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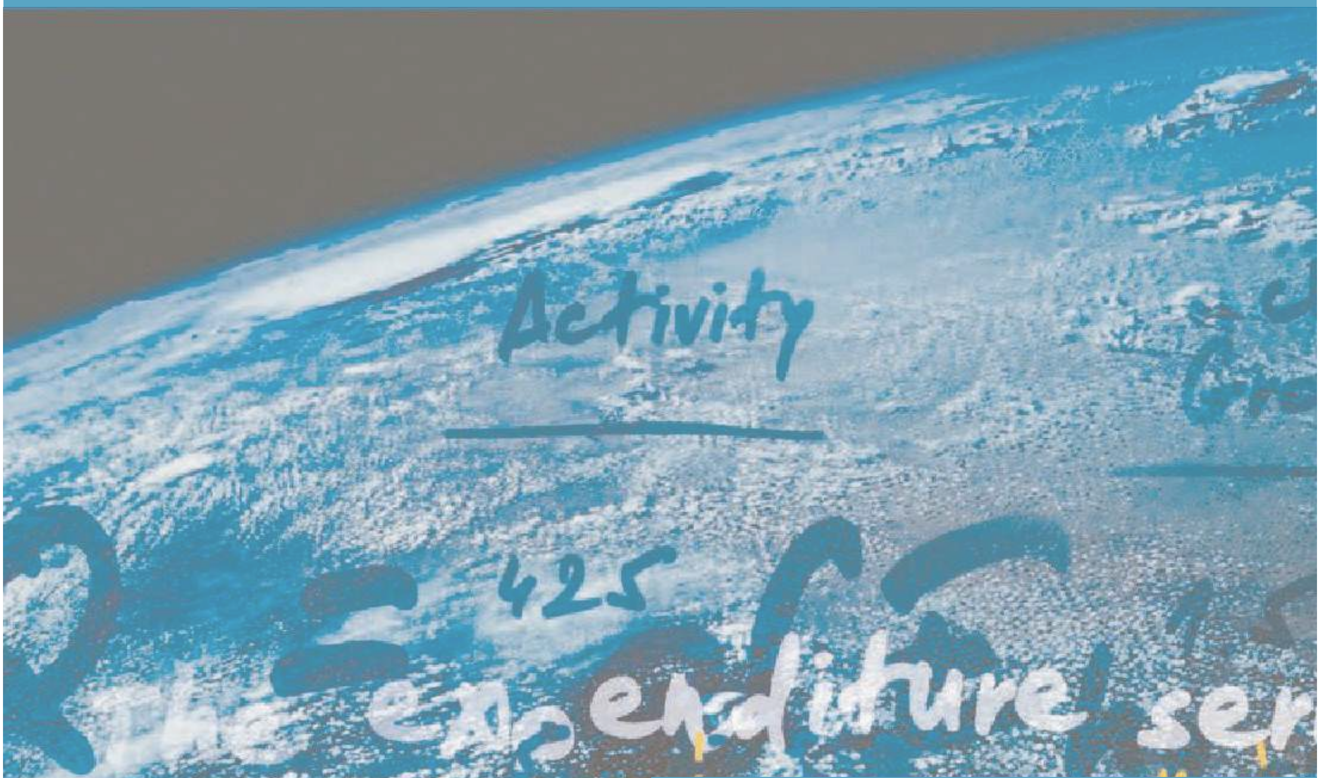

First Do No Harm – The Impact of Financial Incentives on Dental X-rays

Martin Chalkley, Stefan Listl

CHE Research Paper 143

First do no harm – The impact of financial incentives on dental x-rays

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Abstract

This paper assesses the impact of dentist remuneration on the incidence of potentially harmful dental x-rays. We use unique panel data which provide details of 1.3 million treatment claims by Scottish NHS dentists made between 1998 and 2007. Controlling for unobserved heterogeneity of both patients and dentists we estimate a series of fixed-effects models that are informed by a theoretical model of x-ray delivery and identify the effects on dental x-raying of dentists moving from a fixed salary to fee-for-service and patients moving from co-payment to exemption. We establish that there are significant increases in x-rays when dentists receive fee for service rather than salary payments and patients are made exempt from payment. There are further increases in x-rays when a patient switches to a fee for service dentist relative to them switching to a salaried one.
JEL Code I11. Keywords: Healthcare, incentives, matched data, dentistry.

