. In the conditions without competition, the subject's quantity choice q_i for the passive patient has only two effects: First, it determines the health benefit of the patient, $B(q_i)$, and, second, it determines the subject's profit earned from this patient, $\pi(q_i)$.

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[4] We refer to experimental conditions instead of treatments to distinguish between medical treatments and experimental conditions.

[5] This simplifying assumption is useful to reduce the complexity of the experiment.

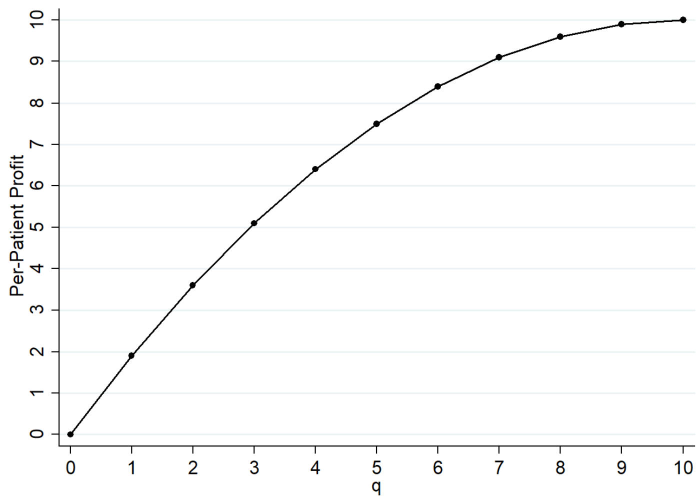

Figure 1: Treatment profit

A subject's profit per patient $\pi(q_i)$, the patient benefit per low severity patient $B^L(q)$ and the benefit per high severity patient $B^H(q)$ are the same in all experimental conditions and are described in detail below. All parameters of the experiment, $\pi(q_i)$, $B^L(q)$, and $B^H(q)$ are common knowledge to subjects in all conditions.

Physician profit

In all conditions, a physician receives a fee-for-service remuneration $R(q) = 2q$ and incurs a cost $c(q) = 0.1q^2$ for each patient treated.[6] Accordingly, a physician's profit per treated patient is $\pi(q) = 2q - 0.1q^2$.[7] Figure 1 depicts the profit per treated patient as a function of the quantity of medical services $q \in Q$. A physician's total profit is given by the sum of profits over all patients treated.

Patient benefit

With regard to patient benefit, we consider two types τ of patients: patients with a high severity of illness ($\tau = H$) require a high quantity of medical services, while patients with a low severity of illness ($\tau = L$) require a low quantity. We assume all patient types to be fully insured.[8] For both patient types, a certain quantity of medical services q results in a patient benefit, $B^\tau(q) = 10 - |q^\tau - q|$, where q^τ denotes the patient-optimal quantity of medical services. For patients with high severity of illness, we set $q^H = 7$; for patients with low severity, we set $q^L = 3$. Notice that the patient benefit function $B^\tau(q)$ is concave, has a unique global maximum, and is mirror-symmetric at this maximum (see Figure 2).

Maximum patient benefit at $q = q^\tau$ equals 10 for both patient types, i.e. $B^\tau(q^\tau) = 10$ for $\tau = H, L$. In addition, the patient benefit is symmetric across treatments, i.e., we have $B^L(q) = B^H(10 - q)$ for all $q \in Q$. The patient-optimal quantity of treatment q^τ serves as a benchmark for identifying the extent of

[6] The assumption of convex costs it often made in the theoretical health economic literature; see McGuire (2000) for a summary.
[7] This profit function has been used also by Brosig-Koch *et al.* (2016, 2017b,a).
[8] Full insurance is commonly assumed in theoretical models of physician behaviour (see McGuire, 2000, for an overview).

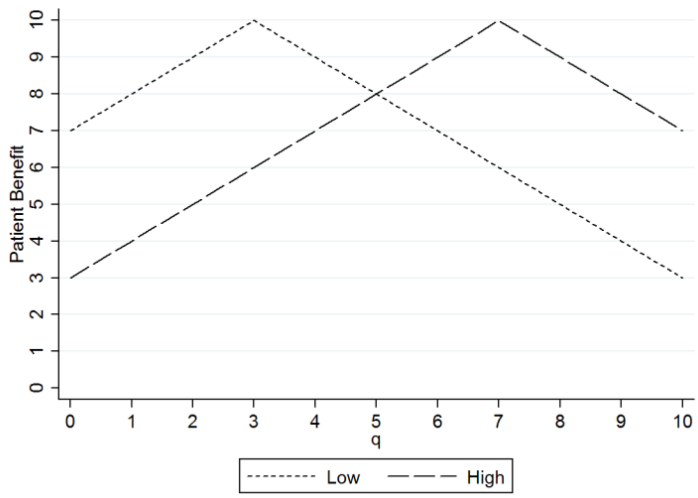

Figure 2: Patient benefit for patient type L and H

overprovision experienced by the patients. Figure 2 displays patient benefit $B^{\tau}(q)$ as a function of the quantity provided $q \in Q$ for the two patient types $\tau = H$ and $\tau = L$.[9]

The patient benefit $B^{\tau}(q)$ is given in monetary terms. Even though no subject takes the role of a patient, real patients outside the lab benefit from the subjects' treatment decisions: subjects are informed that the monetary equivalent of the total patient benefit resulting from their decisions is transferred to an organization (Christoffel Blindenmission) that uses the money exclusively for surgical treatment of patients with eye cataract (for details of the procedure see Section 3.2). In this way, subjects' decisions affect real patients' health. Given that cataract surgery is a necessary but relatively cheap medical treatment, we come close to a linear relationship between the patient health benefit provided in the experiment and the number of real patients who benefit from surgery.

Experimental conditions

The four conditions with competition vary with respect to the distribution of patients' state of health in the population. Figure 3 illustrates the market structure in each condition with competition. Active patients are shown in the overlapping area. Two conditions focus on populations that are homogeneous with respect to the patients' state of health (*HomLow* and *HomHigh*). In condition *HomLow* all active and passive patients have a low severity of illness. In condition *HomHigh* all active and passive patients have a high severity of illness. The other two conditions with competition consider populations, which are heterogeneous with regard to patients' state of health (*MixedPassive* and *MixedActive*). In condition *MixedPassive* one of the two passive patients has a low severity of illness, and the other has a high severity of illness. The two active patients have a low severity of illness in this condition. In condition *MixedActive* one of the two active patients has a low severity of illness, and the other has a high severity of illness. The two passive patients have a low severity of illness in this condition.

[9] Our patients' characteristics correspond to illness B and severities x and z in Brosig-Koch *et al.* (2016) and Brosig-Koch *et al.* (2017b).

The two conditions without competition vary with respect to the state of health of the single patient. In condition *LowNC* subjects are faced with low-severity patients. In condition *HighNC* subjects are faced with high severity patients.[10] Table 1 provides an overview of all conditions and reports the possible number of patients per participant and round as well as the number of subjects participating in each of the six conditions.

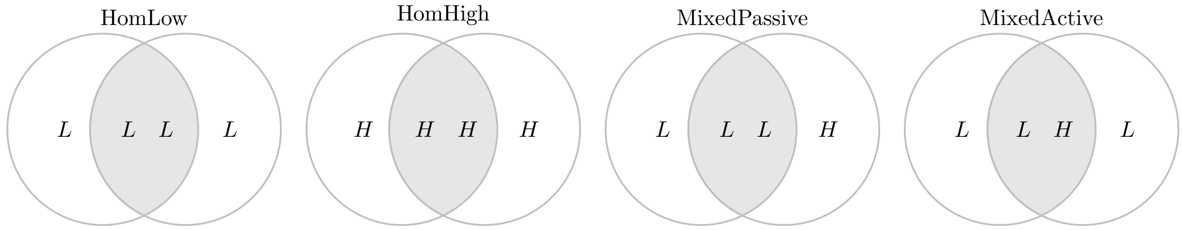

Figure 3: Market structure in experimental conditions with competition. Each circle includes the patients potentially treated by a physician. The overlapping area contains the active patients. *L*=low-severity patients, *H*=High-severity patients.

Table 1: Overview of experimental conditions

	Condition	# Patients per participant and round		# Participants
		Low severity	High severity	
No Competition	LowNC	1	-	22
	HighNC	-	1	23
Competition (Homogeneous)	HomLow	1 passive; 0, 1, or 2 active	-	20
	HomHigh	-	1 passive; 0, 1, or 2 active	22
Competition (Heterogeneous)	MixedPassive	0 or 1 passive; 0, 1, or 2 active	0 or 1 passive	20
	MixedActive	1 passive; 0 or 1 active	0 or 1 active	20

3.2 Experimental protocol

The experiment was programmed with z-Tree (Fischbacher, 2007) and conducted in the Essen Laboratory for Experimental Economics (elfe) at the University of Duisburg-Essen, Germany. 127 participants were recruited by means of the online recruiting system ORSEE (Greiner, 2015) and randomly assigned to conditions. As Brosig-Koch *et al.* (2016, 2017b, 2019) did not find any qualitative differences between treatment decisions made by real physicians, treatment decisions made by medical students, and treatment decisions made by students from other fields, we invited students from various fields of study.[11] Of the 127 participants, 51 were male and 76 were female.

Upon arrival in the lab, all subjects were randomly assigned to cubicles. After handing out the instructions, subjects were given time to read and understand them. To ensure that subjects understood the setup correctly, they were asked to answer a set of comprehension questions (instructions and comprehension questions are included in Appendix A). All clarification questions were answered in private. In

[10] Note that these two condition were also used by Brosig-Koch *et al.* (2017a), who investigate a different research question in a different experimental set-up.

[11] Although previous research demonstrates that our sample allows identifying behavioural regularities with regard to medical service provision, we are careful with drawing conclusions with regard to specific effect sizes.

the four conditions with competition, subjects were matched into pairs at the beginning of each session, generating 10 resp. 11 independent observations per condition. The pairs remained fixed over all 20 rounds. In the two conditions without competition, subjects did not interact and, thus, were not matched, generating 22 resp. 23 independent observations per condition. After each round, all subjects were given a history table that summarised the following information for the actual and past rounds: the chosen quantity of medical services for each patient (and, in the conditions with competition, the other subject's decisions as well), the number of patients actually treated by each of the two subjects in a pair, the benefit of the patients treated, and the total profit per round.

Physician profits and patient benefits were displayed in the experimental currency unit *Taler*. At the end of the experiment, the total physician profits and patient benefits of all 20 rounds were summed up and exchanged to Euro at 100 Taler = 6 Euro (with competition) resp. 8 Euro (without competition). Exchange rates were calculated to keep the monetary incentives per hour roughly the same across conditions. The conditions without competition lasted on average 60 minutes, the conditions with competition lasted on average 90 minutes (including a short questionnaire and payment procedures). Subjects earned on average Euro 17.88, and the total patient benefit amounted to Euro $2,737$. The patient benefit was transferred to the Christoffel Blindenmission that used the money exclusively to support surgical treatments of cataract patients in a hospital in Masvingo (Zimbabwe) staffed by ophthalmologists from the charity. With an eye cataract surgery costing approximately Euro 30.00 per patient, more than 90 real patients could be treated.

To ensure a credible transfer of money, we randomly selected a subject after the experiment to monitor the transfer procedure. This subject had to verify that a correct transfer order was sent to the university's financial department. The monitor and the experimenter deposited the correct order in a sealed envelope, walked together to the nearest mailbox, and inserted the envelope to the mailbox. The monitor was paid an additional Euro 5.[12]

4 Theoretical predictions

Deriving the predictions for our experimental design, we start with investigating the decision problem without physician competition. Subsequently, we address the case of competition.

4.1 Absence of competition

To allow for physician altruism, let

$$U^\tau(q;\alpha) = (1-\alpha)\pi(q) + \alpha B^\tau(q)$$

[12] Starting with Hennig-Schmidt *et al.* (2011), similar or equivalent mechanisms have been employed in several behavioural experiments in health analyzing medical service provision.

denote the utility of a physician, who exhibits a degree of altruism $\alpha \in [0,1]$, chooses a quantity of medical services $q \in Q = \{0, 1, \ldots, 10\}$, and treats a patient of type $\tau = L, H$.[13] Accordingly, an altruistic physician maximizes a weighted average of profit $\pi(q)$ and patient benefit $B^\tau(q)$. Let $q^\tau(\alpha)$ denote a corresponding utility-maximizing quantity of medical services. In the absence of competition each physician's number of patients is exogenously given. Therefore, a *profit-maximizing physician* ($\alpha = 0$) chooses $q^\tau(0) = 10$, independently of the patient's type $\tau = H, L$. In contrast, a *purely altruistic physician* ($\alpha = 1$) implements the patient-optimal quantity $q^\tau(1) = q^\tau$, that is, she picks $q^L(1) = 3$ for a patient of type L and $q^H(1) = 7$ for a patient of type H. For *intermediate levels of altruism*, $\alpha \in (0, 1)$, a trade-off arises between choosing the profit-maximizing and the patient-optimal quantity and the physician chooses $q^\tau(\alpha) \in \{q^\tau, \ldots, 10\}$. Because of $q^L < q^H$, the trade-off is more pronounced for patients of type L. Correspondingly, the set of treatment decisions compatible with an altruistic physician maximizing a weighted average of profit and patient benefit is larger for type L patients than for type H patients. Moreover, observe that an altruistic physician provides a (weakly) higher quantity of medical services to patients of high severity, i.e., $q^L(\alpha) \leq q^H(\alpha)$, for a given level of altruism $\alpha > 0$. In particular, a physician with a level of altruism $\alpha \in (0, 1]$ implements the patient-optimal level of treatment for α sufficiently large.[14]

Part (a) of Proposition 1 below summarizes the utility-maximizing treatment decisions of physicians differing in their degree of altruism. In part (b), we state the implications for patient benefit.

