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Abstract

We study the link between illness severity and the use of public health care services by the privately insured under a public health system. Our theoretical model shows that this relationship will depend on the prioritization established by the public health authorities, the cost of waiting and the private sector's risk selection behavior. In our empirical exercise, based on the British Household Panel Survey data, we find the consistent pattern that both the most severe cases and the least severe cases are more likely to be treated under the public system, leading to a U-shaped relationship between severity and public use. As our theoretical model points out, this is not necessarily a consequence of risk selection by private health providers, but it could be just a consequence of prioritization by the public sector.

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1 Introduction

Different types of agents participate in a health system: insurers, providers and consumers. The heterogeneity in their characteristics and objectives is a salient feature of most health systems. In this paper, we focus on the public-private interaction, which is relevant not only to study equity and efficiency issues but also to understand more specific features as waiting lists, the demand for private health insurance and voters' support for a public system.

We consider a National Health System (NHS) where everyone is entitled to free treatment under the NHS. Despite the availability of free treatments through the NHS, a considerable fraction of the population buys private health insurance (PHI). Having PHI allows this group of people to obtain treatment through a separate set of suppliers: the private hospitals and doctors.[1] Hence, this group of people enjoy double coverage as they can obtain health care from both the public and private suppliers. Although the specific advantages of PHI will depend on the country, a common feature is that PHI insurees can circumvent long waiting lists of the public system as waiting lists in the private system are almost nil [2]

Conversely, the reader may wonder why should a patient who is privately insured want to have treatment through the public system. Since this is actually observed, there must exist some intrinsic cost in using the private rather than the public system. For instance, even privately insured individ-

[1] Some individuals also resort to private suppliers despite not enjoying any PHI coverage, that is, they pay the treatment out-of-pocket. However, as this is relatively infrequent, the data does not show enough variation. We therefore restrict attention to individuals that have purchased private insurance.

[2] See Propper, 1989; Richmond, 1996; and Besley, Hall, and Preston, 1999 for the UK, Jofre-Bonet, 2000 for Spain, and Hurley and Johnson, 2014 for Canada..

uals bear some co-payment that is absent in most NHS treatments, or the private provider might be further away from their home. Also, by using the public system, the individual may avoid an increase in the following year insurance premium. This allows the individual to circumvent experience rating (the "malus" mechanism).

Our objective is to study the relationship between public/private use of health care and illness severity. This is important both in the short-term and the longer-term. In the short term, for a given NHS budget, those who buy PHI might indirectly benefit those who don't, because they will use less NHS services, and hence the *per-capita* resources for those who don't buy PHI will increase (Propper and Green, 2001). However, the extent of the savings will crucially depend on the extent to what those with PHI use NHS services, and at what levels of severity. In the longer term, the NHS budget is not fixed, and whether PHI insurees support tax increases and a larger NHS budget will also depend on the extent to which they use NHS services, and at what level of severity. In other words, PHI insurees could be more supportive of NHS budget expansions if they use NHS services frequently, and especially if they use them for most severe cases.

We accomplish our objective by combining a theoretical model and empirical analysis to answer two interrelated research questions: How does the PHI insurees' demand of private *vs.* public health care depend on illness severity?, as well as, in what sector (private/public) will PHI insurees be actually be treated depending on illness severity? The wedge between demand and actual use highlights the role of risk selection by the private sector in determining how demand gets translated to actual use.

As for our first question (demand of public vs. private healthcare), our theoretical model emphasizes the role of the waiting costs per unit of time and the extent to which NHS patients are prioritized according to their severity.[3] Obviously, individuals in a more severe condition bear a larger waiting cost per unit of time. However, severity-based prioritization in the NHS implies that individuals in more severe condition have to wait less than average while individuals in less severe condition have to wait more than average (Dimakou, Dimakou, and Basso , 2015). Since waiting time in the private sector is negligible, prioritization shapes the pattern of public *vs.* private health care demand as a function of illness severity.

As for our second question (the final allocation of patients across sectors), risk selection by the private sector comes into play. Indeed, the private sector might not want to serve the most severe patients, as they might be costlier. Although it could engage in dumping by which it refuses outright to treat patients with the most severe conditions (Ellis, 1998), more subtly it might practice "service-level selection" by not investing in the technologies aimed at treating the most severe patients (Glazer and McGuire, 2000).

Even with a simple economic model, we can show that the relationship between severity and demand cannot be determined *a priori*, and will depend on the intensity of prioritization. Intuitively, take an individual in severe condition. His or her cost of waiting per unit of time will be large. However, in the presence of intense prioritization, he or she will not have to wait a long time to be treated. If the first (second) effect dominates, he or she will be demanding private (public) treatment.

[3] Gutacker, Siciliani and Coockson (2016) precisely estimate the degree of prioritization for the specific case of hip and knee replacements in the UK, and find that most severe patients have shorter waits than less severe ones, by about 24% (11%) for hip (knee) replacement, and that the association is approximately linear, which provides support for our theoretical model

We are however able to provide two quite a general predictions. First, the public sector will tend to treat the individuals in least severe condition. This result is mostly driven by the fact that such individuals are more willing to wait.[4] Second, if one observes that individuals in most severe condition obtain treatment from the private sector, then obviously the private sector does not engage into risk selection and prioritization must be very mild or absent. Conversely, if one observes that individuals in most severe condition are treated by the public system, this does not necessarily mean that private providers are avoiding the most severe cases. Indeed, we show that this could also be due to a sufficiently intense severity-based prioritization policy in the public sector. More emphatically: risk selection by the private sector and prioritization in the public sector are observationally equivalent. We believe that our paper is the first one to point this equivalence out. The implications of this are important. One cannot identify strategic behavior by the private sector from observations on illness severity and on health care provider allocation.

Our empirical investigation shows that the likelihood of using the NHS providers as a function of a severity proxy is U-shaped. In other words, individuals in the extremes of the severity range are more likely to be treated by the NHS, whereas individuals with intermediate severities are more likely to be treated by the private sector. Whilst the empirical result at the lower level of severity matches the first prediction of our theoretical model, the empirical result at high severity levels resolves the ambiguity of the theoretical model, although the theory is still very useful as it emphasizes that the use

[4]This result is reinforced if the reduction in waiting time for the more severe patients is accomplished with additional resources, that is, if individuals in mild condition are not made to wait more. However, this does not seem to be the case in our testing arena and time period Dimakou, Dimakou, and Basso (2015).

of the NHS by the most severe cases does not need to be the result of risk selection by the private sector, but it might be due to prioritization by the NHS.

