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Eleonora Fichera
James Banks
Matt Sutton

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School of Social Sciences
The University of Manchester
Manchester M13 9PL

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Abstract

The joint-production of health by patients and doctors can be conceptualised as a double moral hazard problem as the efforts of each party are at least partially hidden from the other. As a result, levels of investment in health will depend on whether patient and doctor inputs are strategic substitutes or complements. We use data on the physical activity, drinking and smoking behaviours of over 2,000 individuals aged over 50 with cardiovascular diseases in England. Through a new data linkage and a first-differenced control function regression, we relate changes in these behaviours to the changes in treatment efforts of their primary care providers generated by changes in their payment system between 2004 and 2006. Practices increased the proportion of patients with controlled disease from 76% to 83% in response to the payment change. Patients responded by reducing the frequency of drinking alcohol and their cigarette consumption. This suggests that patients treat their efforts as strategic complements to doctors' effort. Payers should take the doctor and patient strategic interaction into account when designing initiatives to influence doctors' efforts.

Keywords: Double moral hazard; health behaviours; doctor's effort.

JEL classification: C25, C35, D01, I12, I18

*Eleonora Fichera and Matt Sutton are at the Manchester Centre for Health Economics, University of Manchester. James Banks is at the Institute for Fiscal Studies, London and Economics, University of Manchester. Correspondence: 4.320 Jean McFarlane Building, Manchester Centre for Health Economics, University of Manchester. Oxford Road M13 9PL Manchester. Phone: +44 (0)161 275 5204. Email: eleonora.fichera@manchester.ac.uk.
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1 Introduction

Population health is influenced both by the health behaviours of individuals and by the activities of health care providers. This is particularly true of the health of individuals with long-term conditions – the harmful effects of diabetes, hypertension and heart disease, for example, can be both reduced by medical treatment and mitigated through lifestyle modification. This 'joint-production' process for health may be characterised by complex interactions between patients and their doctors and it is important to understand the precise nature of these interactions when designing incentives targeted at either of the two groups.

The doctor-patient interaction is affected by a double asymmetric information problem as patients do not know the quality of doctors' medical treatment [see for example Arrow (1963) and Richard (1996)] and doctors do not know their patients' lifestyle behaviours. Yet most of the theoretical and empirical literature in health economics still focuses on principal-agent models where (only) one party is subject to moral hazard [see for example Evans (1974) and Pauly (1968)]. Only Schneider (2004) has considered the double-moral hazard case, applying the framework of Cooper and Ross (1985) to the interaction between doctors and patients.

In this paper we modify Schneider's (2004) double-moral hazard model to allow non-linear payment schedules for doctors and to allow each agent's effort to depend on their subjective belief about its strategic relation with the other agent's effort. We then estimate this new model on UK panel data, adopting an instrumental variable strategy that exploits changes in doctors' payment incentives, in order to robustly identify the doctor and patient interaction.

We apply this model to three health behaviours and a doctor's intervention to control their patient's cardiovascular disease (CVD). As health behaviours, we consider the level of physical activity, the frequency of alcohol drinking and the consumption of cigarettes. We then test the strategic relation implied by the model using a unique dataset linking individual-level measures of the health behaviours of individuals to the average treatment activities of the family doctors with whom they are registered. We do this for a large sample of individuals diagnosed with CVD from the English Longitudinal Survey of Ageing between 2004 and 2006.

To preface our results we find that, in general, doctors compensate for their patients' unhealthy consumption of alcohol and cigarettes with more effort in controlling their CVD. However, exogenously induced increases in doctors' disease control effort are associated with improvements in patients' health behaviours, suggesting that patients perceive their efforts to be strategic complements to their doctors' efforts. This association is stronger for alcohol and cigarettes consumption which are more observable to the doctor and likely to generate the highest health benefits to the patient. As the impact is substantial, payers should consider the doctor and patient interaction when designing health care reforms if they do not want to underestimate its effects on health behaviours.

Despite the importance of doctor-patient interactions, and the apparent salience of this double moral hazard model in that framework, very few empirical studies exist on the topic. Fichera and Sutton (2011) examined the interaction between doctor's medical treatment and their patients' smoking behaviour and found that prescription of lipid-lowering drugs was associated with higher incidence of quitting smoking in patients with CVD. But their economic model did not allow for two-way strategic behaviour in the doctor-patient interaction. Furthermore, since they use pooled cross-sectional data, their identification strategy was based on an essentially untestable assumption of no direct effect of the severity of CVD on smoking behaviour. Schneider and Ulrich (2008) used two waves of the German Socio-Economic Panel Study to test the Schneider (2004) double moral hazard directly but with rather limited information on doctors' effort. They showed a positive correlation between patients' health behaviours and the number of doctor visits, and that both were influenced by the existence of health insurance.

One reason for the relative scarcity of such empirical studies is the difficulty of finding valid identification strategies and instruments that can generate exogenous variation within various elements of the health production function – in the case of Schneider and Ulrich (2008) for example, it was necessary to assume that a number of instrumental variables (specifically stress, economic worries and a regional dummy for living in East Germany) affect health behaviours but not healthcare utilisation. A second reason is a comparative lack of data with information on the behaviours of both doctors and their patients. Our paper is motivated by each of these issues. The advantage of our linkage of individual data on health behaviours to administrative data on practice-level treatment rates is that we can simultaneously address the lack of appropriate data and avoid issues of potential reverse causality between the doctor's decision to supply medical treatments and the doctor's expectation of the patient's health behaviours. Furthermore, we are able to use an Instrumental Variables framework that exploits a change in the pay-for-performance system used for General Practitioners in England between 2004 and 2006, which led them to increase their rates of disease control.

The paper is structured as follows. Section 2 gives some brief background to the double moral hazard problem and outlines our theoretical framework. The data and descriptive statistics are reported in section 3. Section 4 describes the empirical strategy and results are discussed in section 5. Section 6 concludes.