PROPOSITION 1. (a) *Let $\alpha \in [0, 1]$ and $\tau \in L, H$ be arbitrary. We have $q^\tau(\alpha) = 10$ for $\alpha = 0$, $q^\tau(\alpha) = q^\tau$ for $\alpha = 1$, and $q^\tau(\alpha) \in \{q^\tau, \ldots, 10\}$ for $\alpha \in (0, 1)$.*

(b) *Let $\tau \in L, H$. (i) We have $B^\tau(q^\tau(\alpha)) \leq B^\tau(q^\tau) = 10$, for all $\alpha \in [0, 1]$, where the inequality holds strictly for low degrees of altruism (viz. for $\alpha < 1/3$ if $\tau = H$ and for $\alpha < 13/23$ if $\tau = L$). (ii) We have $B^\tau(q^\tau(\alpha)) \geq B^\tau(10)$, for all $\alpha \in [0, 1]$, with strict inequality for sufficiently large degrees of altruism (viz. for $\alpha > 1/11$). (iii) Finally, we have $B^L(q^L(\alpha)) \leq B^H(q^H(\alpha))$, for all $\alpha \in [0, 1]$, with strict inequality for low degrees of altruism (viz. for $\alpha < 13/23$).*

Proof: See Appendix B.

Accordingly, Proposition 1 implies the following set of hypotheses that apply in the absence of competition. Firstly, patient benefit in the experiment resulting from medical service provision is weakly lower than that from patient-optimal treatment, $B^\tau(q^\tau) = 10$. Secondly, patient benefit in the experiment weakly exceeds that from profit-maximizing treatment, $B^\tau(q^\tau(0)) = B^\tau(10)$. Thirdly, comparing patient benefit in the experiment across states of health, the benefit is weakly higher for high-severity patients than for low-severity patients. Given that a pool of subjects usually shows a substantial heterogeneity in the subjects' degree of altruism (e.g., Godager and Wiesen, 2013; Brosig-Koch *et al.*, 2017b), all these inequalities should hold strictly, once averages across subjects are considered.

[13] Physician altruism is a common assumption in health economics models (see, e.g., Ellis and McGuire, 1986; McGuire, 2000; Allard *et al.*, 2011). This assumption has been supported by previous laboratory research (see, e.g., Godager and Wiesen, 2013; Brosig-Koch *et al.*, 2017b).

[14] More specifically, we obtain that $q^H(\alpha) = q^H$ maximizes utility $U^H(q; \alpha)$ for $\alpha \geq 1/3$, while $q^L(\alpha) = q^L$ maximizes $U^L(q; \alpha)$ for $\alpha \geq 13/23$.

4.2 Competition

In the experimental conditions with competition, a physician's total profit equals the sum of profits earned from all of his patients treated. Since physicians choose a quantity of medical services for each patient separately, we can examine each of the corresponding decision problems separately. Like in Varian (1980) and Gu and Hehenkamp (2014), we distinguish two polar cases of responsiveness. *Passive* patients always consult the same physician. Hence, they are not subject to competition and the results of Proposition 1 carry over. In contrast, physicians compete for *active* patients, who only visit the physician offering the highest patient benefit. Therefore, a physician's profit is jointly determined by the quantity choice (q_1, q_2) of the two physicians. Correspondingly, we set

$$\begin{aligned} \pi_1^\tau(q_1, q_2) &= n^\tau(q_1, q_2)\pi(q_1), \\ \pi_2^\tau(q_1, q_2) &= (1 - n^\tau(q_1, q_2))\pi(q_2), \end{aligned}$$

where

$$n^\tau(q_1, q_2) = \begin{cases} 0 & \text{if} \quad B^\tau(q_1) < B^\tau(q_2) \\ 1/2 & \text{if} \quad B^\tau(q_1) = B^\tau(q_2) \\ 1 & \text{if} \quad B^\tau(q_1) > B^\tau(q_2) \end{cases}$$

represents the expected number of type τ patients treated by physician 1 and where $\pi(q_i)$ denotes the profit per treatment of a physician choosing q_i. If both physicians provide the same benefit for a patient, then each one treats the patient with probability 1/2. To avoid risk issues, we instead implement ex-ante expected payoff in this case. Observe that a physician's profit from treatment of an active patient depends on that patient's type through the interaction with the other physician.

Total patient benefit also depends on the number of patients treated by physicians 1 and 2, respectively. Correspondingly, we set

$$\begin{aligned} B_1^\tau(q_1, q_2) &= n^\tau(q_1, q_2)B^\tau(q_1) \\ B_2^\tau(q_1, q_2) &= (1 - n^\tau(q_1, q_2))B^\tau(q_2) \end{aligned}$$

to denote the total patient benefit received at physicians 1 and 2, respectively. As before, patient benefit $B^\tau(q)$ depends on the patient type $\tau = H, L$.

To allow for altruistic preferences, let $(\alpha_1, \alpha_2) \in [0, 1]^2$ denote the degree of altruism of physicians 1 and 2, respectively. We assume, each physician maximizes utility, which represents a weighted average of profit and patient benefit, i.e.

$$U_1^\tau(q_1, q_2; \alpha_1) = (1 - \alpha_1)\pi_1^\tau(q_1, q_2) + \alpha_1 B_1^\tau(q_1, q_2),$$
$$U_2^\tau(q_1, q_2; \alpha_2) = (1 - \alpha_2)\pi_2^\tau(q_1, q_2) + \alpha_2 B_2^\tau(q_1, q_2),$$

All this, we assume to be common knowledge among physicians. The proposition further below identifies the Nash equilibrium for each patient type. It shows that, in equilibrium, each physician chooses the patient-optimal quantity for *active* patients. The proof of the proposition is instructive in that it shows that our experimental design is robust against introducing incomplete information about each other physician's degree of altruism. The analysis is restricted to pure strategy Nash equilibria.

PROPOSITION 2. *Let* $(\alpha_1, \alpha_2) \in [0,1]^2$ *and* $\tau \in L, H$ *be arbitrary.*

(a) *Physicians treat passive patients in accordance with Proposition 1. They treat each active patient patient-optimally, that is, the unique Nash equilibrium is* $(q_1^\tau(\alpha_1,\alpha_2), q_2^\tau(\alpha_1,\alpha_2)) = (q^\tau, q^\tau)$*, where* q^τ *represents the patient-optimal quantity (i.e.* $q^L = 3$ *for type* L *patients and* $q^H = 7$ *for type* H *patients). Moreover, the Nash equilibrium is strict.*

(b) *For passive patients, the results of Proposition 1(b) apply. For each active patient, benefit in Nash equilibrium is maximal, i.e. we have* $B_i^\tau(q_1^\tau(\alpha_1,\alpha_2), q_2^\tau(\alpha_1,\alpha_2)) = B^\tau(q^\tau) = 10$ *for both physicians* $i = 1, 2$.

Proof: See Appendix B.

The following set of hypotheses follows from parts (b) of propositions 1 and 2, respectively. Firstly, for *active* patients of both types, $\tau = H, L$, the average patient benefit resulting from medical service provision is higher in all conditions with competition than that of passive patients in the corresponding condition without competition. Moreover, for all conditions with competition, the average patient benefit does not differ from the maximum benefit of patient-optimal treatment, $B^\tau(q^\tau) = 10$. Accordingly, comparing across patient types of low and high severity, there neither is a difference in patient benefit. All of this holds true independent of whether the experimental condition exhibits a homogeneous or a heterogeneous patient population. Secondly, for *passive* patients of both types, $\tau = H, L$, the average patient benefit does not differ between conditions with competition and conditions without competition; moreover, in conditions with competition, the benefit for passive patients is strictly lower than the benefit maximum and hence than the average benefit of active patients. Similar to the above, the composition of the patient population should not make any difference. Thirdly, comparing between passive patients of low and high severity, the benefit of the latter is higher than that of the former.

To conclude this section, we point out that the equilibrium described in Proposition 2 is unique. Therefore, in the finitely repeated game of the experiment there exists a unique subgame perfect equilibrium, which involves repeated play of the unique stage game equilibrium. Theoretically, this leaves no scope for collusion. However, based on previous experimental evidence, we would expect collusion to occur during the earlier periods of the repeated interaction (see, e.g., Potters and Suetens, 2013; Engel, 2015; Brosig-Koch *et al.*, 2017b).

5 Experimental results

In this section, we briefly report the provided quantities and resulting patient benefits for the two conditions without competition first. Then we compare these findings to our observations made with competition. In our analyses on the effects of competition, we differentiate between active patients and passive patients (i.e., those who choose the physician providing the highest benefit and those who visit the same physician independent of the quality provided). To reconcile incentives from the treatment of low- and high-severity patients, we focus our analysis on patient benefits instead of provided quantities. In doing so, patient-optimal medical treatment results in 10 benefit units in all experimental conditions, while profit-maximising treatment leads to 3 and 7 benefit units for low-severity and high-severity patients, respectively. The statistical tests reported in this section are based on individual data averaged over all rounds. We employ nonparametric tests, where the number of independent observations corresponds to the number of matching groups for active patients and the number of subjects for passive patients.[15] In all competition conditions, in which physicians are faced with two active patients with an identical severity of illness (i.e., conditions *HomLow*, *HomHigh*, and *MixedPassive*), we pool the data of the two active patients as medical treatment of these patients does not differ significantly ($p > 0.203$). Table 2 provides the average quantity of medical services and the average patient benefit for all types of patients in each experimental condition.

Table 2: Average quantity of medical treatment and average patient benefit

	Quantity of medical treatment				Patient benefit			
	Low severity		High severity		Low severity		High severity	
	passive	active	passive	active	passive	active	passive	active
HomLow	8.68	3.93			4.31	8.99		
	(0.56)	(0.58)			(0.56)	(0.58)		
MixedPassive	9.50	4.33	8.99		3.50	8.63	7.70	
	(0.18)	(0.47)	(0.35)		(0.18)	(0.47)	(0.28)	
MixedActive	8.30	3.79		7.15	4.68	9.19		9.62
	(0.54)	(0.28)		(0.10)	(0.54)	(0.27)		(0.12)
HomHigh			9.18	7.12			7.61	9.77
			(0.31)	(0.06)			(0.22)	(0.06)
LowNC	6.80				6.19			
	(0.43)				(0.43)			
HighNC			8.09				8.61	
			(0.30)				(0.24)	

Notes: Average quantity of medical treatment and average patient benefit over 20 rounds per experimental condition for each patient type. Robust standard errors in parentheses are clustered by group level. In conditions *LowNC* and *HighNC* subjects provide medical treatment in the absence of competition. *HomLow*, *HomHigh*, *MixedPassive*, and *MixedActive* comprise conditions with competition. Patient-optimal medical treatment is achieved with 3 units of medical treatment for low-type patients and 7 units of medical treatment for high-type patients. Maximum patient benefit is 10 for all types of patients.

[15] For between-subject analyses, we employ Mann-Whitney U tests. For within-subject analyses, we use Wilcoxon signed rank tests. When comparing decisions with predicted treatment levels, one-sample Wilcoxon signed rank tests are employed. Throughout the paper, we report two-sided tests and also exact tests when the number of independent observations is below 25.

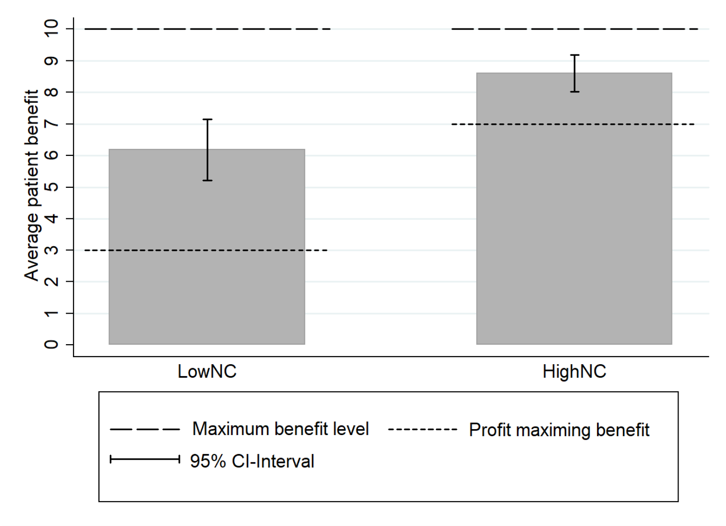

Figure 4: No Competition – Average patient benefit: The figure illustrates the average patient benefit per subject in the absence of competition for *LowNC* and *HighNC*. The maximum patient benefit is 10. With physicians providing the payoff-maximizing quantity, the patient benefit is 3 for *LowNC* and 7 for *HighNC*.