1. Introduction

> "In 1992, shortly after Gerd Gigerenzer[1] moved to Chicago, he took his six-year-old daughter to the dentist. She didn't have toothache, but he thought it was about time she got acquainted with the routine of sitting in the big reclining chair and being prodded with pointy objects. The clinic had other ideas. 'The dentist wanted to x-ray her,' Gigerenzer recalls. 'I told first the nurse, and then him, that she had no pains and I wanted him to do a clinical examination, not an x-ray.' "

Dental x-rays are one of the most common sources of x-ray exposure. Whilst they are an important diagnostic tool, x-rays are a known human carcinogen and there is no threshold below which exposure is considered totally safe. So clinical guidance indicates that x-rays should only be undertaken if the clinical benefits to the patient warrant the risk. The financial arrangements of the physician or their patient should not come into play. In this article we examine the extent to which, notwithstanding that clinical imperative, they actually do. Specifically we estimate the effect of a dentist changing from a fee-for-service to a salaried arrangement on the probability that they x-ray a patient over the course of treatment and on the effect of patient changing from co-payment to full exemption on that same probability.

Health economists have long posited that financial incentives matter and have constructed and tested models of the impact of different financial arrangements on numerous aspects of medical treatment. The idea that insulating patients from the costs of treatment might induce excessive treatment has a very long heritage (see, for example Zweifel and Manning, 2000) whilst physician remuneration viewed in the context of agency relationships as described in McGuire (2000) suggests that fee-for-service (FFS) payment may induce more treatment. This aspect of FFS has led to calls for its phasing out (Schroeder and Frist, 2013). As with the majority of studies the recent contribution by Clemens and Gottlieb (2014) finds very little effect of excess treatment on patient well-being. Many treatments – routine examinations and investigations – do not pose health risks for patients so whilst extra treatment induced by FFS may result in waste, it might be benign in regard to health. This cannot be said for x-rays and ours is the first study to bring the interpretative lens of the economics of incentives and empirical evidence onto this potentially harmful treatment.

Ionizing radiation can directly induce cell death but the low doses used in dental imaging are more likely to induce DNA damage and can result in cancer and leukaemia (Little, 2003). A widely accepted concept in this context is the *linear non-threshold hypothesis* which postulates that the likelihood of developing cancer increases linearly with radiation dose and that there is no threshold level of radiation exposure below which carcinogenesis does not occur (Kellerer, 2000). Empirical evidence about the impact of low radiation doses, such as those caused by dental x-rays, on carcinogenesis is relatively sparse due to sample sizes which often are too small for detecting significant relations (White and Mallya, 2012). However, some studies, such as Memon *et al* (2010) and Preston-Martin and White (1990), suggest that dental imaging is specifically associated with meningiomas, salivary gland tumours and thyroid tumours. A recent population-based case-control retrospective study by Claus *et al* (2012) found that patients with meningioma have twice the likelihood of reporting having ever had a bitewing examination than patients without meningioma. This and similar evidence about potential risks of x-raying substantiates the recommendation of the International Commission on Radiological Protection (ICRP) that activities that cause exposure to radiation can only be justified if they do more good than harm (ICRP, 2008) for the patient. In this context evidence that the remuneration of a dentist positively impacts on the decision to carry out an x-ray examination is concerning since such remuneration is not a clinical benefit to the patient.

To examine whether, contrary to clinical guidance, x-ray use responds to financial arrangements we make use of an extensive and detailed dataset concerning the incidence of x-ray imaging in dental treatment in the NHS in Scotland. Our data follow patients and dentists over multiple treatment episodes for 10 years and thus track changes in the use of x-rays associated with changes in a dentist's method of

[1] Gerd Gigerenzer is director of the Harding Center for Risk Literacy in Berlin and this quotation appeared in a British Broadcasting Corporation internet article commenting on attitudes of physicians to risk; see, http://www.bbc.co.uk/news/magazine-28166019