We use the British Household Panel Survey (BHPS, University of Essex, 2021), a multi-purpose panel household survey, which follows households over time. We use two different variables to measure the use of public health care services: whether the respondent had a NHS-funded consultation with a hospital consultant as outpatient, and whether the respondent had a NHS funded hospitalization. There is no information on the specific cause of the hospitalization or the consultation, except for whether the hospitalization was for childbirth.

We build our severity proxy using an index built using responses to 14 specified health problems (diabetes, cancer, stroke, digestive problems, heart and circulation problems,...). Co-morbidities indexes are routinely used for clinical prognosis research because co-morbidities can worsen a wide range of illnesses faced by patients (Austin et al. 2015, Lieffers et al. 2011, Lix et al. 2011), and they have shown to be positively correlated with illness severity measures (Gross et al., 1999, Christensen et al., 2011).

Using non-parametric plots, we consistently find a U-shape pattern between either of our two measures of health care use (NHS hospitalization, and NHS outpatient consultation) and our illness severity proxy. The U-shape pattern is confirmed using parametric Probit models, which allow us to control for other variables.

Broadly speaking, our paper contributes to the literature on the interaction between public and private sectors within an NHS (see the surveys by Barros and Siciliani, 2011; Goulao and Pereleman, 2014; Hurley and Johnson, 2014), but it does so at the point where the individual already enjoys double coverage. Hence the decision to purchase PHI has already been taken and we only consider those who do enjoy PHI and are already ill. A body of literature has studied theoretically the relation between public vs. privately funded care and illness severity, focusing on either prioritization by the public sector or risk selection by the private sector, but we are the first ones in incorporating both mechanisms in the same model. Barros and Olivella (2005) study a model of risk selection by the private sector in the presence of waiting lists in the public one, but they do not address the issue of prioritization (public services are assumed to be provided in a first-come-first-served basis). Theoretical studies that study the effects of prioritization include Goddard and Tavakoli (1994) and Dimakou, Dimakou, and Basso (2015). However, these studies do not consider risk selection by the private sector. The welfare effects of prioritization are analyzed by Gravelle and Siciliani (2008) in the context where one of the patient's characteristics determining the benefit of treatment is unobservable, but they do not address the possibility of seeking private treatment.

Empirically, an important strand of the literature has examined what factors influence the demand for PHI. The emphasis has been on waiting lists (Besley, Hall and Preston 1999, Jofre-Bonet 2000), and availability of private sector hospitals and doctors (Propper, Rees and Green 2001). On the use of private *vs.* public health care (rather than demand for PHI), the focus has been on waiting time, political ideology, dynamics of health care use, and availability of PHI (Propper 2000, Rodríguez and Stoyanova 2004). We are not aware of other empirical studies which focus on the relation between illness severity and the use of public vs. private funded care.

The rest of the paper is organized as follows. In the next section we outline the theoretical model and derive the relation between illness severity and the use of public health care. In the third section we describe the data, the empirical model, and we obtain the empirical results. The last section concludes.

2 Theory

In this section we develop a theoretical model that aims at clarifying the interaction among three forces that determine how severity affects the final allocation of individuals holding private insurance across the public and the private sectors. These forces are the costs of waiting, the possible prioritization policy implemented by the public provider, and the possible risk selection carried out by the private provider. This will allow us to predict the public/private allocation profile across severities depending on the relative strength of these three forces. Since the data allows us to discover the actual allocation of patients depending on their severity, this will allow us to infer which (combination) of these forces is actually playing a dominant role. This is important because while prioritization improves vertical equity (the patients in less severe condition subsidize, in terms of waiting time, the patients in more severe condition), risk selection fails to do so. In what follows, we start by describing the three players: the patient, a private supplier, and a public supplier (NHS).

2.1 The patient

The patient suffers pain, discomfort, and perhaps some income loss per unit of time while waiting, which depend on the severity of his condition Once the individual becomes ill, he must choose between seeking treatment at the public provider, which is free but requires waiting, and seeking treatment at the private provider, which is also costly for the patient even if he holds private insurance (as we will explain below). The trade-off between public and private costs will determine which individuals seek treatment in which sector. However, in the presence of risk selection, the private provider could avoid providing treatment to some individuals, hence we must distinguish between seeking treatment in the private sector and indeed receiving it. This will also be further discussed below.

Formally, we denote a patient's severity by s. The minimum severity is 0 and the maximum $s^{\max} > 0$.Hence, the range of s is $[0, s^{\max}]$.[5] The costs borne by the patient of receiving treatment from the private provider are denoted by p. We assume that private treatment would be received immediately, so the individual's waiting cost is in the private sector is null. Since the individual holds private insurance, p represents the deductible and/or the present discounted value of any "malus" clause. In the UK, our empirical setting, the levels of yearly deductibles are relatively small, which justifies that we assume that p does not depend on severity.[6] Our results extend to the case where p is mildly increasing in severity. In any case, p goes to the insurer, not the private provider.

[5] Assuming that zero is the lower bound on severity within patients seeking free treatment is consistent with ex-post moral hazard, according to which individuals who are completely insured against all pecuniary outlay request treatment even when it is not really needed. A lower bound for severity of $s^{\min} > 0$ would lead to some more casuistics that are not essential for the main message of our work.

[6] At the time of writing, the largest private health insurer only offered through their website yearly deductibles in the [£0, £500] range, with £1000 and £2000 only available over the phone. Similarly, the online offer of the second largest insurer was restricted to [£0, £500], with larger deductibles only available over the phone and only together with other coverage restrictions. The third largest offers a wider choice of yearly deductible, but no larger than £5,000.

With all these assumptions in mind, the patient will seek treatment by the public provider if

$$c(t,s) \leq p. \tag{1}$$

2.2 The public provider and prioritization

The public provider's behavior is modelled in reduced-form. The waiting time allocated to the patient depends solely on his severity, that is, $t = \pi(s)$, a non- increasing function, which reflects prioritization. By replacing t by the function π in the waiting cost function, we obtain the *indirect waiting cost function (*IWCF henceforth*)*

$$\tilde{c}(s) \equiv c(\pi(s), s).$$

Simple differentiation yields the following results. First,

$$\frac{d\tilde{c}(s)}{ds} = \underbrace{\frac{\partial c}{\partial t}}_{+}\underbrace{\frac{\partial \pi}{\partial s}}_{-} + \underbrace{\frac{\partial c}{\partial s}}_{+},$$

which has ambiguous sign. Intuitively, an increase in in severity increases the waiting costs per unit of time but it also reduces the waiting time if prioritization is present.