5.1 Absence of competition

Without competition, subjects provide, on average, 6.80 medical services for patients with a low severity of illness (condition *LowNC*) and 8.09 medical services for patients with a high severity (*HighNC*). This implies that, without competition, fee-for-service payment incentivizes physicians to choose a quantity of medical services that is higher than the patient-optimal quantity (where $q^L = 3$ and $q^H = 7$). The observed overprovision is significant at the 1-per cent level in both conditions. However, the chosen average quantities of medical services are lower than those predicted with pure profit maximisation of 10 medical services in both conditions ($p = 0.000$). Figure 4 illustrates the resulting average patient benefits per condition. The average patient benefit is significantly higher for high-severity patients than for low-severity patients ($p = 0.018$). This difference is in line with the fact that physicians' trade-off between maximising their own profit and maximising patient benefit is more pronounced for patients with a low severity of illness. Overall, the behaviour observed in the absence of competition is in line with our theoretical predictions. It implies that, on average, subjects seem to care not only about their own profit but also – to some extent – about patients' benefit. Our assumption of physician altruism may account for this (see, e.g., Godager and Wiesen, 2013; Brosig-Koch *et al.*, 2017b).

Although there is no feedback about other subjects' behaviour in the conditions without competition, we observe a slight decline of patient benefits over time, which is significant at the 5-per cent level (see Figure 5 and Table C1 in Appendix C for regression results).[16] The statements made in previous paragraphs hold for all 20 rounds, though.

[16] Note that this corresponds to time trends observed in repeated dictator games (for an overview see, e.g., Engel, 2011) and repeated dictator game experiments (Brosig-Koch *et al.*, 2017d), respectively.

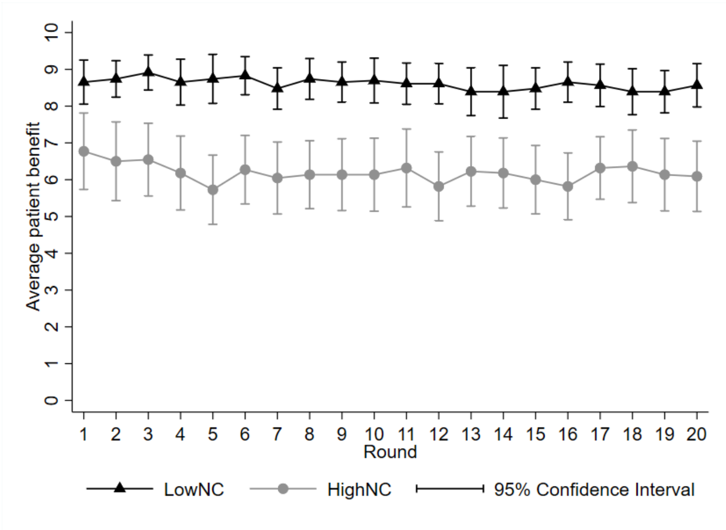

Figure 5: No Competition – Development of average patient benefit: The figure illustrates the development of the average patient benefit in the absence of competition for high-severity patients (triangles) and low-severity patients (circles). The maximum benefit level is 10 for both conditions, *LowNC* and *HighNC*. With physicians providing the payoff-maximizing quantity, the patient benefit is 3 for *LowNC* and 7 for *HighNC*.

5.2 Effects of competition for active patients

With competition, an active patient always chooses the physician providing the highest benefit for him or her. For these patients, competition is predicted to eliminate the distortive effect of fee-for-service incentives (i.e., overprovision) and should maximise their benefit. Figure 6 illustrates the average benefit for (active) patients observed in conditions with and without competition. It reveals that active patients benefit from competition. Compared to *LowNC*, the average benefit of active patients with a low severity of illness is significantly higher independent of the composition of the patient population (*LowNC* vs *HomLow*: $p = 0.003$, *LowNC* vs *MixedActive*: $p = 0.0004$, *LowNC* vs *MixedPassive*: $p = 0.002$). We observe similar results for active patients with a high severity of illness. Also, for these patients, average benefits are significantly higher with than without competition independent of the composition of the patient population (*HighNC* vs *HomHigh*: $p = 0.014$, *HighNC* vs *MixedActive*: $p = 0.037$).

Figure 6 suggests that, with competition, average benefits for active patients are still lower than those resulting from patient-optimal treatment. This effect is significant for both patient types, those with a high severity and those with a low severity of illness ($p < 0.002$ for all competition conditions). This might be an indication of tacit coordination between physicians in competition conditions. We come back to this issue when analysing the dynamics of decisions in competition conditions in Section 5.4. Comparing the average benefits between active patients with a low and a high severity of illness in competition conditions in which physicians are faced with a homogeneous population in terms of the state of health, we do not find a significant difference (*HomLow* vs *HomHigh*: $p = 0.640$). This does not hold in the competition condition in which active patients are heterogeneous with regard to their state of health (*MixedActive*). Here, the average benefit resulting for active low-severity patients is still significantly

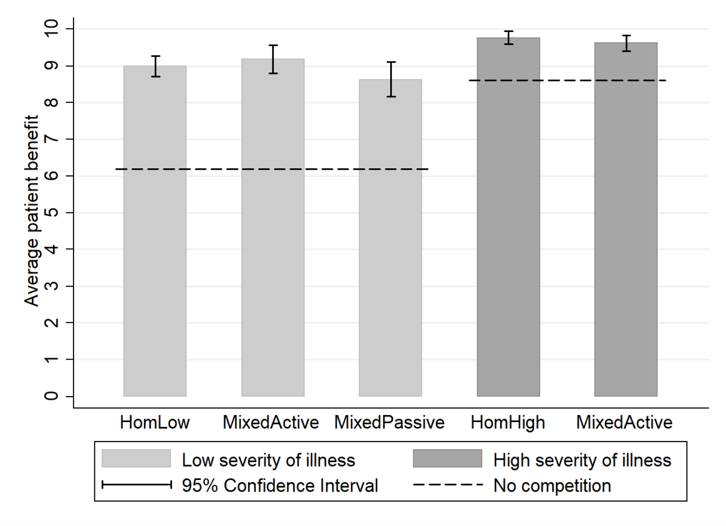

Figure 6: Average benefit for active patients with competition: Average patient benefit for patients in conditions with competition *HomLow*, *HowHigh*, *MixedActive* and *MixedPassive* with 95% Confidence Intervals. Dashed line for average benefit in conditions without competition *LowNC* and *HighNC*.

lower than the benefit for active high-severity patients (9.19 vs 9.62, $p = 0.018$). The latter result is not in line with our theoretical prediction.

To control for potential additional influencing factors such as individual characteristics and time trends, we also run multilevel linear mixed effects regressions of patient benefit. This accounts for our complex data structure, as our units of analysis are nested within clusters and repeated over time.[17] The regression models regarding the effects of competition (models 1-3) include random effects for round t (level 1) and subject i (level 2).[18] Level 2 represents the units of analysis (subjects in the role of a physician), and level 1 represents the repeated measures made over time (round). The specification for model (1) is

$$b_t i = \beta_0 + \beta_1 C_i + \beta_2 L_i + \beta_3 R_t + u_{0i} + u_{1i} R_t + \epsilon_{ti} \quad \text{(I)}$$

Parameters β_0 trough β_3 represent the fixed effects associated with the intercept and the individual level covariates, u_{0i} and u_{1i} are the random effects with the intercept and time slope associated with a subject, and ϵ_{ti} represents the residual. We assume that the residuals are independent and identically distributed, with constant variance across rounds. The individual covariates for models (1)-(3) are dummy variables for Competition (= 1 for conditions *HomLow* and *HomHigh*, C_i) and patient type (= 1 for Low severity, L_i). We also control for the time trend (Round, starting with round 1, R_i). For models (1)-(3), we restrict our sample to patients in conditions without competition (*LowNC* and *HighNC*) and conditions with competition and a population that is homogeneous with regard to the severity of illness (*HomLow* and *HomHigh*).[19]

[17] Panel regressions with clusters on group level reveal similar results; see Table C2 in Appendix C. The results are included in Table 3.

[18] As subjects in the no-competition conditions are not assigned into groups, we disregard the group-level effects for the competition conditions in models (1)-(3).

[19] For *HomLow* and *HomHigh*, we use the average patient benefit provided per physician.

Models (4) and (5) are restricted to competition conditions only to address the composition of the patient population. We add the random group effect u_{0j} to specification (II) above and account for subjects nested in a group of two physicians (level 3). The specification for model (4) is

$$b_t i = \beta_0 + \beta_1 C_i + \beta_2 L_i + \beta_3 R_t + u_{0j} + u_{1i|j} R_t + \epsilon_{tij} \tag{II}$$

In models (4) and (5), we control for the severity of illness, time trends, and include condition dummies with *HomLow* serving as baseline. Models (2) and (3) as well as (4) and (5) are identical except for the presence of additional covariates for individual characteristics such as age, gender, and field of study.[20]

In model (1), the significant coefficient estimates on Competition and Low severity confirm the results from our non-parametric analyses. Benefit increases for active patients with competition, and patients with a high severity of illness have a higher benefit than patients with a low severity. The insignificant coefficient for Round does not reveal a time trend. Apparently, the trends for conditions with and without competition seem to compensate each other (see Figure 5 in the previous section and Figure 8 in the next but one section). In models (2) and (3), we add an interaction term on competition and severity (competition x severity). Here, the significant positive coefficients reveal that competition has a larger effect for patients with a low severity of illness than for patients with a high severity. This is not surprising as the deviation from the maximum benefit was higher for patients with a low severity of illness than for patients with a high severity of illness in the absence of competition. Descriptively, the average benefit improvement due to competition is for active patients with a low severity of illness on average 45 per cent, while it is for active patients with a high severity of illness on average 14 per cent.

Models (4) and (5) reveal that the coefficient for *Low severity* is still negative and highly significant when considering conditions with competition only. The results further reveal a small but significant upward time trend in benefit, which seems to stem from low-severity patients, see Figure 8.[21] Models (4) and (5) also demonstrate that the composition of the patient population has no effect on the benefit of active patients, since the dummy variables for all experimental conditions are insignificant.

5.3 Effects of competition for passive patients

Next, we focus on the analysis of benefits that result from competition for passive patients, i.e., those patients who always visit the same physician. For these patients, we expect that competition does not affect benefit. Depending on the physicians' degree of altruism, the patient benefit from medical treatment should still deviate from the maximum. Figure 7 displays the average benefit resulting for each severity type of passive patients in each condition with competition. The average benefit resulting without competition for each patient type is included as a dashed line. For passive patients with a low severity of illness, we observe that the average benefits are significantly lower with competition than without competition (*LowNC* vs *HomLow*: $p = 0.004$, *LowNC* vs *MixedActive*: $p < 0.007$, *LowNC* vs

[20] Subjects' individual characteristics do not have a significant effect on results.

[21] We also included interaction terms for time and condition. We did not find any significant effect for this interaction. However, as additional interaction terms strongly reduced explanatory power, these results should be interpreted with caution.

Table 3: Regression results: Effects of competition for active patients

	(1)	(2)	(3)	(4)	(5)
Fixed effects					
Competition	1.743***	0.921**	0.955**		
	(0.321)	(0.430)	(0.436)		
Low severity	-1.619***	-2.428***	-2.443***	-0.430***	-0.430***
	(0.321)	(0.430)	(0.445)	(0.087)	(0.087)
Round	0.006	0.006	0.006	0.030***	0.030***
	(0.007)	(0.007)	(0.007)	(0.009)	(0.009)
Competition x severity		1.680***	1.655***		
		(0.619)	(0.629)		
HomHigh				0.365	0.381
				(0.588)	(0.591)
MixedPassive				-0.395	-0.388
				(0.595)	(0.598)
MixedActive				0.262	0.253
				(0.597)	(0.599)
Individual characteristics	No	No	Yes	No	Yes
Constant	8.258***	8.659***	8.807***	9.094***	8.488***
	(0.275)	(0.303)	(1.208)	(0.445)	(0.596)
Random effects					
Subject level					
Var(Round)	0.002***	0.002***	0.002***	0.005	0.005
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Var(Constant)	2.175***	2.006***	2.091***	1.005***	0.999***
	(0.368)	(0.343)	(0.365)	(0.234)	(0.232)
Cov(Round, Constant)	-0.008	-0.007	-0.009	-0.068***	-0.068***
	(0.011)	(0.011)	(0.012)	(0.014)	(0.014)
Group level					
Var(Constant)				1.725**	1.738**
				(0.433)	(0.434)
Var(Residual)	0.887***	0.887***	0.888***	1.525***	1.525***
	(0.031)	(0.031)	(0.031)	(0.039)	(0.039)
Subjects	87	87	87	82	82
Groups	66	66	66	41	41
Observations	1740	1740	1740	1640	1640

Notes: Multilevel mixed effects REML regressions showing the fixed and random effects of competition (models 1-3) and composition of the patient population (models 4-5) on patient benefit. Baseline category for experimental condition is *HomLow*. Individual characteristics comprise age, gender and field of study. Standard errors are in parentheses. *** $p < .01$, ** $p < .05$, * $p < .1$

MixedPassive: $p < 0.001$). This is also the case for passive patients with a high severity of illness (*HighNC* vs *HomHigh*: $p = 0.005$, *HighNC* vs *MixedPassive*: $p = 0.052$).[22] Thus, as opposed to active patients and in contrast to the theoretical prediction, for passive patients, competition does even strengthen the distortive effects resulting from fee-for-service incentives. This result suggests that subjects compensate at least to some degree the financial pressure regarding active patients resulting from competition. We investigate this issue in more detail in Section 5.5.