reimbursement whilst also permitting us to control for changes in a particular patient's circumstance, including whether or not they contribute to the cost of their treatment, and to account for time invariant unobserved patient and dentist characteristics. We interpret these data in the context of a model of interactions between physician and patient and their respective financial arrangements. Our results indicate that a dentist's reimbursement method induces a significant impact on x-ray use with dentists who are paid a separate fee for each x-ray providing more x-rays. This effect is greater if the patient is also exempt from payment. We also find an effect *ceteris paribus* of a patient being made exempt and again the effect is to increase the number of x-rays they receive and to a greater extent if the dentist is paid fee-for-service. We further explore the consequences of a patient switching dentist and find that when such a switch occurs they face a higher probability of an x-ray if they encounter a fee-for-service provider. Whilst our findings cannot establish whether harm is done by the prevalence of dental x-rays in our study population, they do establish that financial incentives are not consistent with the avoidance of harm. Furthermore they establish that harm is significantly more likely when a dentist is paid under FFS (relative to salary) and their patient is exempt from charges. Based on these results, current regulatory arrangements for reducing the potential risks of dental imaging may be insufficient, whilst proposals to modify the remuneration of dentists or patient charges need to be mindful of the potential impact on x-ray use of these financial incentives, both individually and jointly.

Previous empirical evidence regarding the effect of dentists' financial incentives is limited. Findings by Birch (1988) suggest that there are incentives for over-treatment for dentists receiving fee-for-service payments in the British NHS. Similarly, Chalkley *et al* (2010), Chalkley and Tilley (2006) and Listl and Chalkley (2014) have investigated the effects of different dentists' reimbursement schemes in Scotland. In agreement with studies from other areas of medical practice these show that dentists receiving fee-for-service payments treat patients more intensively than their salaried counterparts. For Norway, Grytten *et al* (2009) also find that "the transition to an incentive-based remuneration system led to an increase in the number of individuals under supervision, without either a fall in quality or a patient selection effect". Whilst all of these studies provide evidence of the effect of financial incentives on various measures of dental treatment none are able to focus on a potentially harmful treatment. Some support for potentially harmful effects of excessive dental treatment is provided by Whittaker and Birch (2012) and McDonald *et al* (2012) but these studies do not access individual longitudinal data of the kind we consider, cannot identify a specific treatment item and cannot account for unobserved heterogeneity.

Establishing a causal linkage between financial arrangements and treatment requires not only detailed data permitting identification but also a plausible causal mechanism. To establish the latter, we set out a theoretical framework that is conducive to understanding the interaction between a dentist and their patient and the consequences of that interaction for the probability of observing an x-ray examination. Understanding our data necessitates a description of the institutional arrangements that generate them and we describe these arrangements in Section 3. We then describe our data and our empirical strategy for examining the relationship between dentist remuneration and the incidence of x-ray examinations. We present and describe our key findings in Section 4, and Section 5 concludes.

2. Theoretical framework

We adopt a framework in the spirit of Dranove (1988) which places emphasis on the interaction between a physician, in our case a dentist, and their patient. We model an x-ray examination that takes place depending on the physician being prepared to supply *and* the patient being prepared to accept.

In what follows we assume that the dentist is a monopoly supplier at the point of treatment[2] and the only treatment decision is whether to undertake an x-ray examination[3]. We allow for heterogeneity across patients captured by $i \in [\underline{I}, \overline{I}]$ distributed with density $f(i)$ and heterogeneity across dentists captured by $j \in [\underline{J}, \overline{J}]$ distributed with density $g(j)$. Before presenting for treatment we assume the patient receives a random drawing determining their state of dental health, $Z \in [0, \overline{Z}]$ from a distribution of health states $\phi(Z)$, which reflects all of the relevant information to inform a treatment decision; we normalise such that $Z = 0$ corresponds to a patient who exhibits no symptoms indicating the need for an x-ray. Both dentist and patient know Z for each interaction. Finally, we assume that the the health effect of an x-ray on patient i with state Z as evaluated by dentist j is given by $h(Z, i, j)$ which is increasing in Z. In the publicly funded health system we study the health impacts of treatments reflected in h are usually measured in terms of QALYs.

2.1. Avoiding harm

An important feature of x-rays is the potential to cause harm. Thus whilst $h(Z, i, j)$ may be negative the principle of “first do no harm" implies that no x-ray should be undertaken when that is the case. This also accords with the optimal choice of x-rays in a health care system for which the objective is to maximise patient health for a given budget. If the total cost[4] of delivering an x-ray is c, and the opportunity cost of funds (the health gain that would be lost if an extra unit of expenditure is devoted to an x-ray) is δ then the delivery of an x-ray should satisfy a *cost-effectiveness* threshold; $h(Z, i, j) \geq \delta c$.