2 Theoretical framework

In order to get the basic intuition underlying the theoretical framework to be used here it is useful to briefly revisit the original papers on the Double Moral Hazard model. Cooper and Ross (1985) studied the effect of double moral hazard (DMH) on the seller-consumer interaction when the product being exchanged is covered by a warranty. Warranties may act as an incentive mechanism because sellers and consumers' actions affect the probability that the product will break down. So, sellers have to carefully choose warranties because of consumers' moral hazard, but also need warranties to signal the quality of their product. The authors study a non-cooperative game with simultaneous moves. The consumer decides how much effort to put in maintaining the warranted product, given her beliefs on the quality of the product itself. The seller, on the other hand, determines the quality of the warranted product, given her beliefs on the maintenance effort that the consumer will provide. The slopes of the reaction functions depend on the degree of complementarity or substitutability between consumer's effort and seller's quality input. When the coverage of the warranty is not complete, Cooper and Ross (1985) showed that the second-best solution under asymmetric information is inferior to the first-best one under full information when effort and quality are complements because both parties have incentives to lower the level of inputs. A similar concept has been applied to study a variety of warranty types [Emons (1989); Dybvig and Lutz (1993)], agricultural contracts [Reid (1977); Eswaran and Kotwal (1985)] and contracts provided by firms [Prendergast (1993) and Prendergast (1999); Agrawal (2002); Parsons (2011)].

Schneider (2004) characterised the doctor and patient interaction as a double moral hazard problem, arguing that neither agent could fully observe the actions taken by the other agent or verify their respective contributions based on the realised state of health. His theoretical analysis showed that this could lead to lower or higher levels of effort by both the patient and the doctor and that the consequences of interventions to influence the effort of one of the parties would depend on whether the efforts of both parties were strategic complements or strategic substitutes. He showed that asymmetric information leads to lower patient's compliance and medical effort than in a full-information solution if the two inputs are either strategic complements or independent of each other. However, if the inputs are strategic substitutes it is possible that one of the inputs is above the first best level and the other is below. The introduction of a coinsurance for the patient shifts her reaction function towards the cooperative one. In contrast to the case without coinsurance, an increase in the amount of medical services always raises patient's compliance because her effort is now relatively cheaper in comparison to the medical services.

In what follows we adapt the model of Schneider (2004) prior to estimating it using panel data on older adults in England. As the patients in our model and in our empirical application have already been diagnosed with CVD they have already made the choice of visiting the doctor. Hence we do not model the participation decision but instead consider whether and how doctors' disease control effort affects three lifestyle behaviours.

As in Schneider (2004), the patient's expected utility depends on I, her net income[1]. There are two health states, H_s, after treatment is received: either the patient is healthier, $s = 1$ or not, $s = 0$ with $H_1 > H_0$. We then depart from Schneider (2004) as we consider each agent ι (either the doctor or the patient) to have a subjective belief about the effectiveness of medical treatment and lifestyle changes on producing better health. Each agent ι believes that a better state of health, H_1, can be realised with probability $\varphi_\iota \in (0, 1)$ and a worse state, H_0, can be realised with probability $1 - \varphi_\iota$. These probabilities depend on patient's lifestyle behaviours (y) and medical services supplied by the doctor (a) with $\varphi'_{\iota y} > 0; \varphi'_{\iota a} > 0; \varphi''_{\iota y} < 0; \varphi''_{\iota a} < 0$.

The patient is risk-averse, the utility function, U, is concave and depends on income. Therefore, the expected utility can be written as:

$$EU = \varphi_\iota(y, a)U(I(H_1)) + [1 - \varphi_\iota(y, a)]U(I(H_0)) - g(y) \tag{2.1}$$

where $g(y)$ is the cost of lifestyle behaviours with $g' > 0$ and $g'' > 0$.

The doctor is assumed to be risk-neutral, and her expected utility depends on income, her "code of conduct" determined by clinical guidelines, and medical effort. In addition to a flat payment $\omega > 0$, she receives a performance payment $q(a)$ that, unlike Schneider (2004), can be a nonlinear function of her effort. The performance payment is such that $q_a > 0$ and $q_{aa} < 0$, that is, payment increases with doctor's effort

[1] We can think of income as the monetary loss of working days due to illness.

but at a decreasing rate. There is also a cost in the effort of providing medical treatment denoted by $c(a)$ with $c^{'} > 0$ and $c^{''} > 0$. The doctor's expected utility can be written as:

$$EW = [\omega + q(a)] + \alpha[\varphi_\iota H_1 + (1 - \varphi_\iota)H_0] - c(a) \tag{2.2}$$

$\alpha \in [0, 1]$ proxies the degree of doctor's "altruism" with a higher value indicating that the doctor gives a higher weight to the patient's expected health status.

Double moral hazard occurs because health outcome is determined by a joint production between doctor's medical services and patient's behaviour each of whom cannot infer the effort of the other agent from the realised state of health. The patient maximises her expected utility:

$$\max_y EU = \varphi_\iota(y, a)U_1 + [1 - \varphi_\iota(y, a)]U_0 - g(y) \tag{2.3}$$

$$\frac{\partial EU}{\partial y} \equiv \varphi_{\iota y}(U_1 - U_0) = g^{'} \tag{2.4}$$

Equation 2.4 shows that the patient chooses the level of her lifestyle behaviour at the point where the marginal utility equals the marginal cost of effort.

The doctor also maximises her utility:

$$\max_a EW = [\omega + q(a)] + \alpha[\varphi_\iota(y, a)H_1 + (1 - \varphi_\iota(y, a))H_0] - c(a) \tag{2.5}$$

$$\frac{\partial EW}{\partial a} \equiv q_a + \alpha\varphi_{\iota a}(H_1 - H_0) = c^{'} \tag{2.6}$$

Equation 2.6 shows that doctor's effort level is the one where the marginal utility of income and marginal utility of her patient's better health both equal the marginal cost of effort.