Also, with competition, the average benefits of low-severity passive patients are lower than those of high-severity passive patients. Comparing the average benefits of passive patients between conditions with a population which is homogenous with regard to the severity of illness (*HomLow* vs *HomHigh*) or between passive patients in the condition in which the severity of illness differs between the two passive patients (*MixedPassive*), the differences are significant (*HomLow* vs *HomHigh*: $p = 0.002$, *MixedPassive*: $p = 0.0001$).

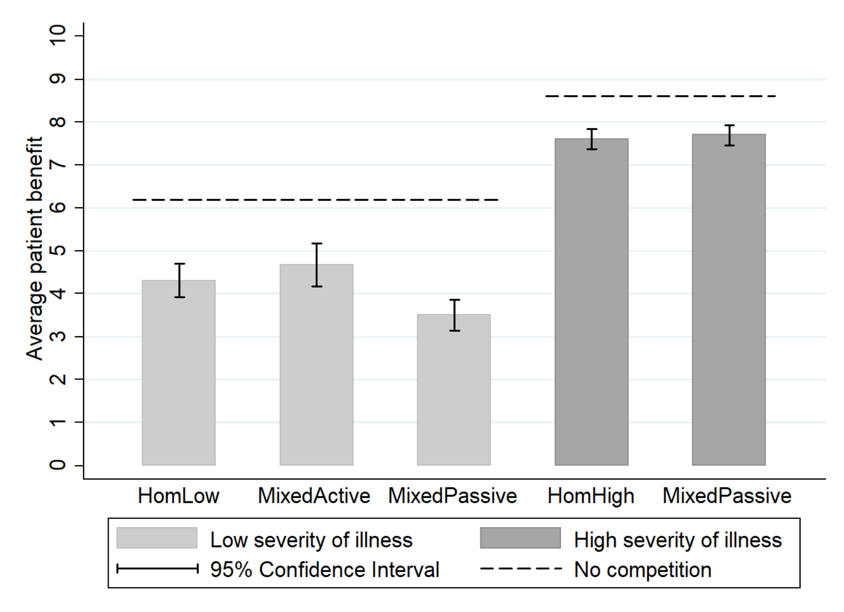

Figure 7: Average benefit for passive patients with competition: Average patient benefit for passive patients in conditions with competition *HomLow*, *MixedActive*, and *MixedPassive* with 95%-confidence intervals. Dashed line for average benefit in conditions without competition *LowNC* and *HighNC*. The maximum benefit resulting from optimal treatment behaviour is 10. The minimum benefit due to physicians' profit maximization is 3 for low-severity patients and 7 for high-severity patients.

Table 4 presents estimation results from linear multilevel mixed effects models (see Section 5.2 for a detailed model specification) on patient benefit.[23] In models (1)-(3), our sample is restricted to patients in the absence of competition and passive patients in conditions with a patient population that is homogeneous with regard to the severity of illness. Models (4) and (5) address potential effects resulting from the composition of the patient population. These models are restricted to passive patients in conditions with competition.

[22] This implies that the observed benefit is significantly lower than the maximum benefit, irrespective of the experimental condition ($p < 0.01$).

[23] Panel regressions with clusters on group level reveal similar results, see Table C3 in Appendix C.

Table 4: Regression results: Effects of competition for passive patients

	(1)	(2)	(3)	(4)	(5)
Fixed effects					
Competition	-1.430***	-1.000**	-0.990**		
	(0.346)	(0.479)	(0.484)		
Low severity	-2.855***	-2.426***	-2.538***	-4.204***	-4.164***
	(0.346)	(0.479)	(0.493)	(0.551)	(0.572)
Round	-0.016**	-0.016**	-0.016**	-0.029***	-0.029***
	(0.006)	(0.006)	(0.006)	(0.009)	(0.009)
Competition x severity		-0.891	-0.876		
		(0.690)	(0.697)		
HomHigh				-0.908	-0.822
				(0.790)	(0.818)
MixedPassive				-0.814	-0.782
				(0.642)	(0.650)
MixedActive				0.364	0.361
				(0.579)	(0.584)
Individual characteristics	No	No	Yes	No	Yes
Constant	8.986***	8.776***	7.461***	8.816***	8.087***
	(0.297)	(0.338)	(1.338)	(0.694)	(1.569)
Random effects					
Subject level					
Var(Round)	0.002***	0.002***	0.002***	0.006	0.005
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Var(Constant)	2.589***	2.565***	2.592***	2.095***	2.152***
	(0.368)	(0.426)	(0.439)	(0.428)	(0.448)
Cov(Round, Constant)	-0.010	-0.010	-0.009	-0.059***	-0.057***
	(0.011)	(0.011)	(0.011)	(0.019)	(0.020)
Group level					
Var(Constant)				0.919	0.890
				(0.457)	(0.479)
Var(Residual)	0.871***	0.871***	0.871***	1.957***	0.957***
	(0.031)	(0.031)	(0.031)	(0.035)	(0.035)
Subjects	87	87	87	82	82
Groups	66	66	66	41	41
Observations	1740	1740	1740	1640	1640

Notes: Multilevel mixed effects REML regressions showing the fixed and random effects of competition (models 1-3) and composition of the patient population (models 4-5) on patient benefit. Baseline category for experimental condition is *HomLow*. Individual characteristics comprise age, gender and field of study. Standard errors are in parentheses. *** $p < .01$, ** $p < .05$, * $p < .01$

The regression results confirm the previously detected negative effects of competition and of low severity of illness. For passive patients, we do not find a significant effect of the interaction of coefficients for competition and severity.[24] As for active patients, we observe that the benefit of low-severity passive patients is lower than that of high-severity passive patients when we compare competition conditions only. Again, there are no significant effects of experimental conditions revealing that the composition of the patient population does not influence the medical treatment of passive patients. For all models, we see significant negative coefficients of Round indicating that treatment quality even seems to worsen over the course of 20 rounds (see also Figure 8 in the next section).

5.4 Comparison of active and passive patients over time with competition

Figure 8 displays the average patient benefit for active and passive patients over time for all conditions with competition (active patients: gray line, passive patients: black line). Low-severity patients are displayed on the left-hand side, and high-severity patients are displayed on the right-hand side of the figure. For both severity types of active patients, we observe that, in the first round, average patient benefits are still significantly different from the maximum benefit in all conditions with competition ($p < 0.01$). Over time, the average benefits of active patients converge to the predicted maximum benefit in all conditions with competition. In condition *MixedPassive* (dotted line), the patient-optimal treatment is reached rather late, though.[25] This points to some tacit coordination between physicians in conditions with competition (we investigate this issue at the end of this section; see Table 5).

Already in the first round, the average benefits resulting for passive patients are significantly lower than those resulting for active patients with equal severity of illness ($p < 0.030$).[26] Throughout the experiment, the average benefits of passive patients further decline towards the lowest possible benefit (implied by the physician profit maximum). However, they are still significantly different from that level even in the last round ($p < 0.085$, except for passive patients with a low severity of illness in condition *MixedPassive* where $p = 0.158$). For passive patients with a high severity of illness, benefits are already quite close to the lowest possible benefit and do not change much further over time.

Overall, our results on the evolution of benefits for active and passive patients suggest that the gap between active and passive patients increases over time. This is supported by panel regressions on the difference between the benefit for active and passive patients with a low severity of illness (=gap); see Table C4 in Appendix C. The regressions reveal a positive time trend, which is significant at the 1 per cent-level. Given the positive and significant interaction term Round x *MixedActive*, the gap appears to be most pronounced in condition *MixedActive*.

[24] From Figure 7, one might infer a small difference between the effect of competition for passive patients with a low and with high severity of illness, though. Descriptively, the average benefit decline resulting from competition is on average 30% for passive patients with a low severity of illness and on average 12% for passive patients with a high severity.

[25] For *HomHigh* (*HomLow*) from round 3 (9) onwards medical treatment is not significantly different from patient-optimum. For *MixedActive* (*MixedPassive*), medical treatment is not significantly different from patient-optimum from round 11 (19) onwards.

[26] Results are obtained from within-subjects comparisons of active and passive patients. For patients with a low severity of illness, we separately test benefits in conditions *HomLow*, *MixedActive*, and *MixedPassive*. For patients with a high severity, we use data from *HomHigh* only.

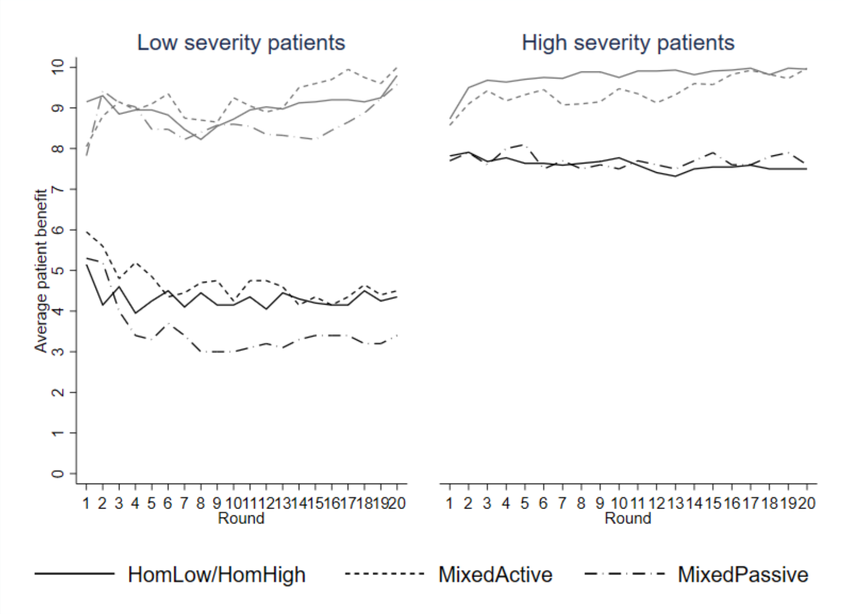

Figure 8: Evolution of average benefits for active and passive patients: Evolution of average patient benefit for active (gray line) and passive (black line) patients with competition in *HomLow*, *MixedActive* and *MixedPassive*. Maximum benefit level resulting from optimal treatment behaviour is 10. Minimum benefit level due to physicians' profit maximization is 3 for low-severity patients and 7 for high-severity patients.

The observed deviation of the average benefits for active patients from the maximum benefit at least in the first rounds of competition conditions suggests some tacit coordination between physicians. We, therefore, take a closer look at pairwise choices made for each of the two active patients in these conditions. To analyze the incidences of tacit coordination, we distinguish between full collusion, coordination as well as attempts of full collusion, and attempts of coordination (see Table 5). Full collusion occurs if both subjects choose the joint profit-maximal quantity $q = 10$ (implying a benefit of 7 for patients with high severity of illness and a benefit of 3 for patients with low severity of illness). Coordination covers all choice pairs with the equal deviation between the patient-optimal quantity and the full collusion quantity (i.e., both subjects deviate by $1, 2, 3, 4, 5,$ or 6 quantities for low-severity patients and both deviate by 1 or 2 quantities for high-severity patients).

Attempts of full collusion/coordination relate to individual one-sided deviations from the patient-optimal quantity. Table 5 also includes the number of pair decisions with at least one subject deviating from the patient-optimal quantity (equivalent to the sum of full collusion/coordination and attempts of full collusion/coordination). The number of pairs in which at least one subject deviates from the patient-optimal quantity but who failed to collude/coordinate is given by failed to collude/coordinate. Overall, collusive behaviour is rather rarely observed in our experiment. In each condition with at least one high severity active patient (*HomHigh* and *MixedActive*), full collusion occurs in less than 1 per cent of all 840 cases. In conditions with two active low-severity patients (*HomLow* and *MixedPassive*), full collusion is somewhat more frequent, i.e., it occurs in more than 7 per cent of all cases.

Table 5: Absolute frequency of full collusion, coordination, attempts of collusion, and attempts of coordination.

	HomLow	*HomHigh*	*MixedActive*	*MixedPassive*
# Rounds	20	20	20	20
# Individual decisions	800	880	800	800
# Pair decisions	400	440	400	400
# Full collusion	30 (7.5)	0 (0.0)	3 (0.8)	52 (13.0)
# Coordination	7 (1.8)	0 (0.0)	10 (2.5)	17 (4.3)
# Attempts of full collusion	17 (4.3)	20 (4.5)	30 (7.5)	25 (6.3)
# Attempts of coordination	96 (12.0)	73 (8.3)	113 (28.3)	33 (4.1)
# With at least one deviating from patient-optimum	150	93	156	127
# Failed to collude/coordinate	113 (75.3)	93 (100)	143 (91.7)	58 (45.7)

5.5 Profit compensation

Considering the imbalance of treatment quality across active and passive patients, one might ask whether physicians treat their active patients at the expense of passive patients. This would suggest that physicians offset the reduced profits from competition for active patients by deviating more from patient-optimal treatment with respect to passive patients for whom they do not have to fear competition.

To explore the general nature of potential offsetting behaviour, we consider changes in subjects' realized profits as the rounds progress. First, we count the number of subjects per round, whose profits (either those for active patients or those for passive patients or both) change compared to the previous round. The dotted line in Figure 8 displays the development of this number as a percentage of the total number of subjects per condition. Apparently, the number of what we label as 'profit changers' decreases over time. Second, we analyze whether subjects respond to a decrease of profits from the treatment of active (passive) patients by increasing profit from the treatment of passive (active) patients.[27] For this, we count the number of subjects per round, who compensate their profit decrease for active (passive) patients by an identical profit increase for passive (active) patients. We label these subjects as 'perfect profit compensators'.