2.3 The private provider and risk selection

Let us now focus on the private provider. Since the individual enjoys private insurance, the private provider receives a fee for service from the insurer, say $p^*(s)$, when a patient with severity s is treated. If the fee is cost-adjusted, it will be increasing in s. Of course, the costs that the private provider bears from treating a patient will also increase in severity, and we denoted these costs by $\psi(s)$. We assume that ψ is (weakly) convex whereas p^* is (weakly) concave, which reflects the possibility that cost-adjustment may not be perfect, although we do assume that $\psi(0) = 0$, whereas $p^*(0) > 0$, so the incentives for risk selection disappear at the lowest end of severities. In other words, it could be the case that $\psi(s) > p^*(s)$ for some s, that is, that the private provider may have an incentive to engage into risk selection by avoiding individuals with such severities. However, and also because the individual holds private insurance, he should be treated no matter what his severity is. Therefore, one thing is to say that the private provider has incentives to select patients and another thing is that the private provider acts on these incentives. In any case, as for the existence of incentives for risk selection, notice that the assumptions made on the functions ψ and p^* ensure that only two mutually exclusive cases are possible:

(a) p^* and ψ cross exactly once in $(0, s^{\max}]$ say at s^c, and that $p^*(s) < \psi(s)$ for all $s \in (0, s^{\max}]$, so the private provider has incentives to avoid patients with severities in this interval.

(b) p^* and ψ do not cross at all in $(0, s^{\max}]$, so there are no incentives for risk selection.

2.4 Final allocation

In order to determine the final allocation of patients across sectors, not only we need to compare the IWCF with p, but also take into account the possibility that the private provider engage into risk selection. However, we have already seen that not even the sign of the partial derivative of the IWCF with respect to severity can be established in general. We therefore break the analysis in two parts: the case without prioritization and the case with prioritization. We start with the former, which it is simpler.

2.5 No prioritization

Now $\pi = t_0$ (constant) and $\frac{d\tilde{c}(s)}{ds} > 0$. Hence the more severe the patient is, the more likely he is to seek private treatment. This leads to the following Lemma:

Lemma 1 *Suppose that $\pi = t_0$ and assume that $c(t_0, 0) < p < c(t_0, s^{\max})$, then there exists $\tilde{s} \in [0, s^{\max}]$ such that $c(t_0, \tilde{s}) \equiv p$ and that all patients with $0 < s < \tilde{s}$ seek public treatment.*

Proof. This is a direct consequence of $\frac{d\tilde{c}(s)}{\partial s} > 0$. ■

In the next proposition, we combine this lemma on patients' choice with the possibility of risk selection discussed above. This gives us the final allocation of patients across sectors.

Proposition 2 *Suppose that $\pi(s) = t_0$.*
Scenario 1: the private provider either does not have an incentive to engage into risk selection (case (b) above) or even if it does have this incentive (case (a) above), it refrains from acting on it. Then, all individuals with s in the interval $[0, \tilde{s}]$ seek and receive public treatment and all individuals with s in the interval $(\tilde{s}, s^{\max}]$ seek and receive private treatment.
Scenario 2: the private provider has an incentive to avoid patients with severity $s \in (s^c, s^{\max}]$ (case (a) above) and acts on it. Suppose also that $\tilde{s} < s^c$. Then
(i) (Mildest condition patients) For all s in $[0, \tilde{s}]$, the patient with such severity is treated in the public sector;
(ii) (Intermediate condition patients) For all $s \in (\tilde{s}, s^c)$, the patient with such severity requests treatment in the private sector and is not rejected;

(iii) (Patients in most severe condition) For all $s \in [s^c, s^{\max}]$, the patient with such severity requests treatment in the private sector but is rejected.
Scenario 3: As in the previous scenario but $\tilde{s} \geq s^c$. In this case the private sector is inactive since all individuals who would seek treatment there wold be rejected.

Proof. The conclusion follows directly from the previous discussion and lemma. ■

Notice this proposition predicts a U-shaped relationship between the use of public treatment and severity only if the private provider is active but engages into risk selection. Otherwise, this relationship will be decreasing.

We now turn to the more complex case, where prioritization of the more severe cases exists.

2.6 Prioritization is in place

As mentioned above, a full characterization is impossible at this degree of generality. Therefore, we answer this question for particular functional forms for the prioritization policy and for the *direct* waiting cost function. These functional forms capture all the effects at play.

Even with particular functional forms, multiple cases can arise. Let us advance our results in words first. Two main cases are possible: either prioritization is intense (Case 1 henceforth), or prioritization is mild or absent (Case 2). In the first case, the IWCF becomes inverse-U-shaped, and this allows, for an intermediate values of p, that a U-shaped relationship between severity and public use arises, *even in the absence of risk selection.* Namely, the IWCF lies below p for both the individuals in mildest condition and for the individuals in most severe condition. Intuitively, starting with the individuals in severe condition, the fact that prioritization is intense implies that their waiting time is decreased enough to compensate their high pain and discomfort per unit of waiting time. As for patients in mildest condition, despite the fact that prioritization is intense (so these individuals suffer quite a strong de-prioritization), their willingness to wait is high because their severity is small.[7] We again remark that the U-shaped relationship holds even in the absence of risk selection by the private provider. It is in this sense that we state that risk selection by the private provider and (intense) prioritization in the public provider are observationally equivalent. Indeed, the U-shaped relationship between severity and public use arises both under risk selection and no prioritization (Proposition 2) and under (strong) prioritization and no risk selection. In the second case (prioritization is mild or absent) the IWCF is always increasing, which leads to the same results as in Proposition 2. Notice that this is unsurprising given the continuity of all our functional forms.

Formally, we propose the following functional forms. If the patient waits t units of time, let total waiting costs be given by

$$c(t, s) = \delta t s, \tag{2}$$

where $\delta > 0$ is the marginal disutility of severity per unit of waiting time. As for waiting time, we assume the following functional form:

$$t = t_0 + \gamma \left(s^{BASE} - s\right), \tag{3}$$

where t_0 is the base waiting time that a patient that is neither prioritized nor

[7] As mentioned in a previous footnote, this prediction for the individuals in mild condition is reinforced if the decrease in waiting time enjoyed by the individuals in most severe condition is accomplished trough devoting additional resources.

de-prioritized bears. This base waiting time is augmented or diminished by a severity component (prioritization) given by $\gamma\left(s^{BASE}-s\right)$, where s^{BASE} as the severity level for which prioritization does not have any effect and is given by

$$s^{BASE}=\frac{s^{\max}}{2}, \tag{4}$$

where γ represents how intense prioritization is. Hence, if someone is prioritized, someone else must be de-preoritized. Waiting time is above (below) the base waiting time if severity is below (above) s^{BASE}, reflecting de-prioritization (prioritization).