An alternative formulation of this policy is to note that conditional upon a realisation of i and j it specifies a *health-state* threshold such that an x-ray should only be undertaken if the patient's health state exceeds a critical value. Specifically if Z^* satisfies $h(Z^*, i, j) = \delta c > 0$ then an x-ray should only be undertaken if $Z > Z^*(i, j)$ which indicates that the decision is independent of any financial payments to (or from) the dentist (patient). Denoting an indicator of when an x-ray will occur by I_{ah}, then under the avoidance of harm requires

$$\begin{aligned} I_{ah}(Z, i, j) &= 1 \text{ if } Z \geq Z^*(i, j) \\ &= 0 \text{ otherwise,} \end{aligned} \tag{1}$$

and this can be used to determine the probability that an x-ray will be observed in an encounter between a patient of type i and a dentist of type j, denoted $P_{ah}(i, j)$ as:

$$P_{ah}(i, j) = \int_0^\infty I(Z, i, j) f(Z) dZ. \tag{2}$$

[2] One justification for this assumption could be that patients will likely have a preference for repeated interactions with one trusted dentist rather than switching between various dentists.

[3] We abstract from considerations of the alternative use of time which a dentist might have, including any consideration of the option of waiting for another patient who might be more amenable to treatment. A dynamic extension of the framework to account for a flow of patients and a corresponding shadow cost of treating the current patient is straightforward, but would not add to the central results that are of concern here, namely establishing the role for, and interaction of, supply-side and demand-side incentives.

[4] This cost includes the value of all resources used to conduct and x-ray and thus the value of the dentist's time

2.2. Dentist-patient interactions

The conduct of an x-ray can only occur if both parties are willing and the prevailing financial system can be expected to affect that willingness. To examine this issue further we consider the dentist's and the patient's assessments of the value of an x-ray and where these differ we allow for the dentist to expend effort to persuade the patient of its worth. We then consider what decision rule for determining when to x-ray will result – and upon what it will depend.

We assume that a patient of type i derives utility from their expectation of the health gain from having an x-ray conditional of their health state, denoted $H(Z,i)$, and their wealth W adjusted for any financial implications of treatment. We denote by e the effort that the dentist expends in persuading the patient and for convenience we denominate effort in money equivalent terms. We assume that the patient pays a price of p for the x-ray and therefore write

$$\begin{aligned} U^p(Z,i,p,W,e) &= u(H(Z,i)),W-p+e), \text{ if an x-ray is received} \\ &= u(0,W) \text{ otherwise.} \end{aligned} \tag{3}$$

The dentist derives utility from the health gain consequent on carrying out an x-ray and from any financial surplus or deficit that results. Supposing the dentist bears a cost C, receives a transfer T (which may be zero or less, or more, than c) and expends effort e we write their utility as

$$\begin{aligned} V^d(Z,i,j,T,C,e) &= v(h(Z,i,j),T-C-e) \text{ if an x-ray is given} \\ &= 0 \text{ otherwise.} \end{aligned} \tag{4}$$

Since the dentist observes the patient's condition Z and type i they can determine how much effort would be required to persuade the patient to undergo an x-ray. If $\tilde{e}$ satisfies $u(H(Z,i)),W-p+\tilde{e})-u(0,W)=0$ then the minimum effort required is,

$$e^m(i,Z,p) = \max[0,\tilde{e}(i,Z,p)]. \tag{5}$$

From the assumptions made this effort is decreasing in Z. Given this minimum effort the dentist will determine whether it is worthwhile doing an x-ray according to whether $v(h(Z,i,j),T-C-e^m(i,Z,p))$ is positive in which case they will expend effort $e^m(i,Z)$ and carry out the x-ray. Otherwise no x-ray will be given and the patient is either sent away, or other treatment items are undertaken.[5]

This approach again defines a critical cut-off health state Z for an x-ray being given but the cutoff will depend on i, j, p, C and T. Hence we define $\tilde{Z}(i,j,T,p,c)$ such that:

$$v(h(\tilde{Z},i,j),T-C-e^m(i,\tilde{Z},p)) = 0. \tag{6}$$

It follows directly from our assumptions that $\tilde{Z}$ is decreasing in T and increasing in p so that in contrast with the decision rule required implying no harm (given by Z^*) the propensity to x-ray responds to financial incentives and there exist values of T for which some patient - dentist interactions can result in harm. Using an indicator of when an x-ray will occur of I_{dp}, this satisfies