We can derive the effect of an increase in the payment for performance:

$$\frac{da}{dq} = -\frac{1}{q_{aa} + \alpha\varphi_{\iota aa}(H_1 - H_0) - c^{''}} > 0 \tag{2.7}$$

because of the second order conditions the denominator is negative. Therefore, an increase in the performance payment leads to higher effort by the doctor.

The slopes of patient and doctor's reaction functions can be derived by applying the implicit function derivation rule to Eq.2.4 and Eq.2.6, respectively:

$$\frac{dy}{da} = -\frac{\varphi_{\iota ya}(U_1 - U_0)}{\varphi_{\iota yy}(U_1 - U_0) - g''} \tag{2.8}$$

$$\frac{da}{dy} = -\frac{\alpha\varphi_{\iota ya}(H_1 - H_0)}{q_{aa} + \alpha\varphi_{\iota aa}(H_1 - H_0) - c''} \tag{2.9}$$

since the denominators of both equations are negative, the sign of the relation between patient's health behaviour and doctor's effort depends on each agent's subjective belief about the joint effectiveness of her own effort and the other agent's effort in producing a better health state, $\varphi_{\iota ya}$. Strategic complementarity (i.e. $\varphi_{\iota ya} > 0$) occurs when patients believe that their healthier lifestyles can increase the productivity of doctors' medical effort (and vice versa). Strategic substitutability (i.e. $\varphi_{\iota ya} < 0$) occurs when patients believe that better lifestyles would actually reduce the marginal productivity. Strategic independence occurs when neither of those actions affects the other (i.e. $\varphi_{\iota ya} = 0$).

Eqs.2.8 and 2.9 imply that complementarity, substitutability and independence between the agents efforts depend on their strategic relationship. As an illustrative example, imagine a patient with high cholesterol is in a doctor's consultation room. Both the doctor and the patient have to decide their actions at the same time, i.e. they do not know what the other will do. The patient will avoid eating fatty food if she thinks healthy eating can increase the productivity of lipid-lowering drugs in lowering her cholesterol levels. Alternatively, she might think that avoiding fats will have no effect or will even hinder the effectiveness of doctor's treatment. At the same time, the doctor has to decide prescription and/or the amount of lipid-lowering drugs given her belief of the strategic relation between her disease control effort and the patient's lifestyle effort.

In the empirical analysis we examine the DMH solution of the combined Eqs.2.8 and 2.9. We then use an exogenous change in the performance part of doctor's income $q(a)$ to determine the patient's side moral hazard and test in Eq.2.8 whether $\frac{\partial y}{\partial a}$ is positive, negative or equal to zero and, consequently, whether there is strategic complementarity, substitutability or independence.

3 Data and Descriptive Statistics

Examining the DMH problem requires data on both patients' and practices' behaviours. We therefore link two data sources to each other: the English Longitudinal Study of Ageing (ELSA) and the National Health Service Quality Management and Analysis System (QMAS) database. In this section we describe each data source in turn and provide some simple descriptive statistics of our sample before discussing the way in which we utilise information on doctors' payment incentives.

3.1 English Longitudinal Study of Ageing (ELSA)

The English Longitudinal Study of Ageing (ELSA) is a biannual survey and the first study of its kind in the UK to connect the full range of topics necessary to understand the economic, social, psychological and health elements of the ageing process. Our analysis uses waves 2 and 3 of ELSA corresponding to the years 2004 and 2006, respectively, because the exogenous change in doctors' remuneration occurs in this period.

ELSA is designed to be a representative sample of those aged 50 or over and living in private households in England. For the purpose of our analysis we use data from the "core" ELSA interview questionnaires on diagnosis of diseases, health behaviours, demographic characteristics, and wealth. ELSA participants were asked whether they have been diagnosed by a doctor with one of the following conditions: diabetes, high blood pressure (hypertension), angina, heart attack, heart failure, heart murmur, irregular heart rhythm and other heart problems. We choose to use this subset of conditions because they correspond to the target population for the doctors' performance payments. Participants who confirmed at least one of these conditions were classified as having CVD. We select individuals who reported CVD in the 2004 wave of ELSA so that we do not pick up case-finding due to the (reforms to the) payment system. From an initial sample of over 7,000 individuals in 2004 and over 6,000 in 2006 who can be successfully matched to their doctors (more details on the matching are described in sub-section 3.2) we obtain a sample of over 3,000 individuals with CVD who are observed both in 2004 and 2006.

We consider a number of socioeconomic characteristics such as household size, and whether the respondent is married or cohabiting as opposed to being divorced or separated, widowed or never married. We also consider whether the respondent is employed or self-employed as opposed to unemployed, disabled, looking after home or family or retired. We use total wealth as the socio-economic variable since it demonstrates a higher correlation with health than income in older populations [see Demakakos et al. (2008)]. Total (non-pension) wealth is defined as the sum of financial wealth, physical wealth (such as business wealth, land or jewellery) and housing wealth after deducting debts. This variable is measured in pounds sterling and deflated by the Consumer Price Index with 2005 as the base year.

As lifestyle behaviours we consider physical activity, smoking and drinking behaviour because they are available both in 2004 and in 2006. All lifestyle behaviours have been coded to be increasing in health effort (i.e. the number of cigarettes is coded as negative). We use a measure of physical activity derived from self-reports and categorised as follows: 1 (none) - not working or sedentary occupation, or engages in only mild exercise; 2 (low) - working in a job involves standing and/or engaging in moderate activity; 3 (moderate) - working in a job involving physical work and/or engaging in vigorous activity once a week to 1-3 times a month; 4 (high) - engaged in heavy manual work and/or doing vigorous leisure activity more than once a week. In each wave of the survey respondents are asked the number of cigarettes smoked on a weekday or weekend. We calculate a weighted average of the two to determine the average number of cigarettes smoked per day. We recode it to be negative in order to indicate a lifestyle behaviour increasing in health effort. Alcohol consumption is defined as frequency of consumption in the past year. It is categorised as follows: 1=Daily; 2=Frequently: once per week or more; 3=Rarely: once/twice per week or once every two months; 4=Never.