As a technical aside, waiting time cannot be negative, so it must be true that $t_0+\gamma\left(s^{BASE}-s\right)\geq 0$ for every $s\in[0,s^{\max}]$ This expression is minimized at $s=s^{\max}$, so it necessary and sufficient to impose that it is satisfied at $s=s^{\max}$. Recalling the definition of s^{BASE} given in (4),this leads to the following definition.

Definition 1 *The maximum admissible prioritization* γ is given by

$$\frac{2t_0}{s^{\max}}\equiv\gamma^{\max}$$

Notice that waiting time for the individual with $s=s^{\max}$ is zero if $\gamma=\gamma^{\max}$ and that $\gamma\leq\gamma^{\max}$ guarantees that $\tilde{c}\left(s\right)$ is always positive. Substituting (3) into (2) yields our IWCF, which can be rewritten as

$$\tilde{c}\left(s\right)=\delta s\left(t_0+\gamma\left(s^{BASE}-s\right)\right).$$

2.6.1 The shape of the IWCF

We characterization the shape of he IWCF in next proposition. In a subsequent subsection we introduce the patient's cost of using the private provider (p) and derive the configuration of usage across sectors.

Proposition 3 *There exists a threshold for* γ*, given by* $\underline{\gamma}^{s^* \leq s^{\max}} = \frac{2}{3} \frac{t_0}{s^{\max}}$*, with* $\underline{\gamma}^{s^* \leq s^{\max}} < \gamma^{\max}$*, such that:*
Case 1 (U-shaped IWCF). The IWCF is inverse-U shaped in its domain $[0, s^{\max}]$ *if and only if* $\gamma \geq \underline{\gamma}^{s^* \leq s^{\max}}$*.*
Case 2 (Increasing IWCF). The IWCF is increasing for all $s \in [0, s^{\max}]$ *if and only if* $0 \leq \gamma < \underline{\gamma}^{s^* \leq s^{\max}}$*.*

Proof. See the Appendix. ■

This formalizes the intuitive arguments given above. We provide a numerical example next.

Numerical example

Suppose $s^{\max} = 1$, $\delta = 1$, and $t_0 = 3$ months, so that $\gamma^{\max} = 6$ and $\underline{\gamma}^{s^* \leq s^{\max}} = 2$. Then, for $\gamma \in \left[\underline{\gamma}^{s^* \leq s^{\max}}, \gamma^{\max}\right] = [2, 6]$ (Case 1) the IWCF is inverse-U shaped whereas for $\gamma \in [0, \underline{\gamma}^{s^* \leq s^{\max}}) = [0, 2)$ the IWCF is increasing.

2.6.2 Who *seeks* which provider?

We now bring in the patient's cost of using the private provider p to derive the intervals of severities seeking treatment in each sector. The patient compares the cost p of attending the private provider with the waiting cost of attending the public provider.

In Case 1 (U-shaped IWCF), i.e., for $\gamma \geq \underline{\gamma}^{s^* \leq s^{\max}}$, the private provider is only viable if $p < \tilde{c}(s^*)$. We then have two sub-cases.

In subcase 1.1, If p is still relatively high, namely $p \in (\tilde{c}(s^{\max}), \tilde{c}(s^*))$, we obtain two cutoff values for severity, $0 < s_0 < s_1 < s^{\max}$ where $\tilde{c}(s_0) = \tilde{c}(s_1) = p$ and the profile (from less to more severity) is:

a) Seek treatment in the public sector if $s \in [0, s_0]$,

b) Seek treatment in the private sector if $s \in (s_0, s_1)$,

c) Seek treatment in the public sector if $s \in [s_1, s^{\max}]$.

This is illustrated in Figure 1 below, drawn for the same parameter values used in the previous numerical example and where we let $\gamma = 4 < 6 = \gamma^{s^* \leq s^{\max}}$ (which leads to a IWCF given by $\tilde{c}(s) = 5s - 4s^2$). The private cost is set at $p' = 1.3$.

In subcase 1.2, p is low, namely, $0 \leq p < \tilde{c}(s^{\max})$, and we obtain a single cutoff value for severity, say $s^* \in (0, s^{\max})$, where $\tilde{c}(s^*) = p$ and we have the profile:

a) Seek treatment in the public sector if $s \in [0, s^*]$,

b) Seek treatment in the private sector if $s \in (s^*, s^{\max}]$.

This is also illustrated in Figure 1, where this time we set the private cost at $p'' = 0.75$.

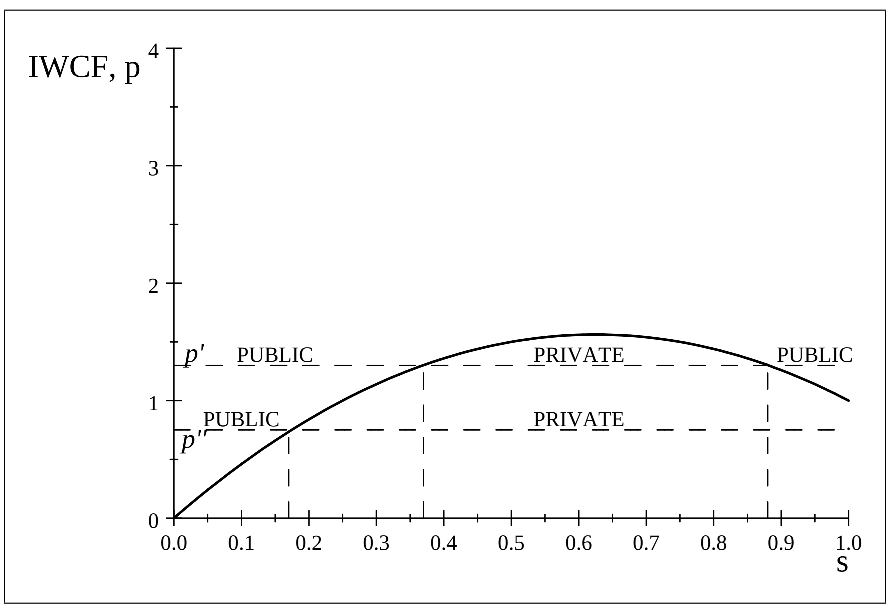

Figure 1. The IWCF in Case 1, with $s^{\max} = 1$, $\delta = 1$, and $t_0 = 3$ months; and

$\gamma = 4 \in \left[\underline{\gamma}^{s^* \leq s^{\max}}, \gamma^{\max}\right] = [2, 6]$. Choice of sector where to seek treatment when $p = p' = 1.3$ (subcase 1,1) and choice of sector when $p = p'' = 0.75$ (subcase 1.2)

In Case 2 (increasing IWCF), i.e., for $0 \leq \gamma < \gamma^{s^* \leq s^{\max}}$, the private provider is only active if $p \leq \tilde{c}(s^{\max})$ and in this case we obtain a single cutoff and the same profile as in the previous subcase. This is illustrated in Figure 2 below, where we let $\gamma = 1$ (which leads to a IWCF given by $\tilde{c}(s) = \frac{7}{2}s - s^2$ and $\tilde{c}(s^{\max}) = \frac{7}{2} - 1 = 2.5$) and $p = 2$.