[5] The model set out here also accords with the approach adopted by Chandra, Cutler and Song (2012) which views the quantity of treatment being observed as the minimum of the doctor's (supply) and patient's (demand) choices. We differ in allowing for a doctor to transfer resources to the patient (effort) in order to persuade them of the efficacy of their chosen treatment. We view such a transfer as inherent in the patient-physician interaction, whereas side-payments from the patient to their physician to induce higher than medically advised treatment would run foul of medical ethics.

$$
\begin{aligned}
I_{dp}(Z,i,j,T,p,C) &= 1 \text{ if } Z \geq \tilde{Z}(i,j,T,p,C) \\
&= 0 \text{ otherwise,}
\end{aligned} \tag{7}
$$

and this can be used to determine the probability of observing an x-ray in an encounter between a patient of type i and a dentist of type j, denoted $P_{dp}(i,j)$ as:

$$
P_{dp}(i,j) = \int_0^{\infty} I_{dp}(Z,i,j,T,p,c) f(Z) dZ. \tag{8}
$$

It follows directly from our assumptions that Z^* is decreasing in T and increasing in p so the probability that an x-ray is greater if the dentist is paid more or the patient is charged less.

This stylised model suggests that the probability that an x-ray is observed in any particular patient-dentist encounter will depend on the characteristics (the types j and i) of dentist and patient, the dentist's remuneration, the extent to which the patient pays and the patient's dental health state at the time of the interaction. When, as described subsequently we observe characteristics of the dentist and patient that relate to their respective types and the patient's dental health state, it is natural to use these as explanatory variables for the observation of an x-ray examination. Clearly no set of observable variables will completely capture patients' and dentists' types but repeated observations of given individuals can be used to control for any time invariant unobserved heterogeneity. We operationalise this model by estimating a linear probability empirical analogue of equation (8).

In our data we observe whether a patient is visiting a particular dentist for the first time, i.e. whether they have switched dentist since their last treatment. Whilst not formally modelled here, it is plausible that such switching is correlated with i and j, so that patients who have more (or less) pressing dental problems seek out a more (or less) treatment focused dentist. It is also possible that the cost a dentist incurs in persuading a patient of the value of treatment depends on the long term relationship that they have developed. Hence, the model gives some insight into why patients that are new to a particular dentist may be more or less likely to receive x-rays.

3. Empirical framework

3.1. Institutional background

Primary dental care in Scotland is provided by both the public and private sectors. The majority of public sector primary dental care is provided by the General Dental Service (GDS). The reimbursement of GDS dentists takes two different forms. Non-salaried GDS dentists are self-employed and are paid under a mixed system consisting of capitation and fee-for-service (FFS) elements. They receive a fixed payment for every person registered with them and a fee for every treatment procedure performed (Scottish Dental Practice Board, 2001). Salaried GDS dentists are employed by the public sector and as such receive a salary independent of the actual treatments they perform. The exact arrangements of GDS reimbursement are constituted in the Statement of Dental Remuneration which is described in Scottish Dental Practice Board (2001). Patients who are treated by the GDS may be exempt from paying any charges for one of several reasons[6] or non-exempt in which case they pay 80% of the treatment fee up to a limit[7].

3.2. Dataset and estimation strategy

The data used for our study originate from the Management Information and Dental Accounting System (MIDAS). This database includes claims by GDS dentists. For the purposes of our analysis we obtained a 5 per cent random sample from the MIDAS database for claims made between January 1998 and September 2007. The sample was created by extracting claims made by salaried dentists and non-salaried self-employed dentists. In total, our sample contains 1,300,665 treatment claims made by Scottish GDPs. Because there are specific arrangements for treatment as a consequence of dental trauma (accidents) and for persons aged 18 years or below, these claims are not considered for the purposes of this paper so the resulting number of observations we analyse comprises 1,294,012 treatment claims, covering 200,326 separate patients and 3,144 separate dentists. The database provides the advantage of following individual patients and dentists continuously. These panel characteristics enable us to examine the impact on the utilization of x-rays of changes in a patient's exemption status and changes in a dentist's method of remuneration .

Our regression models utilise a binary variable as dependent variable; **x-ray** indicates whether a small dental x-ray (a 'dental film') was provided during treatment, irrespective of any accompanying treatments. In the sample such an x-ray occurs in 19.3 per cent of treatments (see Table 2 for summary statistics). The identification of the impact of financial incentives relies on dentists who change their remuneration status, and because we allow the impact to vary with patients' exemption, on patients who switch exemption status. The first column in Table 1 summarises the extent of the movement between payment and remuneration categories.