Table 6.1 reports descriptive statistics for 2,500 CVD patients (top panel) and 240 smokers amongst them (bottom panel). The distribution of physical activity shifts towards higher intensity from 2004 to 2006. Similarly, the proportion of people drinking either daily or frequently decreases from 2004 to 2006. There is also a reduction in the average number of cigarettes from 14 in 2004 to about 11 in 2006.

3.2 The Quality Management and Analysis System database

The data on quality of care for over 8,000 family practices in England is stored in the National Health Service Quality Management and Analysis System (QMAS) database[2]. We use this database to obtain the codes and addresses of all practices in England.

As part of the nurse visits carried out in 2004 and 2008 ELSA respondents were asked for the name and address of their GP. The initial sample of ELSA respondents for whom we had some information on the

[2]The data is freely available at: http://www.connectingforhealth.nhs.uk/systemsandservices/gpsupport/qmas.

practice they were registered with was 7,332 in 2004 and 8,138 in 2008. After a two-stage imputation process, we have successfully matched to practices about 82% and 80% of wave 2 and 4 initial ELSA respondents. Of the 9,168 individuals who did not move between waves 2 and 4 we successfully matched about 73% to practices in wave 3. The majority of these respondents have been uniquely matched to practices. However, due to incomplete postcode or address information, there were multiple potential matches for about 6% and 5% of respondents in waves 2 and 4 respectively. In this case we use information from all the potential practices, constructing a sampling weight that equals the share of registered patients (i.e. practice j's list size) that respondent ι's matched practice represents to the total list size of all the correspondent matched practices. This share is equal to one if respondent ι is uniquely matched to practice j and it is less than one if she is matched to multiple practices[3].

The geographical coverage of ELSA is quite good. ELSA contains at least one person registered with 32% and 31% of all practices in England in 2004 and 2006, respectively. Practices are grouped geographically into 151 Primary Care Trusts. ELSA contains at least one person from each of the 151 Primary Care Trusts.

Having linked ELSA respondents to their doctors' practices we are in a position to bring in information on the performance of that practice and the behaviours of the doctors within it. General practices in the UK are a group of one to six doctors responsible for a pool of patients. A substantial component (about 20%) of each doctor's income depends on the performance of the practice measured by the Quality and Outcomes Framework (QOF). The budget to finance the programme was set for three years starting from 2004 to be £1.8 billion and increased doctors' income by 25 percent [NHS Review Body (2008)]. We use QOF data at the practice level to obtain proxies for doctors' effort and to measure the exogenous change in their remuneration.

The QOF was officially introduced on 1^{st} April 2004 with measurement of performance on 1^{st} April 2005 for the previous 12 months. Practices are rewarded on the basis of performance on a number of indicators. Indicators are measured in three main areas: clinical care, practice organisation and patient experience. The points determine the amount of money in pounds sterling (£) claimed annually. The revenue the practice earns varies linearly between lower and upper thresholds of coverage, called "achievement" $A \in [0, 1]$[4]. No money is received by the practice if achievement is less than or equal to the lower threshold and the maximum

[3]Our results are unaffected by the inclusion of multiple matches. More details on the data matching process can be made available to the reader upon request.

[4]Note that practice achievement rate $A_j = Prob(a_\iota > 0)$ with a indicating the average doctor's effort to patient ι as described in section 2.

revenue is received if the practice is on or above the upper threshold [see for further details Gravelle et al. (2010); Doran et al. (2011)].

In the first year, 76 clinical indicators measured the quality of specific aspects of care for a set of 10 disease conditions. A total of 33 indicators were available for CVD making up for 40% of the 550 total points available for clinical care in the first year of the scheme[5]. We select indicators for which there was a change in the threshold levels and/or in the number of points from 2004 to 2006 and aggregate them into a Disease Control indicator. Disease Control indicates whether doctors' effort maintains cholesterol and blood pressure under the recommended levels (see Table 6.2).

Practice j's achievement on indicator i is given by $A_{ji} = \frac{N_{ji}}{D_{ji}}$ where N_{ji} is the number of patients for whom indicator i is achieved. The denominator is the number of patients with the specific disease who are eligible for the indicator. We calculate the points weighted average achievement rates for disease control in 2004 and 2006 and we report them in Table 6.3. The points weighted average achievement rates of an average practice is 76% and 83% in 2004 and 2006, respectively.

Practices are paid per point π achieved (after adjustments to patient-mix) with $\bar{\pi}$ indicating the maximum number of available points [see for example, Gravelle et al. (2010)]. Summing up all indicators in Table 6.2 a total of 50 and 52 points, respectively in 2004 and 2006, are available for Disease Control. As the national average price per point in 2004 was $\pounds 76$, increasing to $\pounds 125$ in 2005, an average practice could earn up to $\pounds 2,888$ in 2004 and up to $\pounds 5,395$ in 2006 for its effort on controlling CVD.

For our empirical strategy we need some way of codifying the effect of changes in the GP payment sytem between 2004 and 2006 on GPs incentives to carry out various treatments. In order to do this we define the "power" of the income incentive to be the difference between what practices would receive if they continued to provide the same quality in 2006 as they did in 2004 but with the new 2006 thresholds (i.e. the "counterfactual" income as a proportion of maximum available points) and what they actually received in

[5] More specifically, 15 indicators were available for Coronary Heart Diseases (CHD) with a maximum of 121 points and 18 indicators were available for diabetes with 99 points in total. Note that CVD encompasses both CHD and diabetes.