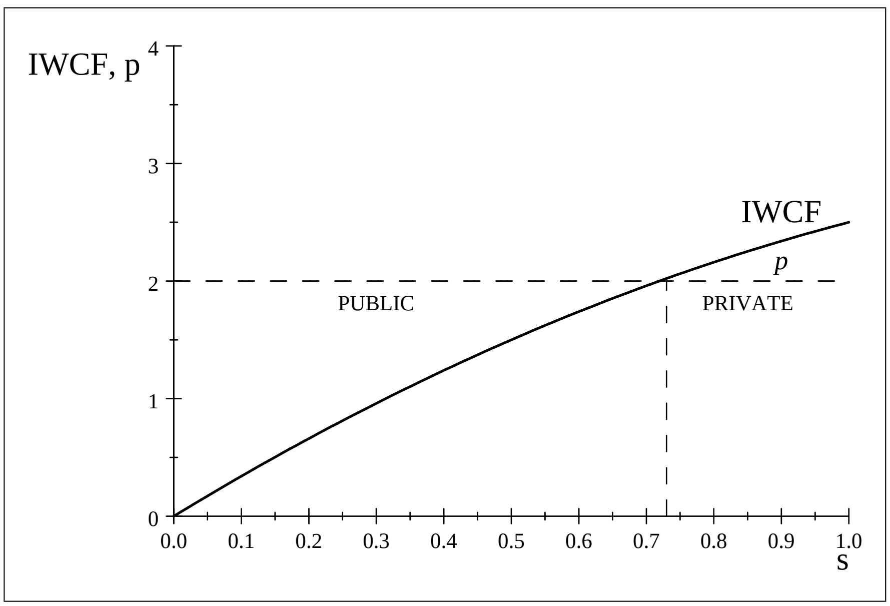

Figure 2. The IWCF in Case 2, with $s^{\max} = 1$, $\delta = 1$, and $t_0 = 3$ months and $\gamma = 1 \in \left[0, \underline{\gamma}^{s^* \leq s^{\max}}\right] = [0, 2]$; and the choice of sector where to seek treatment when $p = p' = 2$.

2.6.3 Who is allocated to which provider?

In the previous analysis we were able to predict in what sector would individuals with different degrees of severity *seek* treatment. Of course, if the private provider either does not have an incentive to select risks or, if even when it does, it does not act on this incentive, seeking treatment in a given sector is equivalent to receiving treatment in that sector. In that case we obtain the same allocation as the one describes in subsection 2.4.2.

What if the private provider does engage into risk selection? This, as we have seen, requires that the conditions discussed in case (b) in subsection 2.2 hold. Namely, there must exist a critical severity level s^c such that the private provider has an incentive to reject patients with severities on or above this threshold. If the private provider does indeed act on this incentive then several cases may arise.

Take first subcase 1.1 above, where only patients with $s \in (s_0, s_1)$ seek private treatment. If $s^c \leq s_0$ the private provider becomes inactive. If $s^c \in (s_0, s_1)$ then we obtain a U-shaped relationship between usage and public use:

a) Receive treatment from the public provider if $s \in [0, s_0]$,

b) Receive treatment from the private provider if $s \in (s_0, s^c)$,

c) Receive treatment from the public provider if $s \in [s^c, s^{\max}]$.

Finally, if $s^c > s_1$ then risk selection becomes irrelevant since the patients that would be rejected in the private sector would not seek treatment there in the first place.

Take now either subcase 1.2 or Case 2, where only patients with $s \in (s^*, s^{\max}]$ seek treatment in the private sector. If $s^c \leq s^*$ the private provider becomes inactive. If $s^c \in (s^*, s^{\max}]$ then we again obtain a U-shaped relationship between usage and public use:

a) Receive treatment from the public provider if $s \in [0, s^*]$,

b) Receive treatment from the private provider if $s \in (s^*, s^c)$,

c) Receive treatment from the public provider if $s \in [s^c, s^{\max}]$.

2.6.4 Summary

The predictions of the model depend on the patients' level of severity. Patients in the mildest condition are willing to wait since their cost of waiting per unit of time is small. Hence, they will demand (and obtain) NHS services. This will lead to a decreasing relationship between severity and the use of public services at low levels of severity.

As for individuals in most severe condition, we need to distinguish between two scenarios. In the first scenario, prioritization is strong and individuals in most severe condition do not suffer long waits and this compensates the fact that their cost of waiting per unit of time is large. These individuals demand and obtain services from the public sector. Therefore a U-shaped relationship between public usage and severity arises. This is true even in the absence of risk selection by the private sector.

In the second scenario, prioritization is absent or very mild, in which case individuals in most severe condition will demand private services. Within this scenario, we have two cases: in the first case, the private sector does not engage into risk selection and therefore these individuals are treated in the private sector. The relationship between public use and severity is decreasing. In the second case, the private sector does engage into risk selection and these individuals are finally treated in the public sector. Here we recover the U-shaped relationship that obtained above.

These results lead us to two important corollaries. First, if one observed a decreasing relationship between public use and severity, then there cannot be risk selection by the private sector (obviously) nor prioritization can be too strong. Second, if one observed a U-shaped relationship, this is consistent with both risk selection and strong prioritization. This last result can be summarized as "risk selection and strong prioritization are observationally equivalent".

3 Empirical Application: the NHS in the UK

In the previous section, we have shown that even a simple economic model cannot generate an unambiguous relation between illness severity and the use of public health care. The relation ultimately depends on assumptions about the actions taken by the private health providers, the prioritization policy in place in the public sector, as well as how the waiting cost per unit of time increases with illness severity. This makes the empirical analysis necessary to determine the nature of the relationship under scrutiny. We focus on the UK and estimate the relation between health status and use of public health care using the British Household Panel Survey

3.1 Institutional Setting

In the UK, the National Health Service (NHS) provides comprehensive health coverage to all citizens and is funded through general taxation and compulsory social security contributions. NHS funded care (doctor visits, hospitalizations, diagnosis, etc.) is free at the point of consumption, except for prescription drugs and dental care, for which there are copayments.