Patient characteristics are controlled for by the variable **patient's age** and a variable for deprivation category **patient's deprivation** which is measured on a scale from 1 (most affluent) to 7 (least affluent). This refers to the postcode of the dental practice but the assumption that most patients utilize dental care where they live allows this variable to be applied as a proxy for patient's deprivation. We also control for **dentist's age** (on average, dentists are 41 years old), the **claims per day** issued per dentist, and in the OLS models for the time period during which treatment claims were issued (variable **financial year**, see Table 2)[8]. Further, we control for whether the patient's last dental visit was with the same or another dentist.

To capture for the potential effect of a patient changing their dentist we distinguish between four different types of switches; whether the patient is or is not exempt from treatment charges and whether (s)he

[6] These include being below below 18 years of age, being in full-time education if aged 19, receiving income support, receiving family credit, receiving income based jobseekers allowance, pregnancy and being a nursing mother (**SDPB**)

[7] This limit was £278 in 2004.

[8] In models with fixed effects, this covariate is dropped because of perfect collinearity with dentist's/patient's age.

switches to a salaried or fee-for-service dentist. The summary statistics for the resulting dummy variables are described in Table 2 with the prefix **switch:**. Finally, **Months' since last visit** is included in order to assess whether the coefficients of interest are affected by the duration of time that has elapsed since the patient's last visit. By inclusion of this variable we control for potential effects due to accumulated treatment needs over time. The inclusion of the two aforementioned categories of control variables (provider switch; time since last visit) results in further loss of observations because there is no information regarding duration since last visit or which dentist was attended the last time for a patient's first appearance in the panel.

We anticipate considerable unobserved heterogeneity regarding the oral health status of patients which will not be captured by the controls set out above. In OLS models this could bias the parameter estimate for patient's cost sharing if health status is correlated with exemption status. For example, a patient's oral health status may be particularly compromised amongst persons with low income, but low income may be a reason for being exempt from treatment charges. We also anticipate considerable unobserved heterogeneity regarding treatment styles of dentists which again leads to bias in an OLS model if the dentist's type of reimbursement is correlated with treatment style. For example, dentists could exhibit different treatment volumes and more productive dentists may select themselves into fee-for-service reimbursement, whereas less productive colleagues may prefer a salary.

We exploit the quasi-panel nature of our data to adopt panel regression methods in order to control for these forms of unobserved heterogeneity and estimate a series of fixed effects models, assuming that patient and/or dentist specific heterogeneity is constant over the observation period. Whilst untestable, these assumptions are plausible given the chronic nature of oral diseases on the one hand and that treatment skills of dentists have been acquired throughout several years of dental education and are unlikely to undergo rapid alterations.

The general form of our regression is:

$$y_{ijk} = \mu + \phi_{ij} + \beta w_{ijk} + \gamma x_{ijk} + \epsilon_{ijk}, \quad (9)$$

where y_{ijk} is a diagnostic procedure provided by dentist j to patient i during course of treatment k; w_{ijk} is a vector of dummy variables indicating the combination of patient i's payment status (exempt or not) and dentist j's remuneration status during treatment k; x_{ijk} is a vector of additional controls that vary across dentists, patients and their treatment courses; μ is a constant;ϵ_{ijk} is an error term and ϕ_{ij} is given by

ν_j	for patient-specific effects;
η_i	for dentist-specific effects.
$\nu_j + \eta_i$	for patient & dentist-specific effects.

The estimated parameters of primary interest, contained in the vector β, enable us to recover the effect of a dentist's financial incentives and the extent to which that varies with the patients exemption status as the theoretical framework suggests it might. All estimations were based on linear probability models and were carried out using STATA/SE 12.0 (StataCorp, College Station, Texas, USA). Estimation of fixed effects models was implemented via the commands xtreg and felsdvreg. A conservative approach was used for statistical inference so that the largest standard errors were chosen amongst heteroscedasticity robust and clustered standard errors (Angrist and Pischke, 2009). One-way clustered standard errors were computed in models with one-way fixed effects (using the respective identifier on the level of patients or dentists). In OLS models and in models which control for patient-specific as well as dentist-specific effects (two-way fixed effects models), two-way clustering was used relying on identifiers on the level of patients and dentists. Computation of two-way clustered standard errors was based on the STATA module CGMREG (Cameron *et al*, 2010).