2004. After letting $\frac{\pi_{ji}^t}{\bar{\pi}_i^t} \equiv p_{ji}^t(L^t, U^t; A^t)$, it follows that:

$$p_{ji}(L^{06}, U^{06}; A^{04}) - p_{ji}(L^{04}, U^{04}; A^{04}) \equiv \frac{\pi_{ji}^{04'}}{\bar{\pi}_i^{06}} - \frac{\pi_{ji}^{04}}{\bar{\pi}_i^{04}} =$$

$$\min\left\{1, \max\left\{\frac{(A_{ji}^{04} - A_{iL}^{06})}{(A_{iU}^{06} - A_{iL}^{06})}, 0\right\}\right\} - \min\left\{1, \max\left\{\frac{(A_{ji}^{04} - A_{iL}^{04})}{(A_{iU}^{04} - A_{iL}^{04})}, 0\right\}\right\} \quad (3.1)$$

with A_{iL}^t and A_{iU}^t indicating the lower and upper threshold, respectively. Notice that $A_{iL}^{04} < A_{iL}^{06}$ and $A_{iU}^{04} < A_{iU}^{06}$ that is, thresholds increase between 2004 and 2006. After aggregating i indicators for disease control we have $P_j^t(L^t, U^t) = \frac{\sum_{i=1}^k p_{ji}^t(L^t, U^t; A^t)\pi_i^t}{\bar{\pi}^t}$ with $\bar{\pi}^t = \sum_{i=1}^k \pi_i^t$. Then the size or power of the incentive is given by $P_j^p \equiv P_j(L^{06}, U^{06}; A^{04}) - P_j(L^{04}, U^{04}; A^{04})$. The absolute value of this incentive determines the expected loss as it indicates the proportion of available payment that practice j would lose at 2006 thresholds if it kept performing in 2006 at the same level as it did in 2004. The incentive power reported in Table 6.3 is on average negative as practices expect to earn less in 2006 than in 2004 if they do not increase their performance. On average, practices would lose around 5%, and they could lose as much as 39% of the available payment if, maintaining 2004 performance in 2006 they fall short of 2006's lower payment threshold.

In order to examine the representativeness of our sample of practices, we compare the practices in ELSA to the full sample of practices in England. In Table A.1 we report the number of practices in England (left panel) and those in the ELSA sample (right panel) with an achievement rate below the lower threshold, between the lower and the upper threshold, and above the upper threshold in 2004 and in 2006. The proportion of total practices in ELSA that fall in each threshold interval is very similar to that of England. In Table A.2 we report the points weighted average achievement rates and the power of incentive of the full sample of English practices. As the mean and minimum values, and the standard deviation of the incentive power in the last row of Table 6.3 do not differ much from that in Table A.2, our sample of practices in ELSA adequately represents that of England.

4 Empirical Strategy

We relate three patients' lifestyle behaviours (intensity of physical activity, rarity of alcohol consumption and reduction of cigarettes) to a proxy of doctors' effort (disease control). Whilst models for physical activity and alcohol drinking are run on the full sample, cigarettes consumption is modelled on the sample of smokers in 2004 as very few individuals started smoking between 2004 and 2006. Lifestyle behaviours are examined separately because we found a very low correlation between changes in health behaviours between 2004 and 2006. This is not a unique feature of ELSA data as it has been found previously in the Health and Retirement Study (Cutler and Glaeser (2005)) which contains detailed information on a large representative sample of individuals aged 50 and over in the United States. We address potential reverse causality between doctor's supply of medical treatment and her expectation of patients' health behaviours in two ways. First, as practice activities are measured up to 15 months prior to their recording time, they are observed prior to the reported lifestyle behaviour. Second, we examine practice-level achievement rates rather than individual treatment.

We consider a linear model for each lifestyle behaviour in 2004 and 2006:

$$y_{\iota(j)t} = \beta_0 x_{\iota(j)t} + \gamma_0 A_{\iota(j)t} + c_{\iota(j)} + \epsilon_{\iota(j)t}$$

and we then take the first-difference between 2006 and 2004:

$$\Delta y_{\iota(j)t} = \beta_0 \Delta x_{\iota(j)t} + \gamma_0 \Delta A_{\iota(j)t} + \Delta \epsilon_{\iota(j)t} \tag{4.1}$$

where Δy indicates the difference in lifestyle behaviours between 2006 and 2004 of individual ι registered with practice j[6]. As a result, the individual time-invariant unobserved component $c_{\iota(j)}$ is differenced out. Amongst the individual effects we consider the (unobserved) propensity to engage in lifestyle behaviours.

$\Delta A_{\iota(j)t}$ indicates the change in practice j's points weighted average achievement rates for disease control between 2004 and 2006 (i.e. the change in the average doctor's effort). The coefficient γ_0 indicates the DMH solution of the reaction functions' slopes in Eqs.2.8 and 2.9 and relates to the fact that both the (average) doctor and the patient choose their actions simultaneously without being able to infer the other agent's effort from the realised state of health. For instance, the doctor may increase her effort in managing CVD because she thinks the patient puts less effort in her lifestyle behaviours; at the same time, the patient might put less

[6] We account for multiple practices matched to individuals as follows. We create a dataset with 10 random draws of practices within each stratum (i.e. an individual-wave observation) where the probability of drawing is given by the constructed sampling weights. Note that if an ELSA respondent is uniquely matched to a single practice then she will be duplicated 10 times. Then we weight the observations in the regression using the constructed sampling weights.

effort in her lifestyle behaviours precisely because she thinks the doctor will increase her effort in managing the disease. Whilst strategic complementarity occurs when the coefficient $\gamma_0 > 0$, strategic substitutability is indicated by $\gamma_0 < 0$ and strategic independence occurs when $\gamma_0 = 0$.

As additional controls we include the change in a set of individual demographic and socio-economic characteristics (Δx) such as marital status, household size, employment status and wealth.

We then use an exogenous change in the 2006 component of the QOF to decompose the DMH effort into one induced by the pay-for-performance scheme and a discretionary one. We use a two-stage residual-inclusion (2SRI) or control function (CF) approach (see Wooldridge (2010)). This approach consists of a two-stage procedure: first stage residuals are computed from a reduced form estimation of the change in the average doctor's disease control effort on the incentive power (equation 4.2) and are then inserted as additional regressor in the second stage equation of the change in lifestyle behaviours (equation 4.3).