Despite the comprehensive coverage provided by the NHS, a share of the population has private health insurance (PHI), which provides access to medical treatment without putting up with long waiting lists, choice of consultant, and provides better hotel services (individual rooms in hospitals,. . .). Individuals with PHI can still access NHS funded treatment, and do not get any tax rebate for using PHI providers.

3.2 Data

We use the British Household Panel Survey (BHPS), a multi-purpose panel household survey, which follows households over time even if they split. All adult household members are interviewed. We restrict the sample to waves 6 to 18 (1996-2008) because they are the ones that include questions on PHI. We only include in the sample individuals with PHI. This is because it is uncommon for those without PHI to use private health care as they have to pay the full cost out-of-pocket, and it is quite expensive.

We use two different variables to measure the use of public health care services: whether the respondent had a NHS funded consultation with a hospital consultant as outpatient, and whether the respondent had a NHS funded hospitalization. There is no information on the specific cause of the hospitalization or the consultation, except for whether the hospitalization was for childbirth. Because PHI does not cover maternity services, we exclude women from the analysis of hospitalizations if they have had a childbirth-related hospitalization in the relevant time period. Table 1 reports sample descriptive statistics.

3.2.1 Severity measure

Indexes based on co-morbidities (diabetes, cancer, stroke, heart and circulation problems, etc.), such as the Charlson Comorbidity Index (Charlson et al ,1987, Deyo et al., 1992) and the Elixhauser score (Elixhauser et al.,1998, van Walraven et al., 2009) are routinely used in clinical prognosis research (Austin et al., 2015, Lieffers et al., 2011, Lix et al., 2011). Co-morbidities indexes have shown to be positively correlated with illness severity measures

(Gross et al., 1999, Christensen et al., 2011) possibly because co-morbidities can worsen a wide range of illnesses faced by patients. Hence, we will rely on the information on co-morbidities collected in the BHPS to build a proxy for illness severity.

In particular, the BHPS asks whether respondents suffer from 14 different and pre-specified health and disability problems (diabetes, cancer, stroke, disability in the limbs, difficulty hearing, digestive problems, heart and circulation problems, etc.) as well as an "other" category. To proxy for illness severity, we will consider two different measures: one is the simple count of the number of health problems that the individual reports to suffer from. The second measure is an index which weights each health problem differently. To compute the weights, we estimate an ordered probit regression of self-assessed health (SAH) (5 categories) over health problem dummies and age, and use the coefficients on the health problem dummies as weights. We re-scale the index between 0 and 1 to ease comparisons.[8] Figure 3 plots the density of the co-morbidity index.

[8]Doiron and Kettlewell (2018) also use SAH as explanatory variables for public versus private usage but the aim of the paper is different (detecting moral hazard). They find that SAH = poor raises usage by 18.3 ppts. However, the increase is 7.6 ppts as for private usage whereas it is 10.7 ppts for public usage. These results are consistent with the increasing part of our U-shape.

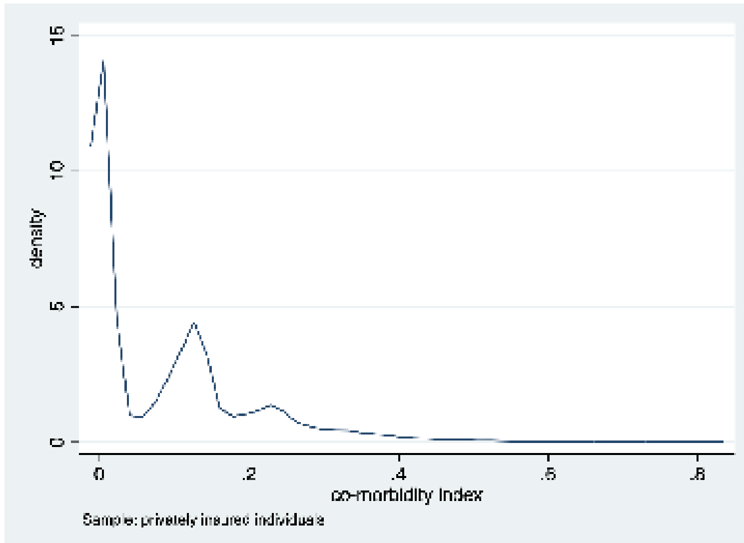

Figure 3: Density of the co-morbidity index.

3.3 Empirical model

To describe the relation between our proxy for illness severity and the use of publicly-funded care, we use the following Probit regression:

$$E[y|Severity, X] = \Phi(\alpha_0 + \alpha_1(Severity) + \alpha_2(Severity)^2 + ... \alpha_P(Severity)^P + \beta X), \tag{5}$$

where y takes value 1 if the use of health care was entirely NHS funded, and 0 if it was partially or fully privately funded and $\Phi(\cdot)$ is the cumulative distribution function of the standardized Normal distribution.

The model includes a polynomial of order P in our severity *proxy* index (Severity). X is a vector of covariates that includes gender, cohabitation status, a quadratic polynomial in age, region dummies, wave dummies, and a cubic polynomial in the duration of the period in which the health care use is measured.[9] Depending on the specification, we also control for education

[9]At the time of the annual interview, which takes place between September of year

dummies and the log of household income. Our parameters of interest are α_1, $\alpha_2, ...\alpha_P$, which describe the relation between illness severity and the use of publicly funded health care.

3.3.1 Descriptive analysis

Figure 4 plot$s$ the share of observations in which health care was fully publicly funded against our proxy for illness severity. For both measures of health care (hospitalizations and outpatient consultations), the figures show a clear U-shaped pattern between our proxy for illness severity and the percentage of observations whose health care was publicly funded. Figure 5 shows the same U-shape patterns, but directly using the number of co-morbidities that the individual suffers instead of the illness severity index that we used for Figure 4.

t and March of year t+1, respondents are asked whether they used health care services between September of year t-1 and the time of the interview. This means that the time period that is relevant for the use of health care can vary between 12 and 18 months, depending on whether they were interviewed in September or March. We control for this differential time of exposure in our empirical analysis.