The long dashed line in Figure 9 illustrates this number of subjects as a percentage of the total number of subjects per condition. Next, we relax the assumption of perfect compensation and count the number of subjects per round, who compensate their profit decrease for active (passive) patients by a profit increase for passive (active) patients. We label these subjects as 'profit compensators' (note that perfect profit compensators are a fraction of profit compensators). The dashed line in Figure 8 displays this number of subjects as a percentage of the total number per condition. We find some offsetting behaviour in all conditions with competition, but there is no perfect compensation indicating that subjects do not aim at some target income.[28]

[27] The case that subjects respond to a decrease of profits for passive patients with an increase of profits for active patients is rather seldom. Note that responses (i.e., treatment changes) can be realized only after being informed about realized profits. To account for this, profit responses are lagged for one round.

[28] We also calculated the arc-elasticity to relate the extent of a change of realized profits resulting from the treatment of active patients to the extent of a change of realized profits resulting from the treatment of passive patients. Also here

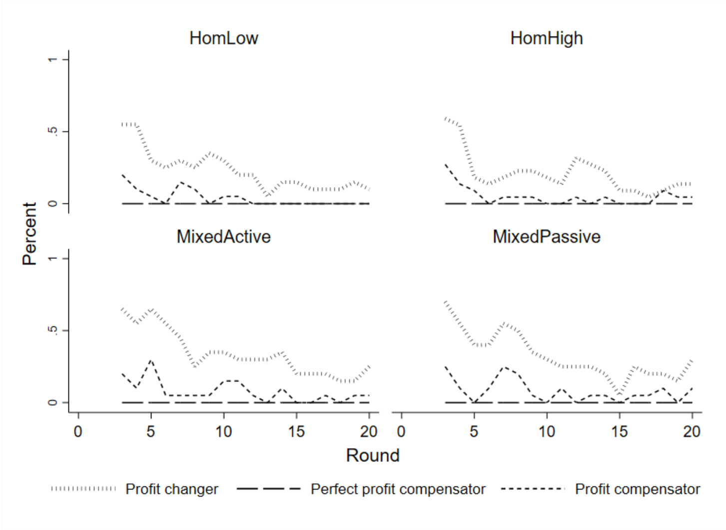

Figure 9: Relative number of subjects with profit change (in per cent): Development of the number of subjects with profit changes as a percentage of the total number of subjects per condition. Dotted line: Number of subjects per round, whose profits (either those for active patients or those for passive patients or both) change compared to the previous round. Dashed line: Number of subjects per round who compensate their profit decrease for active (passive) patients by an identical profit increase for passive (active) patients. Long dashed line: Number of subjects per round who compensate their profit decrease for active (passive) patients by a profit increase for passive (active) patients.

6 Conclusion

This study examines how physician competition affects the quality of medical care when patients are heterogeneous in two respects – their responsiveness to quality (i.e., whether they always visit the same physician or freely choose a physician based on treatment quality) and their state of health (i.e., whether they need a low or a high quantity of medical services to obtain maximum benefit). Across all conditions of our laboratory experiment, we find that the benefits resulting from competition differ across patient groups. Without competition, we find that, in line with the theoretical prediction, the average deviation from patient-optimal treatment is positive but lower than that expected with pure profit maximization. As such, our results point to an average level of altruism $\alpha \in (0, 1)$. Comparing average patient benefits across states of health, the benefits are higher for high-severity patients than for low-severity patients as, for the former, the trade-off between profit-maximization and patient-optimal treatment is less pronounced as for the latter. With competition, we observe for all active patient types that, at least in the long run, average patient benefits do not differ from the respective patient-optimum. Thus, in line with the theoretical prediction, competition eliminates the distortive incentives associated with fee-for-service payment. However, for passive patients, competition even decreases the average benefit. The latter observation is in contrast to the theoretical prediction. Apparently, physicians skimp on the quality of care for passive patients to some degree (though, we observe no perfect profit compensation) while improving the quality of care for active patients. This supports the result of Scott *et al.* (2022) that competition has heterogeneous effects on quality when different sub-groups are affected.

we find that a decrease in realized profits for active patients yields almost no reaction on realized profits for passive patients (see Appendix D).

To conclude, our study provides support for the common view that competition may have positive effects on the quality of medical care. However, it does so for patients who are able to choose their physician based on information about treatment quality only. As such, our study emphasises that competition can evoke inequalities between different patient groups, e.g. when some patients cannot freely choose their physician. Furthermore, depending on the specific composition of the patient population, the effects of competition are sensitive to a patient's state of health. Our results imply that policies that aim at reducing patients' transport costs to the next physician (e.g, by introducing telemedicine or electronic health) or at publicly providing information about the quality of care and at easing the access to this information might help to strengthen the positive effects of physician competition.

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References

Allard, M., Jelovac, I. and Leger, P.T. (2011). 'Treatment and referral decisions under different physician payment mechanisms', *Journal of Health Economics*, vol. 30(5), pp. 880–893.

Allard, M., Thomas Léger, P. and Rochaix, L. (2009). 'Provider competition in a dynamic setting', *Journal of Economics & Management Strategy*, vol. 18(2), pp. 457–486.

Angerer, S., Glätzle-Rützle, D., Rittmannsberger, T. and Waibel, C. (2021a). 'The value of rating systems in healthcare credence goods markets', *Available at SSRN 3965318*.

Angerer, S., Glätzle-Rützler, D. and Waibel, C. (2021b). 'Monitoring institutions in healthcare markets: Experimental evidence', *Health Economics*, vol. 30(5), pp. 951–971.

Beukers, P.D., Kemp, R.G. and Varkevisser, M. (2014). 'Patient hospital choice for hip replacement: empirical evidence from the netherlands', *The European Journal of Health Economics*, vol. 15(9), pp. 927–936.

Bloom, N., Propper, C., Seiler, S. and Van Reenen, J. (2015). 'The impact of competition on management quality: evidence from public hospitals', *The Review of Economic Studies*, vol. 82(2), pp. 457–489.

Brekke, K.R., Gravelle, H., Siciliani, L. and Straume, O.R. (2014). 'Patient choice, mobility and competition among health care providers', *Health care provision and patient mobility*, pp. 1–26.

Brekke, K.R., Holmås, T.H., Monstad, K. and Straume, O.R. (2019). 'Competition and physician behaviour: Does the competitive environment affect the propensity to issue sickness certificates?', *Journal of Health Economics*, vol. 66, pp. 117–135.

Brekke, K.R., Nuscheler, R. and Straume, O.R. (2007). 'Gatekeeping in health care', *Journal of Health Economics*, vol. 26(1), pp. 149–170.

Brook, R.H. and Kosecoff, J.B. (1988). 'Competition and quality', *Health Affairs*, vol. 7(3), pp. 150–161.

Brosig-Koch, J., Hehenkamp, B. and Kokot, J. (2017a). 'The effects of competition on medical service provision', *Health Economics*, vol. 26, pp. 6–20.

Brosig-Koch, J., Hennig-Schmidt, H., Kairies-Schwarz, N., Kokot, J. and Wiesen, D. (2019). 'Physician performance pay: Experimental evidence', *Available at SSRN 3467583*.

Brosig-Koch, J., Hennig-Schmidt, H., Kairies-Schwarz, N. and Wiesen, D. (2016). 'Using artefactual field and lab experiments to investigate how fee-for-service and capitation affect medical service provision', *Journal of Economic Behavior & Organization*, vol. 131, pp. 17–23.

Brosig-Koch, J., Hennig-Schmidt, H., Kairies-Schwarz, N. and Wiesen, D. (2017b). 'The effects of introducing mixed payment systems for physicians: Experimental evidence', *Health Economics*, vol. 26(2), pp. 243–262.

Brosig-Koch, J., Kairies-Schwarz, N. and Kokot, J. (2017c). 'Sorting into payment schemes and medical treatment: A laboratory experiment', *Health Economics*, vol. 26, pp. 52–65.

Brosig-Koch, J., Riechmann, T. and Weimann, J. (2017d). 'The dynamics of behavior in modified dictator games', *PloS ONE*, vol. 12(4), p. e0176199.

Capps, C., Dranove, D. and Satterthwaite, M. (2003). 'Competition and market power in option demand markets', *RAND Journal of Economics*, pp. 737–763.

Chou, S.Y., Deily, M.E., Li, S. and Lu, Y. (2014). 'Competition and the impact of online hospital report cards', *Journal of Health Economics*, vol. 34, pp. 42–58.

Cooper, Z., Gibbons, S., Jones, S. and McGuire, A. (2011). 'Does hospital competition save lives? evidence from the english NHS patient choice reforms', *The Economic Journal*, vol. 121(554), pp. F228–F260.

Dackehag, M. and Ellegård, L.M. (2019). 'Competition, capitation, and coding: Do public primary care providers respond to increased competition?', *CESifo Economic Studies*, vol. 65(4), pp. 402–423.

Di Guida, S., Gyrd-Hansen, D. and Oxholm, A.S. (2019). 'Testing the myth of fee-for-service and overprovision in health care', *Health Economics*, vol. 28(5), pp. 717–722.

Dietrichson, J., Ellegård, L.M. and Kjellsson, G. (2020). 'Patient choice, entry, and the quality of primary care: Evidence from swedish reforms', *Health Economics*, vol. 29(6), pp. 716–730.

Dranove, D. and Jin, G.Z. (2010). 'Quality disclosure and certification: Theory and practice', *Journal of Economic Literature*, vol. 48(4), pp. 935–63.

Dranove, D. and Satterthwaite, M.A. (1992). 'Monopolistic competition when price and quality are imperfectly observable', *The RAND Journal of Economics*, pp. 518–534.

Dunn, A. and Shapiro, A.H. (2018). 'Physician competition and the provision of care: evidence from heart attacks', *American Journal of Health Economics*, vol. 4(2), pp. 226–261.

Ellis, R.P. (1998). 'Creaming, skimping and dumping: provider competition on the intensive and extensive margins', *Journal of Health Economics*, vol. 17(5), pp. 537–555.

Ellis, R.P. and McGuire, T.G. (1986). 'Provider behavior under prospective reimbursement: Cost sharing and supply', *Journal of Health Economics*, vol. 5(2), pp. 129–151.

Ellis, R.P. and McGuire, T.G. (1990). 'Optimal payment systems for health services', *Journal of Health Economics*, vol. 9(4), pp. 375–396.

Engel, C. (2011). 'Dictator games: A meta study', *Experimental Economics*, vol. 14(4), pp. 583–610.

Engel, C. (2015). 'Tacit collusion: The neglected experimental evidence', *Journal of Empirical Legal Studies*, vol. 12(3), pp. 537–577.

Fischbacher, U. (2007). 'z-tree: Zurich toolbox for ready-made economic experiments', *Experimental Economics*, vol. 10(2), pp. 171–178.

Gaynor, M. and Gertler, P. (1995). 'Moral hazard and risk spreading in partnerships', *The RAND Journal of Economics*, pp. 591–613.

Gaynor, M. and Town, R.J. (2011). 'Competition in Health Care Markets', in (M. V. Pauly, T. G. Mcguire and P. P. Barros, eds.), *Handbook of Health Economics*, pp. 499–637, vol. 2 of *Handbook of Health Economics*, chap. 0, Elsevier, doi:10.1016/B978-0-444-53592-.

Gaynor, M. and Vogt, W.B. (2003). 'Competition among hospitals', *The Rand Journal of Economics*, vol. 34(4), p. 764.

Ginsburg, P.B. and Hammons, G.T. (1988). 'Competition and the quality of care: the importance of information', *Inquiry*, pp. 108–115.

Glenngård, A.H., Anell, A. and Beckman, A. (2011). 'Choice of primary care provider: results from a population survey in three swedish counties', *Health Policy*, vol. 103(1), pp. 31–37.

Godager, G., Iversen, T. and Ma, C.t.A. (2015). 'Competition, gatekeeping, and health care access', *Journal of Health Economics*, vol. 39, pp. 159–170.

Godager, G. and Wiesen, D. (2013). 'Profit or patients' health benefit? exploring the heterogeneity in physician altruism', *Journal of Health Economics*, vol. 32(6), pp. 1105–1116.

Gosden, T., Forland, F., Kristiansen, I., Sutton, M., Leese, B., Giuffrida, A., Sergison, M. and Pedersen, L. (2000). 'Capitation, salary, fee-for-service and mixed systems of payment: effects on the behaviour of primary care physicians', *Cochrane Database of Systematic Reviews*, (3).

Gottschalk, F., Mimra, W. and Waibel, C. (2020). 'Health Services as Credence Goods: a Field Experiment', *The Economic Journal*, vol. 130(629), pp. 1346–1383, ISSN 0013-0133, doi:10.1093/ej/ueaa024.

Grabowski, D.C. and Town, R.J. (2011). 'Does information matter? competition, quality, and the impact of nursing home report cards', *Health Services Research*, vol. 46(6pt1), pp. 1698–1719.

Gravelle, H., Liu, D., Propper, C. and Santos, R. (2019). 'Spatial competition and quality: evidence from the english family doctor market', *Journal of Health Economics*, vol. 68, p. 102249.