The first stage regression of the change in the average doctor's disease control effort between 2004 and 2006 can be written as follows:

$$\Delta A_{\iota(j)t} = \zeta P^{p}_{\iota(j)t} + \lambda \Delta x_{\iota(j)t} + \Delta \eta_{\iota(j)t} \tag{4.2}$$

$P^{p}_{\iota(j)t}$, the instrument, measures the power of the incentive for disease control as defined in Eq. 3.1. We argue that this instrument is valid since, even if patients were aware of the price change (which is unlikely) they would not be aware of how the price change affected specific practices or health care indicators.

As well as the ELSA respondents' characteristics described above, vector Δx includes characteristics of practice j's patients such as the low income scheme index (LISI). LISI is a measure of practice list deprivation from prescription data. It indicates the proportion of prescription cost dispensed to people exempt from prescription charges on grounds of low income. From the first stage we predict the residual $\hat{\eta}_{\iota(j)t}$.

The second-stage consists of first differenced linear models of lifestyle behaviours as in equation 4.1, but with the inclusion of the first-stage predicted residual:

$$\Delta y_{\iota(j)t} = \beta_1 \Delta x_{\iota(j)t} + \gamma_1 \Delta A_{\iota(j)t} + \xi \hat{\eta}_{\iota(j)t} + \Delta u_{\iota(j)t} \tag{4.3}$$

$\hat{\eta}$ is the "discretionary" average doctor's effort as it indicates the average doctor's effort that is not induced by the exogenous change in her income. The slope of the patient's reaction function in Eqs.2.8 is represented by γ_1, the patient-side moral hazard (PMH) coefficient. After including the first stage regression residual, the change in effort $\Delta A_{\iota(j)t}$ is one exogenously induced by the payer. As a result, a coefficient $\gamma_1 > 0$ ($\gamma_1 < 0$) indicates that the patient complements (substitutes) higher average doctor's effort with better (worse) lifestyle behaviours.

All models have been estimated separately for all CVD patients and for those amongst them who were smoking in 2004.

5 Results

In Table 6.4 we report first differenced models of the change in lifestyle behaviours between 2004 and 2006 regressed on the changes in disease control and other socio-economic characteristics for all CVD patients (Models I-II) and the smokers amongst them (Model III). The coefficients on disease control indicate the slope of the reaction functions in Eqs.2.8 and 2.9, that is, the patient's response to the average doctor and the average doctor's response to the patient. We find weak evidence of strategic complementarity in cigarettes consumption as the average doctor's effort increases the productivity of the patient's reduced cigarettes consumption and, at the same time, the patient's lower cigarettes consumption increases the productivity of doctor's disease control effort. Although this effect is not statistically significant, the point estimates suggest that a one percentage point increase in disease control would reduce the number of cigarettes per day by almost 0.1. For an average practice increasing its rate of disease control from 76% to 83% this corresponds to about 0.7 cigarettes per day per smoker.

We then use the exogenous change in the payment system to decompose the effort level into one induced by the change in the QOF (i.e. the coefficient γ_1 indicating the PMH solution) and a discretionary one (i.e. the coefficient ξ of the first stage predicted residual)[7].

The first-stage regression in Table 6.5 reports the power of incentive to be a strong predictor of changes in the average doctor's disease control effort[8]. A one percentage point increase in the power of the incentive reduces the average doctor's effort in disease control by about 0.5 percentage points.

[7]As a robustness check we have run all the models in this section with a non-linear specification. The results are qualitatively similar and are available to the reader on request. We have chosen to display the linear specifications because the interpretation of the coefficients is more straightforward.

[8]We run a first stage regression on the sample for each lifestyle behaviour.

The second-stage regressions of each health behaviour are reported in Table 6.6, for all CVD patients (Models I-II) and the smokers amongst them (Model III)[9].

The results suggest that doctors do not make strategic decisions about their induced efforts as the relationship between their induced effort and patients' effort reveals only how patients respond to doctors, not a combination of how doctors respond to patients and patients respond to doctors. We find that patients complement a more effective average disease control effort with better lifestyle behaviours. For an average practice increasing its rate of disease control from 76% to 83% there would be a reduction of the frequency of alcohol drinking by 0.5 days per patient per month and a reduction in cigarettes consumption by 1.4 per day per smoker. But the former is only weakly statistically significant. We find that the DMH effort response is actually lower than the PMH one as $\gamma_0 < \gamma_1$, although it was not statistically significant in Table 6.4. The PMH complementary effort in cigarettes consumption is double the magnitude of the DMH one.

We also find that doctors put more effort in effectively controlling CVD of the patients with unhealthier lifestyles. A one percentage point increase in doctors' discretionary rate of disease control is associated with an increase of the frequency of alcohol consumption by 0.01 days per patient per month and the number of cigarettes per day per smoker by 0.3. The coefficient $\xi < 0$ indicates that the average doctor uses her discretionary effort to substitute for her patient's larger consumption of alcohol and cigarettes.

6 Conclusions

Although it is recognised that health is a joint production process between doctors and patients, the strategic interaction between these agents is often neglected. From the patient's point of view, a doctor's medical intervention may lower the cost of unhealthy behaviours compensating for their negative effects through more effective health care. Individuals may therefore reduce their effort in undertaking healthier lifestyles. Doctors, on the other hand, might also change their effort in response to their patients' lifestyle behaviours. Lack of an appropriate conceptual framework and lack of data are two of the reasons for this gap in research. In this paper we attempt to make a contribution in both areas.

[9] As the proportion of people who are single or are employed is quite low in this old population, we have also tried a model with the levels of marital status and employment and including age and gender. The size of the main coefficient of interest was larger and even more statistically significant. These results are available to the reader on request.

We first conceptualise the patient-doctor interaction in a double-moral hazard framework based on Schneider (2004) where each agent's effort is hidden from the other party. We show that the relation between doctors' and patients' effort depends on their strategic interaction, that is, whether each agent's effort increases the productivity of the other party. As patients' efforts we consider frequency of physical activity, frequency of alcohol drinking and average number of cigarettes per day. As doctors' input we consider their CVD control effort.