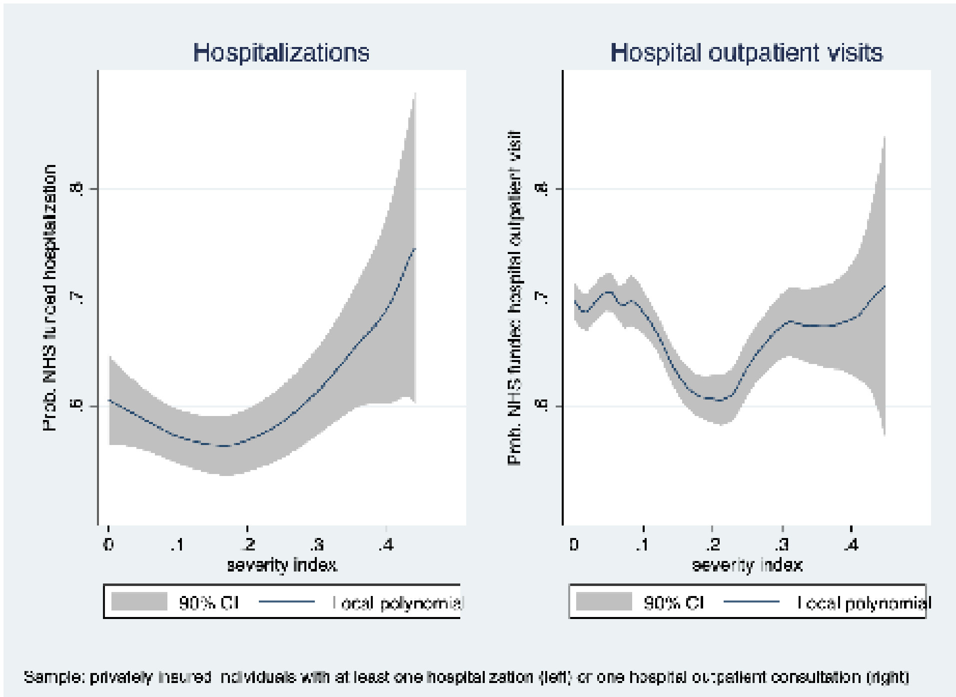

Figure 4: Severity and Use of NHS Services

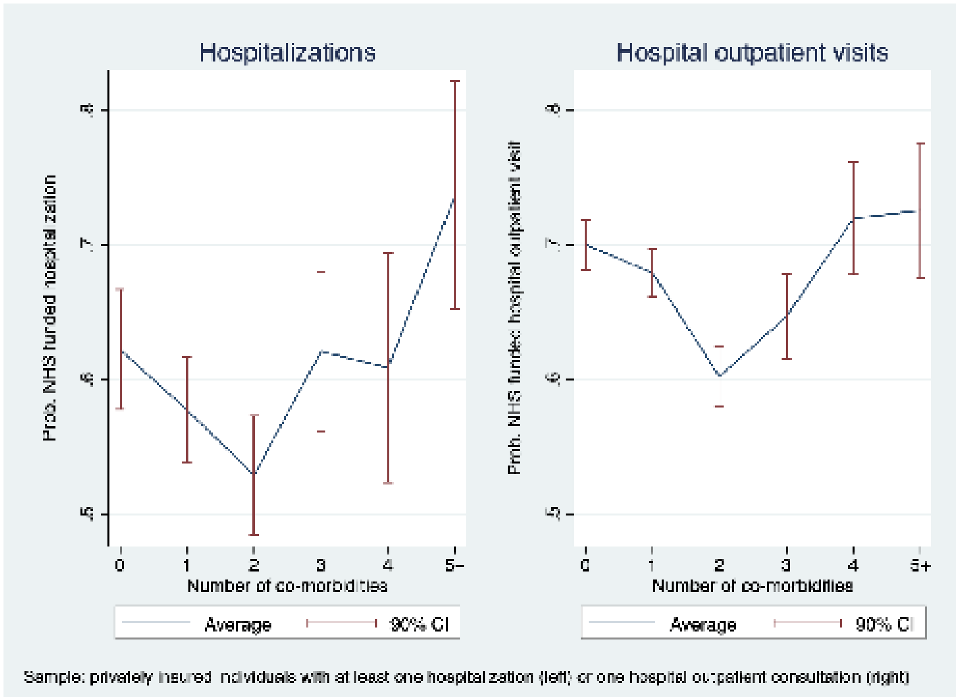

Figure 5: Number of Co-morbidities and Use of NHS Services

3.4 Regression Results

Table 2 reports the results of estimates of the Probit model described in (5), in which the dependent variable takes value 1 if the individual's hospital outpatient visits were funded by NHS, and 0 if they were funded privately or mixed. The coefficients of the polynomials in columns (1)-(3) clearly show a U-shape pattern between illness severity and the probability of publicly funded care, irrespective of whether we control for education and income. Indeed, the minimum of the U-shape is very similar independently of the covariates included in the model. Columns (4) and (5) show that when we add cubic and quartic polynomial terms, they are not statistically significant, indicating that the quadratic polynomial is enough to represent the relationship between our proxy for illness severity and the probability of NHS funded outpatient visits (as expected from Figure 4 and 5). Table 3 reports the results for hospitalizations instead of hospital outpatient visits, and also finds a U-shape pattern, irrespective of whether we control for education and income or not, with the minimum of the U-shape being very similar across specifications.

Empirically, we find a U-shape pattern between the probability of using NHS services and our proxy for illness severity. At the lower end of severity, our empirical results confirm the prediction of the theoretical model, that the probability of using NHS services decreases with illness severity. The empirical findings are even more informative at the higher end of severity, as the prediction of the theoretical model was ambiguous, depending on the extent of risk selection and strength of prioritization.

4 Conclusions

In a mixed public-private health care system as the UK, privately insured individuals cannot opt out of public coverage, and they can still use publicly-funded care. Whether these individuals with double coverage give support to tax increases and higher quality publicly-funded care might depend on the extent to which they use NHS services, and for what levels of severity. We combine a theoretical model which considers the interaction of waiting time, prioritization, and risk selection with empirical analysis based on the British Household Panel Survey to shed light on the pattern between public/private health care use and illness severity by those with double coverage.

We find that the probability of using NHS services follows a U-shape with respect to our proxy for illness severity. At low severity levels, the empirical findings match the prediction of the theoretical model. The empirical findings are most useful at high severity levels, where the theoretical model does not have a tight prediction, although it clarifies that our empirical finding might be due to significant prioritization by the public sector, risk selection by the private sector, or both (observational equivalence). In other words, both risk selection by private providers and significant prioritization by the NHS would lead to the probability of NHS services increasing with severity at high severity levels, which is what we find in our empirical analysis.

Overall, our results indicate that in a mixed public-private system as the UK, privately insured patients still obtain care from NHS services, and particularly so at high levels of severity. One would expect that this is reflected on their support to quality improvements in the NHS.