Gravelle, H. and Masiero, G. (2000). 'Quality incentives in a regulated market with imperfect information and switching costs: capitation in general practice', *Journal of Health Economics*, vol. 19(6), pp. 1067–1088.

Gravelle, H., Scott, A., Sivey, P. and Yong, J. (2016). 'Competition, prices and quality in the market for physician consultations', *The Journal of Industrial Economics*, vol. 64(1), pp. 135–169.

Gravelle, H. and Sivey, P. (2010). 'Imperfect information in a quality-competitive hospital market', *Journal of Health Economics*, vol. 29(4), pp. 524–535.

Green, E.P. (2014). ‘Payment systems in the healthcare industry: An experimental study of physician incentives’, *Journal of Economic Behavior & Organization*, vol. 106, pp. 367–378.

Greiner, B. (2015). ‘Subject pool recruitment procedures: organizing experiments with orsee’, *Journal of the Economic Science Association*, vol. 1(1), pp. 114–125.

Greiner, B., Zhang, L. and Tang, C. (2017). ‘Separation of prescription and treatment in health care markets: A laboratory experiment’, *Health Economics*, vol. 26, pp. 21–35.

Gu, Y. and Hehenkamp, B. (2014). ‘Too much of a good thing? welfare consequences of market transparency’, *Journal of Institutional and Theoretical Economics: JITE*, pp. 225–248.

Han, J., Kairies-Schwarz, N. and Vomhof, M. (2017). ‘Quality competition and hospital mergers–an experiment’, *Health Economics*, vol. 26, pp. 36–51.

Harris, K.M. (2003). ‘How do patients choose physicians? evidence from a national survey of enrollees in employment-related health plans’, *Health Services Research*, vol. 38(2), pp. 711–732.

Hennig-Schmidt, H., Selten, R. and Wiesen, D. (2011). ‘How payment systems affect physicians’ provision behaviour – an experimental investigation’, *Journal of Health Economics*, vol. 30(4), pp. 637–646.

Herbst, D. and Mas, A. (2015). ‘Peer effects on worker output in the laboratory generalize to the field’, *Science*, vol. 350(6260), pp. 545–549.

Ho, K. (2006). ‘The welfare effects of restricted hospital choice in the us medical care market’, *Journal of Applied Econometrics*, vol. 21(7), pp. 1039–1079.

Ho, K. (2009). ‘Insurer-provider networks in the medical care market’, *American Economic Review*, vol. 99(1), pp. 393–430.

Hoffstedt, C., Fredriksson, M. and Winblad, U. (2021). ‘How do people choose to be informed? a survey of the information searched for in the choice of primary care provider in sweden’, *BMC Health Services Research*, vol. 21(1), pp. 1–15.

Huck, S., Lünser, G., Spitzer, F. and Tyran, J.R. (2016). ‘Medical insurance and free choice of physician shape patient overtreatment: A laboratory experiment’, *Journal of Economic Behavior & Organization*, vol. 131, pp. 78–105.

Iversen, T. and Lurås, H. (2012). ‘Capitation and incentives in primary care’, *The Elgar Companion to Health Economics*, p. 280.

Iversen, T. and Ma, C.t.A. (2011). ‘Market conditions and general practitioners’ referrals’, *International Journal of Health Care Finance and Economics*, vol. 11(4), pp. 245–265.

Johar, M., Jones, G. and Savage, E. (2014). ‘What explains the quality and price of gp services? an investigation using linked survey and administrative data’, *Health Economics*, vol. 23(9), pp. 1115–1133.

Karlsson, M. (2007). 'Quality incentives for gps in a regulated market', *Journal of Health Economics*, vol. 26(4), pp. 699–720.

Koch, T., Wendling, B. and Wilson, N.E. (2018). 'Physician market structure, patient outcomes, and spending: an examination of medicare beneficiaries', *Health Services Research*, vol. 53(5), pp. 3549–3568.

Lagarde, M. and Blaauw, D. (2017). 'Physicians' responses to financial and social incentives: A medically framed real effort experiment', *Social Science & Medicine*, vol. 179, pp. 147–159.

Lagarde, M., Erens, B. and Mays, N. (2015). 'Determinants of the choice of gp practice registration in england: evidence from a discrete choice experiment', *Health Policy*, vol. 119(4), pp. 427–436.

Levitt, S.D. and List, J.A. (2007). 'What do laboratory experiments measuring social preferences reveal about the real world?', *Journal of Economic Perspectives*, vol. 21(2), pp. 153–174.

Martinsson, P. and Persson, E. (2019). 'Physician behavior and conditional altruism: the effects of payment system and uncertain health benefit', *Theory and Decision*, vol. 87(3), pp. 365–387.

McGuire, T.G. (2000). 'Physician agency', *Handbook of Health Economics*, vol. 1, pp. 461–536.

Moscelli, G., Gravelle, H., Siciliani, L. and Santos, R. (2018). 'Heterogeneous effects of patient choice and hospital competition on mortality', *Social Science & Medicine*, vol. 216, pp. 50–58.

Patcharanarumol, W., Panichkriangkrai, W., Sommanuttaweechai, A., Hanson, K., Wanwong, Y. and Tangcharoensathien, V. (2018). 'Strategic purchasing and health system efficiency: a comparison of two financing schemes in thailand', *PLoS ONE*, vol. 13(4), p. e0195179.

Pekola, P., Linnosmaa, I. and Mikkola, H. (2017a). 'Competition and quality in a physiotherapy market with fixed prices', *The European Journal of Health Economics*, vol. 18(1), pp. 97–117.

Pekola, P., Linnosmaa, I. and Mikkola, H. (2017b). 'Does competition have an effect on price and quality in physiotherapy?', *Health Economics*, vol. 26(10), pp. 1278–1290.

Potters, J. and Suetens, S. (2013). 'Oligopoly experiments in the current millennium', *Journal of Economic Surveys*, vol. 27(3), pp. 439–460.

Reif, S., Hafner, L. and Seebauer, M. (2020). 'Physician behavior under prospective payment schemes–evidence from artefactual field and lab experiments', *International Journal of Environmental Research and Public Health*, vol. 17(15), p. 5540.

Santos, R., Gravelle, H. and Propper, C. (2017). 'Does quality affect patients' choice of doctor? evidence from england', *The Economic Journal*, vol. 127(600), pp. 445–494.

Schwartz, L.M., Woloshin, S. and Birkmeyer, J.D. (2005). 'How do elderly patients decide where to go for major surgery? telephone interview survey', *BMJ*, vol. 331(7520), p. 821.

Scott, A., Li, J., Gravelle, H. and McGrail, M. (2022). 'Physician competition and low value health care', *American Journal of Health Economics*, forthcoming.

Siciliani, L., Chalkley, M. and Gravelle, H. (2017). 'Policies towards hospital and gp competition in five european countries', *Health Policy*, vol. 121(2), pp. 103–110.

Stiglitz, J.E. (2000). 'The contributions of the economics of information to twentieth century economics', *The Quarterly Journal of Economics*, vol. 115(4), pp. 1441–1478.

Varian, H.R. (1980). 'A model of sales', *The American Economic Review*, vol. 70(4), pp. 651–659.

A Instructions and comprehension questions for *HomLow* and *HomHigh* [*MixedPassive* and *MixedActive*]

(Translation from German)

Welcome to the Experiment!

You are participating in an economic experiment on decision behaviour. You and the other participants will be asked to make decisions for which you can earn money. Your payoff depends on both your decisions and the decisions of the other participants. At the end of the experiment, your payoff will be converted to Euro and paid to you in cash. During the experiment, all amounts are presented in the experimental currency Taler. 100 Taler equals 5 Euro. The experiment will take about 90 minutes. All participants receive the same instructions.

Please read the following instructions carefully. We will approach you in about five minutes to answer any questions you may have. If you have questions at any time during the experiment, please raise your hand and we will come to you.

<u>Decision situations</u>
In each round, you take on the role of a physician and decide on medical treatment for patients. The total number of patients, which can receive medical treatment you will find out in section "patients". At the beginning of the experiment, you will be randomly matched with another participant, who will also take on the role of a physician and decide on medical treatment for patients. The experiment will consist of 20 decision rounds. During the experiment, you solely interact with the same participant. In each round, you determine the quantity of medical treatment for each patient. Your decision is to provide each patient with a quantity of 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, or 10 medical services. Every quantity of medical service yields a particular benefit for the patient. The benefit resulting from a specific quantity of medical services is identical for you and the other physician.

<u>Patients</u>
In each of the 20 rounds, four patients can get medical treatment. [Additional for MixedPassive and MixedActive: The illness of these patients can occur with severity x or z. The severity determines the benefit resulting from medical treatment.] The following applies to each of the 20 rounds. Two out of four patients are regular patients, whereas one regular patient is assigned to you and the other one is assigned to the other physician. Regular patients always remain with the physician to whom they were initially assigned to, independently of the number of medical services you and the other physician provide. The other two patients are patients who are undecided. That is, they have not yet been set to a treating physician. The following applies to each of the undecided patients.

- The patient gets the treatment from you if the medical treatment provided by you leads to a higher benefit than the medical treatment of the other physician.
- The patient gets the treatment from the other physician if his medical treatment leads to a higher benefit than your treatment.

- If a patient receives the same benefit from your treatment and the other physician's treatment, the medical treatment will split equally between both physicians.

You and the other physician independently decide on the number of medical services for all patients. The patients, who have been undecided so far, will then be assigned to a physician according to the benefit they receive.

At the beginning of each of the 20 rounds, the four patients are assigned as follows:

Your regular patients	Regular patients of the other physician	Undecided patient A	Undecided patient B
1	1	1	1

For MixedActive [MixedPassive]

	Your regular patients	Regular patients of the other physician	Undecided patients
Severity x	1 [0]	1	2 [1]
Severity z	0 [1]	1	0 [1]

Profit

In each round you receive a fee-for-service remuneration for treating each of the patients. Your remuneration increases with the amount of medical treatment you provide. You also incur costs for treating the patients, which likewise depend on the quantity of services you provide. Your profit per patient treated is calculated by subtracting these costs from the fee-for-service remuneration. In case your treatment is shared with the other physician, you receive half of the profit for the patient. Your total profit for each round is then the sum of the profits per patient you have treated.

Every quantity of medical service yields a particular benefit for the patient. Hence, in choosing the medical services you provide, you determine not only your own profit but also the patient's benefit.

In each round you will receive detailed information on your screen (see below) about the number of your regular patients, the number of regular patients of the other physician, and the number of patients which are undecided. You also receive information on the amount of your fee-for-service remuneration per patient and – for each possible amount of medical treatment – your costs, profit as well as the benefit for the patients.

After each round, you will receive information on your screen about your decisions, the number of medical services per patient provided by the other physician, as well as the resulting number of patients treated by each physician. Furthermore, this information will be displayed for all previous rounds.

Payment

At the end of the experiment your total profit out of each round will be summed up and paid to you in cash.

For this experiment, no patients are physically present in the laboratory. Yet, the patient benefit of the four patients in each of the 20 rounds does accrue to real patients: The added patient benefit

Your regular patients	Regular patients of the other physician	Undecided patient A	Undecided patient B
1	1	1	1

Calculator

Round of 20

Number of medical services per patient	Your fee-for-service remuneration per patient (in Taler)	Your costs per patient (in Taler)	Your profit per patient (in Taler)	Benefit for your regular patient (in Taler)	Benefit for the regular patient of the other physician (in Taler)	Benefit for the undecided patient A (in Taler)	Benefit for the undecided patient B (in Taler)
0							
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

Which quantity of medical treatment do you want to provide?

Your decision for your regular patient:

Your decision for the undecided patient A:

Your decision for the undecided patient B:

resulting from the medical treatment of the four patients in each of the 20 rounds will be transferred to the Christoffel-Blindenmission Deutschland e.V., 64625 Bensheim, an organization which funds the treatment of patients with eye cataract.

The transfer of money to the Christoffel-Blindenmission Deutschland e.V. will be carried out after the experiment by the experimenter and one participant. The participant completes a money transfer form, filling in the total patient benefit (in Euro) resulting from the decisions made by all participants. This form prompts the payment of the designated amount to the Christoffel-Blindenmission Deutschland e.V. by the University of Duisburg-Essen's finance department. The form is then sealed in a postpaid envelope and posted in the nearest mailbox by the participant and the experimenter.

After the entire experiment is completed, one participant is chosen at random to oversee the money transfer to the Christoffel-Blindenmission Deutschland e.V. The participant receives an additional compensation of EUR 5 for this task. The participant certifies that the process has been completed as described here by signing a statement which can be inspected by all participants at the office of the Chair of Quantitative Economic Policy. A receipt of the bank transfer to the Christoffel-Blindenmission Deutschland e.V. may also be viewed here.

Comprehension Questions

Prior to the decision rounds we kindly ask you to answer a few comprehension questions. They are intended to help you familiarise yourself with decision situations. If you have any questions about this, please raise your hand. The experiment will begin once all participants have answered the comprehension questions correctly.