We then develop a new data linkage between over 2,000 CVD patients aged 50 and over from the English Longitudinal Study of Ageing and the GP practices they are registered with between 2004 and 2006. Through a first-differenced control function regression we find evidence of strategic complementarity, as patients increase their efforts in healthier lifestyle behaviours when doctors increase their treatment efforts in response to an exogenous change in their remuneration system. This association is stronger for frequency of alcohol drinking and cigarettes consumption as they are more observable to the doctor and produce the highest health benefits to the patient. For an average practice increasing its CVD control rate from 76% to 83% there is a reduction of frequency of drinking by 0.5 days per patient per month and cigarettes consumption by 1.4 cigarettes per smoker per day. We also find that the average doctor compensates for her patient's unhealthy smoking and drinking by increasing her effort in CVD control.

One of the limitations of this study is the lack of data on individual doctor's disease control. We use instead the average performance of the practice. This generates a form of measurement error but on the other hand avoids a selection bias caused by matching of doctors and patients. A second limitation concerns the lack of variation in the power of the incentive as instrument for the average doctor's effort. This instrument can only pick up exogenous changes in payment that occur between lower and upper thresholds as practices are not paid anything or they are paid the maximum amount irrespective of how far below or above the lower and upper thresholds they are. Additionally, the small sample size prevents us from analysing practice heterogeneities around the lower and upper thresholds. Despite picking up a local average treatment effect, our results are relevant for all those practices that were not always under or over performing throughout the sample period (over 80% of the 2006 practices). As in other studies, we do have a fair amount variation in the first two years which is one of the reasons we have only analysed the first two years of the policy. Finally, whilst we have attempted to distinguish between double-side and patient's side moral hazard, the lack of an appropriate instrument for the patient's effort prevents us from examining the doctor's side moral hazard.

Our results suggest that neglecting strategic interactions between doctors and patients can lead to underestimating the impact of health care reforms on patients' health behaviours, suggesting that payers should take these interactions into account when designing policies that change doctor's intervention. In addition, our analysis demonstrates the potential value of research exploiting matched data on doctors and their patients. Such data are becoming more readily available for researchers both in the UK elsewhere, and we would expect this development to lead to further important empirical insights on health behaviours and their interaction with healthcare.

Future research should examine how repeated interactions and treatment intensities can affect these double-side asymmetries between doctors and patients. It will be interesting to examine the marginal productivity of lifestyle behaviours, the impact of DMH on long-term outcomes and spillovers between primary and secondary care resulting from information asymmetries.

Table 6.1: *Definition of the variables used in the models by year*

All sample	**Definition**	**2004 Mean**	**2004 S.D.**	**2006 Mean**	**2006 S.D.**
	Outcome variables:				
Physical activity	Physical activity on a 4-point scale:	(2,461)		(2,461)	
	1=no physical activity	0.20%		0.16%	
	2=low physical activity	16.21%		18.77%	
	3=moderate physical activity	55.75%		54.94%	
	4=high physical activity	27.83%		21.13%	
Alcohol drinking	Alcohol drinking in 4 points scale:	(2,267)		(2,267)	
	1=daily	19.01%		17.25%	
	2=frequently	41.02%		40.58%	
	3=rarely	29.20%		29.69%	
	4=never	10.67%		12.48%	
	Individual characteristics:				
Household size	Number of household members	1.9	0.8	1.9	0.8
		(2,913)		(2,913)	
Non single	Married/cohabitee/civil partner	66.6%		64.85%	
		(2,913)		(2,913)	
Ln(wealth)	Natural logarithm of real equivalised household wealth in £	11.8	1.7	11.7	1.7
		(2,626)		(2,626)	
Employed	Whether individual is employed vs. unemployed, disabled, retired, home work	23.46%		20.92%	
		(2,911)		(2,911)	
Smokers in 2004	**Definition**	**2004 Mean**	**2004 S.D.**	**2006 Mean**	**2006 S.D.**
	Outcome variable:				
No. cigs per day	Average no. cigarettes per day (negatively coded)	-13.9	8.7	-12.2	9.3
		(238)		(238)	
	Individual characteristics:				
Household size	Number of household members	1.8	0.8	1.8	0.8
		(238)		(238)	
Non single	Married/cohabitee/civil partner	62.18%		57.98%	
		(238)		(238)	
Ln(wealth)	Natural logarithm of real equivalised household wealth in £	11.1	2.2	11.1	2.2
		(238)		(238)	
Employed	Whether individual is employed vs. unemployed, disabled, retired, home work	26.05%		22.27%	
		(238)		(238)	

Notes: descriptive statistics on the balanced sample of individuals 50+ with CVD for whom practice characteristics are observed. Number of observations in (); S.D.=standard deviation.

Table 6.2: *Description of indicators of doctors' disease control*

Indicator name	Description	2004			2006		
		LT	UT	Points	LT	UT	Points
CHD8	The percentage of patients with coronary heart disease whose last measures cholesterol (measured in the last 15 months is 7mmol/l or less).	25	60	16	40	70	17
DM7	The percentage of patients with diabetes in whom the last HbA1C is 10 or less (or equivalent test/reference range depending on local laboratory) in last 15 months.	25	85	11	40	90	11
DM12	The percentage of patients with diabetes in whom the last blood pressure is 145/85 or less.	25	55	17	40	60	18
DM17	The percentage of patients with diabetes whose last measured total cholesterol within previous 15 months is 5 or less.	25	60	6	40	70	6

LT=Lower Threshold; UT=Upper Threshold.

Table 6.3: *Summary statistics on the average achievement rates and power of incentive*

	Mean	Min.	Max.	Std. Dev.
Disease Control in 2004 $[P_j(L^{04}, U^{04}; A^{04})]$	0.76 (2,644)	0.004	1	0.08
Disease Control in 2006 $[P_j(L^{06}, U^{06}; A^{06})]$	0.83 (2,523)	0.08	1	0.05
Power of incentive $[P_j^p]$	-0.05 (2,096)	-0.39	0	0.07

Note: Statistics weighted by the constructed sampling weights. The achievement rates are weighted by the number of points. Sample sizes in () represent practices.