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6 Appendix: Analysis of the indirect waiting cot function (IWCF)

The IWCF is given by

$$\tilde{c}(s) = \delta s \left(t_0 + \gamma \left(s^{BASE} - s\right)\right) = \left(\delta t_0 + \delta\gamma s^{BASE}\right) s - \delta\gamma s^2.$$

where $s^{BASE} = \frac{s^{\max}}{2}$. Obviously, $\tilde{c}(0) = 0$.

Since the term with s^2 in $\tilde{c}(s)$ has a negative coefficient, we have an Inverse-U-shaped parabola in the real line. The maximum is at $\frac{d\tilde{c}(s)}{ds} = 0$, or

$$s^* = \frac{t_0 + \gamma s^{BASE}}{2\gamma}. \tag{6}$$

Lemma 4 *s^* is positive and decreasing in γ*

Proof. By inspection. ■

Case 1 (U-shaped IWCF)

To ensure that the IWCF is inverse-U shaped in its domain $[0, s^{\max}]$, which allows for the U-shaped relationship between s and public use even in the absence of risk selection in the private provider, we need that s^* be (weakly) to the left of $s^{\max}$. This is so if and only if[10]

$$\gamma \geq \frac{2}{3}\frac{t_0}{s^{\max}} \equiv \underline{\gamma}^{s^* \leq s^{\max}}$$

This is compatible with $\gamma \leq \gamma^{\max}$. Indeed, $\gamma \leq \gamma^{\max}$ can be rewritten as $\frac{2}{3}\frac{t_0}{s^{\max}} \leq \frac{2t_0}{s^{\max}}$,or $s^{\max} < 3s^{\max}$, which is true.

Case 2 (Increasing IWCF)

If $\gamma < \underline{\gamma}^{s^* \leq s^{\max}}$, then $s^* > s^{\max}$ and the IWCF is increasing for all $s \in [0, s^{\max}]$.

The IWCF at the severity limits

We now evaluate and compare the values of the indirect waiting cost function at the extreme severities. Recall that $c(0) = 0$. Now $\tilde{c}(s^{\max}) = \left(\delta t_0 + \delta\gamma\frac{s^{\max}}{2}\right)s^{\max} - \delta\gamma\left(s^{\max}\right)^2 =$

$\delta t_0 s^{\max} - \delta\gamma\frac{(s^{\max})^2}{2}$. Hence $\tilde{c}(s^{\max}) > \tilde{c}(0) = 0$ if and only if $\delta t_0 s^{\max} > \delta\gamma\frac{(s^{\max})^2}{2}$ or $\gamma < \frac{2t_0}{s^{\max}} = \gamma^{\max}$. Notice also that $\frac{\partial\tilde{c}(s^{\max})}{\partial\gamma} = -\delta\frac{(s^{\max})^2}{2} < 0$,

[10] The inequality can be rewritten as $\frac{t_0+\gamma s^{BASE}}{2\gamma} \leq s^{\max}$. Substitute s^{BASE} by $\frac{s^{\max}}{2}$ and solve for γ.

that is, as prioritization becomes more intense, waiting cost at the maximum severity decreases.

Table 1. Descriptive statistics.

Description	Number	Average	Standard Deviation
Dependent variables			
1 if outpatient hospital consultation was funded by the NHS, 0 if they were partially or fully privately funded	6039	0.67	0.47
1 if hospitalizations were funded by the NHS, 0 if they were partially or fully privately funded	1452	0.59	0.49
Covariates			
1 if Female, 0 if male	6239	0.55	0.5
Age (years)	6239	47.8	16.1
1 if no qualification or still in school, 0 otherwise	6198	0.1	0.3
1 if Compulsory Secondary Education, Commercial Qualification, or other qualification, 0 otherwise	6198	0.06	0.23
1 if General Certificate of Education (O-levels) or Appenticeship, 0 otherwise	6198	0.17	0.37
1 if General Certificate of Education (A-levels), 0 otherwise	6198	0.12	0.33
1 if Degree, Nursing, Teaching or Other Higher qualification, 0 otherwise	6198	0.51	0.5
1 if Higher degree (MSc, PhD, etc.), 0 otherwise	6198	0.04	0.19
1 if married or cohabitating	6238	0.7	0.46
LN(household income in 2008 £ / 100,000)	6219	-0.96	0.69

Note: sample includes individuals with private health insurance in the previous wave, who either had at least one hospitalization or one hospital outpatient consultation.

Table 2. Probabiilty of NHS funded outpatient visit. Probit coefficients

	(1)	(2)	(3)	(4)	(5)
co-morbidity index	-0.986**	-1.079***	-1.124***	-1.349**	-0.596
	[0.392]	[0.396]	[0.400]	[0.638]	[1.068]
(co-morbidity index)^2	2.154***	2.234***	2.057**	3.271	-3.695
	[0.813]	[0.825]	[0.826]	[2.756]	[8.060]
(co-morbidity index)^3				-1.453	17.244
				[3.060]	[19.640]
(co-morbidity index)^4					-14.646
					[14.209]
Contros for Education	N	Y	Y	Y	Y
Controls for Income	N	N	Y	Y	Y
Observations	6,038	6,001	5,982	5,982	5,982
Minimum U shape	0.229	0.241	0.273		
Average dep. vble	0.668	0.668	0.667	0.667	0.667

Note: Sample includes individual with private health insurance in the previous wave, who had at least one hospital outpatient visit. Dependent variable takes value 1 if the hospital outpatient visits were funded by the NHS, and 0 if they were partially or fully privately funded. Standard errors clustered at the individual level. *** p<0.01, ** p<0.05, * p<0.1.

Table 3. Probabiilty of NHS funded hospitalizations. Probit coefficients

	(1)	(2)	(3)	(4)	(5)
co-morbidity index	-0.708	-0.893	-1.088	-0.923	-2.157
	[0.685]	[0.687]	[0.704]	[1.215]	[2.041]
(co-morbidity index)^2	2.960**	3.314**	3.269**	2.408	13.911
	[1.330]	[1.314]	[1.347]	[5.145]	[15.347]
(co-morbidity index)^3				1.028	-30.612
				[5.715]	[38.617]
(co-morbidity index)^4					25.759
					[30.107]
Contros for Education	N	Y	Y	Y	Y
Controls for Income	N	N	Y	Y	Y
Observations	1,452	1,443	1,437	1,437	1,437
Minimum U shape	0.120	0.135	0.166		
Average dep. vble	0.592	0.590	0.589	0.589	0.589

Note: Sample includes individual with private health insurance in the previous wave, who had at least one hospitalization. Dependent variable takes value 1 if the hospitalizations were funded by the NHS, and 0 if they were partially or fully privately funded. Standard errors clustered at the individual level. *** p<0.01, ** p<0.05, * p<0.1.