4. Results

Our primary regression results are set out in Table 3 and we focus on the the role of dentist reimbursement, its interaction with a patient's exemption and patients switching between dentists on the propensity to provide x-rays. All regressions include the control variables discussed in Section 3 and described in Table 2. The omitted reference category is a non-exempt patient and a salaried dentist.

We report results for OLS and separately for patient and dentist fixed effects and combined patient and dentist fixed effects. The coefficients of interest and their estimated standard errors vary across the different specification of fixed effects (columns 2 to 4 in the table). In regard to model selection the F-statistics in column 4 indicate that patient and dentist fixed effects are separately and jointly significant so that there is the potential for bias in models that omit one or other category of fixed effects. We therefore focus on the coefficient estimates in column 4. As indicated by R^2 values the various models' explanation of variation in x-rays ranges 4 per cent in OLS to 25 per cent for the most general fixed effects model.

Using column 4 in the table, the impact of patient and dentist financial incentives can be determined as the differences in pairs of the first three coefficients. Since the omitted category is a non-exempt patient treated by a salaried dentist, there are two estimates of the impact of exemption; the third coefficient alone captures the effect of exemption given that the treating dentist is salaried; the difference between coefficients one and two captures the effect of exemption given that the dentist is reimbursed via fee-for-service. Similarly the effect of dentist's remuneration is found from coefficient two alone (given that the patient is non-exempt) and the difference between coefficients one and three (given that the patient is exempt).

A summary of the incentive effects of financial arrangements (expressed as percentage points increases in the incidence of x-rays) implied by our estimates is presented in Table 4. Thus, for example, x-ray utilization increases by 6.8 percentage points (significantly different from zero) as a dentist moves from salaried status to fee-for service and given that the patient is exempt. The effect of exemption status is smaller. A patient switching to exemption who is treated by a salaried dentist will experience a 2.6 percentage point increase in x-rays whereas the same switch results in a 3.4 percentage point increase if they are treated by a fee-for-service dentist.

The results in Table 3 also indicate the impact of a patient newly arriving at a dentist. If an exempt patient arrives for a first treatment at a salaried dentist, x-ray use does not increase significantly; however, significant increases in x-ray use are evident when a non-exempt patient newly arrives at a salaried dentist (2.3 percentage points more x-rays), or an exempt patient newly arrives at a fee-for-service dentist (8.0 percentage points more x-rays), or a non-exempt patient newly arrives at a fee-for-service dentist (10.2 percentage points more x-rays).

Thus overall the results indicate a number of significant and quantitatively large effects on the incidence of x-rays (relative to the mean incidence of x-rays) of a dentist's remuneration in combination with both the patient's exemption status and the arrival of new patients. The former effects are suggested directly by our theoretical framework; whether a dentist who has a financial incentive to deliver an x-ray actually does so depends on whether the patient who they are treating is exempt (or not) from contributing to the cost of that x-ray because the effort required to persuade the patient is lower in the former case. Our model also suggests a rationalisation of the switching coefficients. An increased probability of an x-ray may be a consequence of either newly arriving patients being more easily persuadable or of having more serious dental conditions or their seeking out more 'treatment intensive' dentists. In any case, the effect is larger if a dentist has a financial stake in the treatment and the patient is exempt from charges.

5. Discussion

Accounting for treatment variation is a longstanding and ongoing concern in healthcare. Economics suggests that the remuneration of the physician can have an effect, but disentangling that is challenging on account of confounding factors including the changing payment status of patients. Our findings constitute a new perspective to the extant literature on the impact of financial incentives in health care. We have explicitly considered the role of a patient's exemption status on their dentist's incentives to provide x-ray under different remuneration methods. Dental x-rays are an important element of treatment because whilst beneficial to diagnosis there are well-documented and potentially severe health implications of ionising radiation. The data we have utilised track both the dentist and their patient over time and thus provide a unique opportunity to identify the impact of financial incentives whilst accounting for unobserved heterogeneity on the part of both patient and dentist. The conceptual framework for understanding this form of match-specific effect in determining treatment has been set out by others and we have adapted that framework to the particular setting of our study.

Submitting more than 1 million courses of treatment to fixed effects regression analysis we are able to conclude that; simultaneous accounting for heterogeneity specific to both patient and provider is important; that the impact of a dentist's financial incentives and a patient's financial incentives interact; that x-ray use increases substantially and significantly when dentists are paid fee-for service and that x-ray use increases substantially and significantly when patients switch dentists in some particular circumstances.