Comprehension Questions: HomHigh (HomLow)

Your regular patients	Regular patients of the other physician	Undecided patient A	Undecided patient B
1	1	1	1

Quantity of medical treatment per patient	Fee-for-service per patient (in Taler)	Costs per patient (in Taler)	Profit per patient (in Taler)	Benefit of your regular patient (in Taler)	Benefit of the regular patient of the other physician (in Taler)	Benefit of the undecided patient A (in Taler)	Benefit of the undecided patient B (in Taler)
0	0.00	0.00	0.00	3.00 (7.00)	3.00 (7.00)	3.00 (7.00)	3.00 (7.00)
1	4.00	0.20	3.80	4.00 (8.00)	4.00 (8.00)	4.00 (8.00)	4.00 (8.00)
2	8.00	0.80	7.20	5.00 (9.00)	5.00 (9.00)	5.00 (9.00)	5.00 (9.00)
3	12.00	1.80	10.20	6.00 (10.00)	6.00 (10.00)	6.00 (10.00)	6.00 (10.00)
4	16.00	3.20	12.80	7.00 (9.00)	7.00 (9.00)	7.00 (9.00)	7.00 (9.00)
5	20.00	5.00	15.00	8.00 (8.00)	8.00 (8.00)	8.00 (8.00)	8.00 (8.00)
6	24.00	7.20	16.80	9.00 (7.00)	9.00 (7.00)	9.00 (7.00)	9.00 (7.00)
7	28.00	9.80	18.20	10.00 (6.00)	10.00 (6.00)	10.00 (6.00)	10.00 (6.00)
8	32.00	12.80	19.20	9.00 (5.00)	9.00 (5.00)	9.00 (5.00)	9.00 (5.00)
9	36.00	16.20	19.80	8.00 (4.00)	8.00 (4.00)	8.00 (4.00)	8.00 (4.00)
10	40.00	20.00	20.00	7.00 (3.00)	7.00 (3.00)	7.00 (3.00)	7.00 (3.00)

1. Assume that a physician wants to provide 2 (9) quantities of medical treatment for the patients depicted above.

(a) What is the fee-for-service per patient?

(b) What are the costs per patient?

(c) What is the profit per patient?

(d) What is the benefit for your regular patient?

(e) What is the benefit for the undecided patient A?

(f) What is the benefit for the undecided patient B?

2. Assume that you want to provide 2 (9) quantities of medical treatment for your regular patient and the undecided patients depicted above. The other physician wants to provide 9 (2) quantities of medical treatment for these patients.

(a) How many regular patients would you treat?

(b) How many undecided patients would you treat?

(c) How many patients would you treat in total?

(d) What is your total profit?

Comprehension Questions: MixedActive (MixedPassive)

	Your regular patients	Regular patients of the other physician	Undecided patients
Severity x	0 (1)	1 (1)	1 (2)
Severity z	1 (0)	0 (0)	1 (0)

Quantity of medical treatment per patient	Fee-for-service per patient (in Taler)	Costs per patient (in Taler)	Profit per patient (in Taler)	Benefit per patient with severity x (in Taler)	Benefit per patient with severity z (in Taler)
0	0.00	0.00	0.00	14.00	6.00
1	4.00	0.20	3.80	16.00	8.00
2	8.00	0.80	7.20	18.00	10.00
3	12.00	1.80	10.20	20.00	12.00
4	16.00	3.20	12.80	18.00	14.00
5	20.00	5.00	15.00	16.00	16.00
6	24.00	7.20	16.80	14.00	18.00
7	28.00	9.80	18.20	12.00	20.00
8	32.00	12.80	19.20	10.00	18.00
9	36.00	16.20	19.80	8.00	16.00
10	40.00	20.00	20.00	6.00	14.00

1. Assume that a physician wants to provide 9 quantities of medical treatment for the patients depicted above.

(a) What is the fee-for-service per patient?

(b) What are the costs per patient?

(c) What is the profit per patient?

(d) What is the benefit for the patient with severity x?

(e) What is the benefit for the patient with severity z?

2. Assume that you want to provide 9 quantities of medical treatment for your regular patient and the undecided patients depicted above. The other physician wants to provide 2 quantities of medical treatment for these patients.

(a) How many regular patients would you treat?

(b) How many undecided patients would you treat?

(c) How many patients would you treat in total?

(d) What is your total profit?

B Proofs

Proof of Proposition 1. Recall the utility $U^\tau(q;\alpha) = (1-\alpha)\pi(q) + \alpha B^\tau(q)$ of a physician with a degree of altruism $\alpha \in [0,1]$, who chooses $q \in Q$ and treats a patient of type $\tau = L, H$. Further recall that $q^\tau(\alpha)$ denotes a corresponding utility maximizing quantity, which always exists since Q is finite. Let $\tau \in L, H$ be arbitrary.

Part (a): For $\alpha = 0$, we have $U^\tau(q;\alpha) = \pi(q) = 2q - q^2/10$, which is maximized for $q = 10$. For $\alpha = 1$, we have $U^\tau(q;\alpha) = B^\tau(q) = 10 - |q^\tau - q|$, which is maximized for $q = q^\tau$. For $\alpha \in (0,1)$, we show that $q < q^\tau$ does not maximize $U^\tau(q;\alpha)$. The claim then follows from Q being finite, which guarantees a maximizer $q^\tau(\alpha) \geq q^\tau$ exists.
Fix $\alpha \in (0,1)$ arbitrarily, consider any $q \in Q$ such that $q < q^\tau$ and suppose q maximizes $U^\tau(q;\alpha)$. Observe that $B^\tau(q) < B^\tau(q^\tau) = 10$, since $B^\tau(\cdot)$ is strictly increasing on $\{0,\dots,q^\tau\}$. Moreover, we have $\pi(q) < \pi(q^\tau)$, since $\pi(q)$ is strictly increasing on Q. Combining the two inequalities, we obtain that $U^\tau(q;\alpha) < U^\tau(q^\tau;\alpha)$ in contradiction to the optimality of q.

Part (b): By definition of q^τ, we have $B^\tau(q) \leq B^\tau(q^\tau) = 10$ for all $q \in Q$. Hence, the inequality holds for any $\alpha \in [0,1]$ and for q such that $q = q^\tau(\alpha)$. Let α be sufficiently small such that

$$\alpha < \frac{\pi(q^\tau+1)-\pi(q^\tau)}{\pi(q^\tau+1)-\pi(q^\tau)+B^\tau(q^\tau)-B^\tau(q^\tau+1)}.$$

If $\tau = L$, we insert $q^L = 3$ and the inequality reduces to $\alpha < 13/23$. Similarly, for $\tau = H$, we insert $q^H = 7$ and obtain $\alpha < 1/3$. Observe that the above inequality is equivalent to $U^\tau(q^\tau+1;\alpha) > U^\tau(q^\tau;\alpha)$. It follows that q^τ cannot be optimal, i.e. $q^\tau(\alpha) \neq q^\tau$, and, by part (a), that $q^\tau(\alpha) > q^\tau$. Thus, $B^\tau(q^\tau(\alpha)) < B^\tau(q^\tau)$, since $B^\tau(q)$ is strictly decreasing for $q > q^\tau(\alpha)$, which completes the proof of claim (i).

To see that $B^\tau(q^\tau(\alpha)) \geq B^\tau(10)$ holds for all $\alpha \in [0,1]$, notice that $q^\tau(\alpha) \in \{q^\tau,\dots,10\}$ by part (a). The claim then follows, since $B^\tau(q)$ is strictly decreasing on $\{q^\tau,\dots,10\}$. Furthermore, the inequality holds strictly for α sufficiently large. Let α be such that

$$\alpha > \frac{\pi(10)-\pi(9)}{\pi(10)-\pi(9)+B^\tau(9)-B^\tau(10)} = \frac{1}{11},$$

which is equivalent to $U^\tau(9;\alpha) > U^\tau(10;\alpha)$, both for $\tau = L$ and for $\tau = H$. It thus follows that $q^\tau(\alpha) < 10$ and hence $B^\tau(q^\tau(\alpha)) > B^\tau(10)$ by strict monotonicity of $B^\tau(q)$ on $\{q^\tau,\dots,10\}$. This completes the proof of claim (ii).

To prove claim (iii), notice first that, for all $q > q^\tau$ and all $\alpha \in [0,1)$, the difference

$$U^\tau(q;\alpha) - U^\tau(q-1;\alpha) = (1-\alpha)(\pi(q) - \pi(q-1)) - \alpha$$

is strictly decreasing in q, since $\pi(q)$ is strictly concave.

We distinguish two cases. Firstly, if $\alpha \in (1/3, 13/23)$ then, on the one hand, $\alpha < 13/23$ is equivalent to $U^L(4;\alpha) > U^L(3;\alpha)$ and, by part (a), it hence follows that $q^L(\alpha) > q^L = 3$. This implies $B^L(q^L(\alpha)) < B^L(q^L) = 10$, since $B^L(q)$ is strictly decreasing for $q > q^L$. On the other hand, $\alpha > 1/3$ is equivalent to $U^H(7;\alpha) > U^H(8;\alpha)$. Deploying our preliminary remarks consecutively, we get

$$0 > U^H(8;\alpha) - U^H(7;\alpha) > U^H(9;\alpha) - U^H(8;\alpha) > U^H(10;\alpha) - U^H(9;\alpha),$$

which in turn implies that $U^H(7;\alpha) > U^H(8;\alpha) > U^H(9;\alpha) > U^H(10;\alpha)$. By part (a), it hence follows that $q^H(\alpha) = 7$ and hence $B^H(q^H(\alpha)) = 10$. Combining the two results, we thus obtain $B^L(q^L(\alpha)) < 10 = B^H(q^H(\alpha))$ for $\alpha \in (1/3, 13/23)$.

Secondly, for $\alpha \in [0, 1/3]$ it suffices to show that $q^L(\alpha) \geq 7$. For, in this case, we obtain that $B^L(q^L(\alpha)) = 13 - q^L(\alpha) \leq 6$. Moreover, it follows from $q^H(\alpha) \in \{7, \ldots, 10\}$ that $B^H(q^H(\alpha)) = 17 - q^H(\alpha) \geq 7 > B^L(q^L(\alpha))$, which then completes the proof of claim (iii).

To show that $q^L(\alpha) \geq 7$ indeed applies, fix $\alpha \leq 1/3$ arbitrarily. Recall that $\alpha \leq 1/3$ is equivalent to $U^L(7;\alpha) \leq U^L(8;\alpha)$. By our preliminary remark, it hence follows that

$$\begin{aligned} 0 \leq U^L(8;\alpha) - U^L(7;\alpha) &< U^L(7;\alpha) - U^L(6;\alpha) < U^L(6;\alpha) - U^L(5;\alpha) \\ &< U^L(5;\alpha) - U^L(4;\alpha) < U^L(4;\alpha) - U^L(3;\alpha). \end{aligned}$$

Since the first difference is strictly positive, so are the other differences, which implies $U^L(7,\alpha) > U^L(6,\alpha) > U^L(5,\alpha) > U^L(4,\alpha) > U^L(3,\alpha)$. By part (a), we thus obtain that $q^L(\alpha) \geq 7$, which completes the proof. □

Proof of Proposition 2. Notice that physician utility $U_1(q_1, q_2; \alpha_1)$ from treating a patient of type τ, $\tau \in \{L, H\}$, can be rewritten as

$$\begin{aligned} U_1(q_1, q_2; \alpha_1) &= (1 - \alpha_1)\pi_1^\tau(q_1, q_2) + \alpha_1 B_1^\tau(q_1, q_2) \\ &= n^\tau(q_1, q_2)[(1 - \alpha_1)\pi(q_1) + \alpha_1 B^\tau(q_1)]. \end{aligned}$$

(Existence) Let the patient be of type $\tau = L$, i.e. $q^\tau = 3$. To establish that $(q_1^*, q_2^*) = (q^\tau, q^\tau)$ represents a Nash equilibrium, it suffices to show that, for any degree of altruism $\alpha_1 \in [0, 1]$, physician 1 maximizes utility by choosing q^τ, given that physician 2 picks q^τ. Then, by symmetry, a similar argument applies to physician 2.

To begin with, let $q_1 \neq q^\tau$ denote any alternative quantity choice of physician 1. Define

$$\Delta(q_1, \alpha_1) \coloneqq U_1^\tau(q^\tau, q^\tau; \alpha_1) - U_1^\tau(q_1, q^\tau; \alpha_1).$$

On the one hand, notice that $q_1 \neq q^\tau$ implies $B^\tau(q_1) < B^\tau(q^\tau)$ and hence $n^\tau(q_1, q^\tau) = 0$. Consequently, we have

$$U_1^\tau(q_1, q^\tau; \alpha_1) = n^\tau(q_1, q^\tau)[(1-\alpha_1)\pi(q_1) + \alpha_1 B^\tau(q_1)] = 0,$$

for all $q_1 \neq q^\tau$ and all $\alpha_1 \in [0,1]$. On the other hand, observe that $n^\tau(q^\tau, q^\tau) = 1/2$ implies

$$U_1^\tau(q^\tau, q^\tau; \alpha_1) = n^\tau(q^\tau, q^\tau)[(1-\alpha_1)\pi^\tau(q^\tau) + \alpha_1 B^\tau(q^\tau)] \geq n^\tau(q^\tau, q^\tau)\pi^\tau(q^\tau) = 51/20,$$

where the inequality follows from $\alpha_1 \in [0,1]$ and $\pi^\tau(q^\tau) = 51/10 < B^\tau(q^\tau) = 10$. We thus have $\Delta(q_1, \alpha_1) \geq 51/20 > 0$ for all $q_1 \neq q^\tau$ and all $\alpha_1 \in [0,1]$, i.e. (q^τ, q^τ) represents a strict Nash equilibrium for all $(\alpha_1, \alpha_2) \in [0,1]^2$. A similar argument shows that $(q^\tau, q^\tau) = (7,7)$ constitutes a Nash equilibrium if the patient is of type $\tau = H$ such that $q^\tau = 7$.