Table 6.4: *Coefficients of first differenced linear models of health behaviours*

	Model I: ΔPhysical activity	Model II: ΔAlcohol drinking	Model III: ΔNo. cigarettes
ΔDisease Control (γ_0)	0.29	-0.10	8.41
	(0.24)	(0.23)	(7.25)
ΔNon single	0.01	0.12	1.88
	(0.11)	(0.10)	(1.81)
ΔEmployed	0.02	0.08*	1.31
	(0.06)	(0.04)	(2.04)
ΔHousehold size	-0.01	0.04	-1.06
	(0.03)	(0.03)	(0.93)
ΔLn(equivalised wealth)	0.02	0.02	-0.16
	(0.02)	(0.02)	(0.57)
Constant	-0.07***	0.07***	1.10
	(0.02)	(0.02)	(0.75)
No. observations	22,498	20,810	2,378
No. individuals	2,251	2,082	238
No. practices	1,512	1,401	247

Statistics weighted by the constructed sampling weights and clustered std. errors in (). No. observations for the 10 imputed datasets on the sample of people aged 50+ with CVD. Model III on sample of smokers in 2004. Lifestyles increasing in health effort: intensity of physical activity, rarity of alcohol drinking and reduction in no. cigarettes.
$^{*}p < 0.1, ^{**}p < 0.05, ^{***}p < 0.01$.

Table 6.5: *First stage coefficients of first differenced linear models of practice achievement on the power of the incentive*

	ΔDisease Control on physical activity sample	**ΔDisease Control on alcohol sample**	**ΔDisease Control on no. cigarettes sample**
Power of Incentive	-0.52***	-0.51***	-0.55***
	(0.03)	(0.03)	(0.04)
ΔNon single	0.0004	-0.004	-0.001
	(0.01)	(0.01)	(0.02)
ΔEmployed	-0.01	-0.01	0.003
	(0.004)	(0.005)	(0.01)
ΔHousehold size	0.0004	0.001	-0.001
	(0.002)	(0.003)	(0.01)
ΔLn(equivalised wealth)	0.001	0.0003	0.0001
	(0.002)	(0.002)	(0.004)
ΔLISI	-0.003*	-0.002*	-0.001
	(0.001)	(0.001)	(0.001)
Constant	0.05***	0.05***	0.05***
	(0.002)	(0.002)	(0.004)
No. observations	22,467	20,785	2,378
No. individuals	2,249	2,080	238
No. practices	1,508	1,398	247

Statistics weighted by the constructed sampling weights and clustered std. errors in (). No. observations for the 10 imputed datasets on the sample of people aged 50+ with CVD. Model III on sample of smokers in 2004.
$^{*}p < 0.1, ^{**}p < 0.05, ^{***}p < 0.01$.

Table 6.6: *Second stage coefficients of first differenced linear models of health behaviours*

	Model I: ΔPhysical activity	**Model II: ΔAlcohol drinking**	**Model III: ΔNo. cigarettes**
ΔDisease Control (γ_1)	0.14	0.68*	23.62**
	(0.38)	(0.39)	(9.96)
Disease Control residuals (ξ)	0.22	-1.13**	-29.44**
	(0.47)	(0.46)	(11.66)
ΔNon single	0.01	0.12**	2.02
	(0.11)	(0.10)	(1.66)
ΔEmployed	0.02	0.08*	1.22
	(0.06)	(0.04)	(1.99)
ΔHousehold size	-0.01	0.04	-1.07
	(0.03)	(0.03)	(0.81)
ΔLn(equivalised wealth)	0.02	0.02	-0.15
	(0.02)	(0.02)	(0.57)
Constant	-0.05*	0.01	-0.13
	(0.03)	(0.03)	(0.92)
No. observations	22,467	20,785	2,378
No. individuals	2,249	2,080	238
No. practices	1,508	1,398	247

Statistics weighted by the constructed sampling weights and clustered std. errors in (). No. observations for the 10 imputed datasets on the sample of people aged 50+ with CVD. Model III on sample of smokers in 2004. Lifestyles increasing in health effort: intensity of physical activity, rarity of alcohol drinking and reduction in no. cigarettes.
$^{*}p < 0.1, ^{**}p < 0.05, ^{***}p < 0.01$.

A Comparisons between practices in England and ELSA

Table A.1: *Sample of practices in England and ELSA by threshold levels for Disease Control*

	England:				ELSA/Practice linkage			
	LT	***(LT, UT)***	***UT***	***Total***	***LT***	***(LT, UT)***	***UT***	***Total***
2004/05	3 (0.04%)	2,675 (32.28%)	5,609 (67.68%)	8,287	1 (0.04%)	665.90 (25.17%)	1,979.06 (74.80%)	2,645.96
2006/07	1 (0.01%)	2,077 (24.85%)	6,279 (75.13%)	8,357	0 (0.00%)	428.70 (16.99%)	2,094.23 (83.01%)	2,522.93

Note: Statistics weighted by the constructed sampling weights LT=Upper Threshold level and UT=Lower Threshold level; (LT, UT) between lower and upper threshold. Achievements from ELSA practices are calculated on the sample of individuals 50+. Proportion of total sample in ().

Table A.2: *Summary statistics on the points weighted average achievement rates and power of incentive (England)*

	Mean	**Min.**	**Max.**	**Std. Dev.**
Disease Control $[P_j(L^{04}, U^{04}; A^{04})]$	0.76 (8,287)	0.004	1	0.09
Disease Control $[P_j(L^{06}, U^{06}; A^{06})]$	0.83 (8,357)	0.08	1	0.06
Power of incentive $[P_j^p]$	-0.06 (8,055)	-0.40	0	0.08

Note: Statistics weighted by the constructed sampling weights. Sample sizes in () represent practices.

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