(Uniqueness) Consider a patient of arbitrary type $\tau \in \{L, H\}$ and recall that $B^\tau(q^\tau) > B^\tau(q)$ for all $q \in Q, q \neq q^\tau$. It remains to be shown that (q^τ, q^τ) represents a *unique* Nash equilibrium of the stage game. We show (1) that no other symmetric Nash equilibrium exists and (2) that no asymmetric equilibrium exists either.

Ad (1): Suppose (q, q) represents a second Nash equilibrium such that $q \neq q^\tau$. If $q < q^\tau$ then $q_1 = q + 1$ entails $B^\tau(q+1) > B^\tau(q), n^\tau(q+1, q) > n^\tau(q, q)$, and $\pi(q+1) > \pi(q)$, which implies $U_1^\tau(q+1, q; \alpha_1) > U_1^\tau(q, q; \alpha_1)$ for any $\alpha_1 \in [0,1]$. Thus, (q, q) does not represent a Nash equilibrium for $q < q^\tau$.
On the other hand, if $q > q^\tau$ then $q_1 = q - 1$ entails $B^\tau(q-1) > B^\tau(q)$, which implies that (q, q) does not represent an equilibrium for $\alpha_1 = 1$. Moreover, it follows that $n^\tau(q-1, q) = 1 > n^\tau(q, q) = 1/2$, but also $\pi(q-1) < \pi(q)$. Notice, however, that $\pi_1^\tau(q-1, q) = \pi(q-1) > \pi_1^\tau(q, q) = \pi(q)/2$. To show this, we set

$$\Delta(q) := \pi(q-1) - \tfrac{1}{2}\pi(q) = \tfrac{1}{20}(-q^2 + 24q - 42).$$

Since $\Delta(q)$ is strictly increasing on Q, it follows from $q > q^\tau \geq 3$ that $\Delta(q) > \Delta(3) = 21/20 > 0$, i.e. we have $\pi_1^\tau(q-1, q) > \pi_1^\tau(q, q)$ and thus (q, q) does not represent an equilibrium for $\alpha_1 = 0$. Combined with $B^\tau(q-1) > B^\tau(q)$ this implies that $U_1^\tau(q-1, q; \alpha_1) > U_1^\tau(q, q; \alpha_1)$ for any $\alpha_1 \in (0,1)$, since physicians' utility is linear in α_1. Thus, (q, q) does not represent a Nash equilibrium for $q > q^\tau$ either.

Ad (2): Let (q_1, q_2) represent a Nash equilibrium such that $q_1 \neq q_2$. Observe that $q_1 = q^\tau$ or $q_2 = q^\tau$ cannot be part of an asymmetric equilibrium since (q^τ, q^τ) represents a *strict* Nash equilibrium. Hence, suppose that $q_1 \neq q^\tau$ and $q_2 \neq q^\tau$. Without loss of generality, let $q_1 < q_2$. If $q_1 < q^\tau$ then physician 1 can strictly increase utility by choosing q^τ instead. To see this, notice that $B^\tau(q^\tau) > B^\tau(q_1)$, $n^\tau(q^\tau, q_2) = 1 \geq n^\tau(q_1, q_2)$, and $\pi(q^\tau) > \pi(q_1)$. It thus follows that

$$\begin{aligned} U_1(q^\tau, q_2; \alpha_1) &= n^\tau(q^\tau, q_2)[(1-\alpha_1)\pi(q^\tau) + \alpha_1 B^\tau(q^\tau)] \\ &> n^\tau(q_1, q_2)[(1-\alpha_1)\pi(q_1) + \alpha_1 B^\tau(q_1)] = U_1(q_1, q_2; \alpha_1) \end{aligned}$$

for any $\alpha_1 \in [0,1]$, in contradiction to (q_1, q_2) representing a Nash equilibrium. On the other hand, if $q_1 > q^\tau$, then physician 2 can increase utility by choosing $q_1 - 1$ instead. To see this, observe first that patient benefit strictly increases, $B^\tau(q_1 - 1) > B^\tau(q_1)$, by negative monotonicity of patient benefit for all $q_1 > q^\tau$. Hence, (q_1, q_2) does not represent an equilibrium for $\alpha_2 = 1$. Secondly, this implies

$n^\tau(q_1, q_1 - 1) = 0$ whereas $n^\tau(q_1, q_2) = 1$ because of $q_1 < q_2$, i.e., physician 2 strictly increases her demand. Moreover, we obtain

$$\pi_2^\tau(q_1, q_1 - 1) = (1 - n^\tau(q_1, q_1 - 1))\pi_2(q_1 - 1) > 0 = \pi_2(q_1, q_2),$$

because of $q_1 - 1 \geq q^\tau > 0$. Therefore, (q_1, q_2) does neither represent a Nash equilibrium for $\alpha_2 = 0$. Since physicians' utility is linear in α_2, it hence follows that $U_2(q_1, q_1 - 1; \alpha_2) > U_2(q_1, q_2; \alpha_2)$ for any $\alpha_2 \in (0, 1)$. Thus, (q_1, q_2) does not represent a Nash equilibrium for $q_1 > q^\tau$ either. □

C Further analyses

Table C1: No competition – time trends with regard to patient benefits

	(1)	(2)	(3)	(4)
Low severity	-2.430***	-2.659***	-2.420***	-2.642***
	(0.491)	(0.513)	(0.489)	(0.505)
Round	-0.017**	-0.017**	-0.017*	-0.017*
	(0.008)	(0.008)	(0.009)	(0.009)
Constant	8.786***	6.193***	8.781***	6.467***
	(0.346)	(1.844)	(0.228)	(1.497)
Observations	900	900	900	900
Individual Characteristics	No	Yes	No	Yes

Notes: Fixed effects results of two-level mixed effects REML regressions with clustering levels for subject and round (models 1 and 2). Results of panel regressions with clusters on group level (models 3 and 4). Individual characteristics comprise age, gender, and field of study. Panel data regressions reveal similar results. Standard errors are in parentheses *** $p < .01$, ** $p < .05$, * $p < .1$

Table C2: Panel regression: Effects of competition for active patients

	(1)	(2)	(3)	(4)	(5)
Competition	1.955***	1.163***	1.172***		
	(0.378)	(0.247)	(0.254)		
Low severity	-1.628***	-2.42***	-2.431***	-0.778	-0.724
	(0.386)	(0.487)	(0.493)	(0.565)	(0.539)
Round	0.006	0.006	0.006	0.035***	0.035***
	(0.008)	(0.008)	(0.008)	(0.012)	(0.012)
Competition x severity		1.642**	1.608**		
		(0.744)	(0.758)		
MixedPassive				-0.359	-0.316
				(0.719)	(0.712)
MixedActive				0.199	0.177
				(0.621)	(0.608)
Individual Characteristics	No	No	Yes	No	Yes
Constant	8.160***	8.548***	8.982***	9.406***	10.038***
	(0.284)	(0.238)	(1.636)	(0.143)	(1.678)
Subjects	87	87	87	82	82
Observations	1740	1740	1740	1640	1640

Notes: Results of panel regressions with clusters on group level of competition (models 1-3) and composition of the population (models 4-5) on patient benefit for passive patients only. Baseline category for experimental condition is *HomLow*. Individual characteristics comprise age, gender, and field of study. Standard errors are in parentheses. *** $p < .01$, ** $p < .05$, * $p < .1$

Table C3: Panel regression: Effects of competition for passive patients

	(1)	(2)	(3)	(4)	(5)
Competition	-1.423***	-1.000***	-0.989***		
	(0.373)	(0.319)	(0.337)		
Low severity	-2.843***	-2.420***	-2.527***	-4.200***	-4.139***
	(0.379)	(0.487)	(0.487)	(0.302)	(0.322)
Round	-0.016**	-0.016**	-0.016**	-0.029***	-0.029***
	(0.006)	(0.006)	(0.006)	(0.010)	(0.010)
Competition x severity		-0.877	-0.862		
		(0.753)	(0.753)		
HomHigh				-0.903	-0.765
				(0.652)	(0.664)
MixedPassive				-0.810	-0.785
				(0.565)	(0.549)
MixedActive				0.368	0.357
				(0.745)	(0.745)
Individual characteristics	No	No	Yes	No	Yes
Constant	8.977***	8.770***	7.551***	8.810***	7.906***
	(0.255)	(0.234)	(1.138)	(0.611)	(1.400)
Subjects	87	87	87	82	82
Observations	1740	1740	1740	1640	1640

Notes: Results of panel regressions with clusters on group level of competition (models 1-3) and composition of the patient population (models 4-5) on patient benefit. Baseline category for experimental condition is *HomLow*. Individual characteristics comprise age, gender and field of study. Standard errors are in parentheses. *** $p < .01$, ** $p < .05$, * $p < .1$

Table C4: Competition – time trends with regard to the difference between benefits for active and passive patients with low severity of illness

	(1)	(2)	(3)
	Benefit	Benefit	Benefit
MixedPassive	0.641	0.558	0.202
	(0.790)	(0.755)	(0.649)
MixedActive	-0.156	-0.116	-0.955
	(0.825)	(0.797)	(0.608)
Round	0.068***	0.068***	0.029
	(0.019)	(0.019)	(0.023)
Round x MixedPassive			0.034
			(0.047)
Round x MixedActive			0.080**
			(0.040)
Constant	4.058***	7.865***	8.271***
	(0.617)	(2.210)	(2.236)
Observations	1000	1000	1000
Subjects' characteristics	No	Yes	Yes

Notes: Results from panel regression with robust standard errors at group level. Dependent variable is gap, which is the individual (absolute) difference between benefit of active and passive patients. Baseline category for experimental condition is *HomLow*. Individual characteristics comprise age, gender, and field of study. Standard errors are in parentheses. *** $p < .01$, ** $p < .05$, * $p < .1$

D Arc-elasticity of medical treatment

We also calculated the arc-elasticity of medical treatment for passive patients with respect to changes in medical treatment for active patients. That is, we aim at relating the extent of a change of profits resulting from the treatment of active patients to the extent of a change of profits resulting from the treatment of passive patients. For this, we first calculate the changes of realized profits compared to the previous round. We do this separately for profits resulting for active patients (π^A) and profits resulting for passive patients (π^P). As treatment responses can be realised only after receiving information about profits, the responding profit changes are lagged for one round. The arc-elasticity is then calculated as

$$\eta = \frac{(\pi_r^P - \pi_{r-1}^P)(\pi_{r-1}^A + \pi_{r-2}^A)}{(\pi_{r-1}^A - \pi_{r-2}^A)(\pi_r^P + \pi_{r-1}^P).}$$

The arc-elasticity represents the %-profit change for passive patients by a %-profit change for active patients. Figure D1 reveals that a decrease in realized profit for active patients yields almost no reaction to realized profits for passive patients.

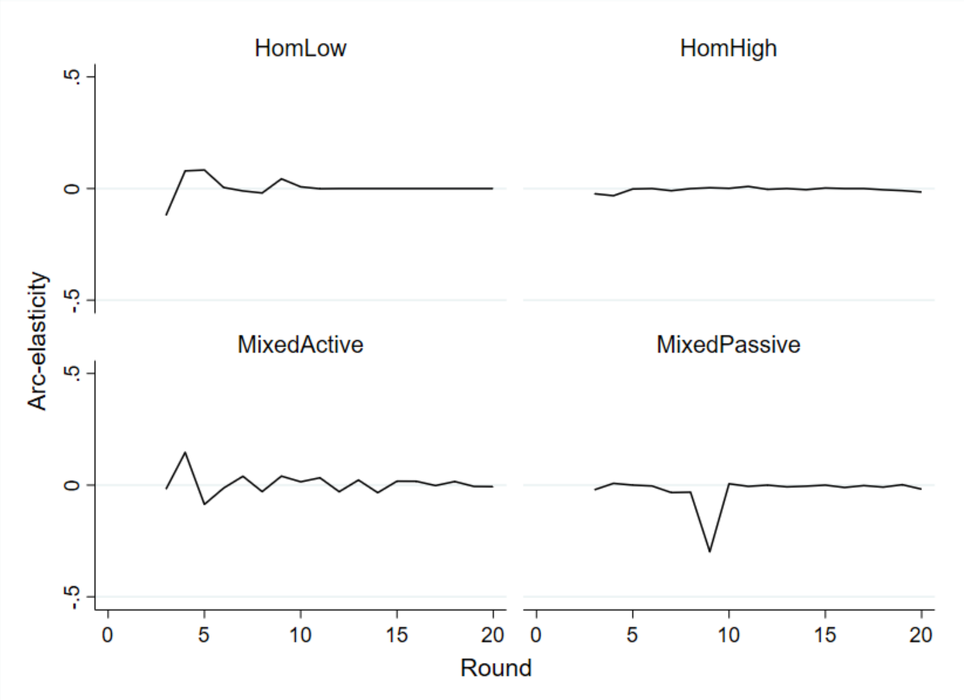

Figure D1: Arc-elasticity of profits for passive patients with respect to changes in profits for active patients hche | Hamburg Center for Health Economics

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