Overall our results confirm the role and importance of physician financial incentives in contributing to variation in health care treatment because in the system we have studied there are variations in provider remuneration, which if eliminated would reduce the variation in the incidence of x-rays. Thus, our results have a bearing on health care policy. We can conclude that allowing variation in provider remuneration contributes to variation in treatment and it is the *combination* of provider remuneration and patient financial incentives that is important – not just their individual components.

As with any natural experiment our results are potentially affected by selection. The relevant treatment effects therefore need to be considered with care. As is standard in a fixed effects framework our estimates relate to those individuals for whom the relevant variation occurs. The impact of a dentist's remuneration is estimated using the small number of dentists who switch between salaried and fee-for-service remuneration. If dentists select into the role of switching remuneration as a consequence of a predisposition to respond more strongly to financial incentives than their non-switching counterparts, then our results provide an estimate of the effect of abolishing fee-for-service only on those specific dentists, who represent about 13 % of all dentists in our sample. The policy intervention that our results predict the effect of in this case is mandating that any dentist who is salaried cannot be retained on a fee-for-service contract. More generally, however, the nature of the potential harm caused by x-rays, the fact that risks increase linearly with usage (there is no safe threshold) and the ubiquity of fee-for-service arrangements for dentistry make our results of potential interest and concern worldwide.

The case we have studied also highlights the difficulty in establishing what might be an appropriate incentive structure in health care. First, our results suggest that the supply-side and demand-side of the market cannot safely be treated separately. But perhaps more fundamentally by considering a treatment that can be harmful we highlight the difficult ethical challenges in designing incentives. From an ethical perspective it may be particularly challenging that patients with similar characteristics receive significantly different amounts of dental x-rays when this is caused by different methods of provider payment. For a patient, the risk-benefit ratio of dental x-raying should be independent of provider's financial incentives. Even if patients may voluntarily opt to receive a lower level of x-raying than would be optimal from a risk-benefit perspective, it nevertheless seems ethically questionable that the amount of x-rays received by patients who are exempt from treatment charges is significantly higher if the provider is paid fee-for-service than if (s)he is paid salary. This either means that patients treated by salaried dentists receive less x-rays than optimal for their oral health or that exempt patients treated by fee-for-service dentists receive too many x-rays.

Our findings suggest that financial incentives have a substantial impact on dental x-raying. Given that we identify significant interaction effects between provider payment and patient exemption, any policy intervention which addresses either alone will not hit its intended target. This interaction of incentives and their empirical magnitude is thus of importance for those who want to ensure an adequate use of x-rays and limit their harmful side-effects. More generally our findings indicate that more research is needed into the combined effects of supply-side and demand-side incentives in healthcare.

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Table 1: Movers and Switchers

Patients — non-exempt to exempt	27,631
Patients — exempt to non-exempt	35,197
Patients — from FFS to Salaried dentist	8224
Patients — from Salaried to FFS dentist	6225
Dentists — from FFS to Salaried	291
Dentists — from Salaried to FFS	216

Table 2: Summary Statistics

Variable	Description	Mean	Std. Dev.	N
x-ray	Equals 1 if "small x-ray" was claimed	19.3 %		1,294,012
deprivation	Deprivation category of dentist's practice			1,294,012
	1 (most affluent)	6.0 %		1,294,012
	2	14.3 %		1,294,012
	3	19.6 %		1,294,012
	4	28.5 %		1,294,012
	5	16.1 %		1,294,012
	6	9.4 %		1,294,012
	7 (least affluent)	6.1 %		1,294,012
patient's age	Patient's age in years	43.841	14.578	1,294,012
months since last visit	Duration since last visit (months)	8.545	9.331	1,095,993
claims per day	Number of claims per dentist per day (5% random sample)	0.348	0.219	1,294,012
dentist's age	Dentist's age in years	41.172	9.804	1,294,012
(non-exempt patient) *(salaried dentist)	Equals 1 if patient is exempt from charges and dentist is salaried	2.0 %		1,294,012
(exempt patient) *(salaried dentist)	Equals 1 if patient is exempt from charges and dentist is salaried	0.9 %		1,294,012
(non-exempt patient) *(fee-for-service dentist)	Equals 1 if patient is exempt from charges and dentist is salaried	71.0 %		1,294,012
(exempt patient) *(fee-for-service dentist)	Equals 1 if patient is exempt from charges and dentist is salaried	26.1 %		1,294,012
financial year	time period during which claim was issued			1,294,012
	year 1	10.0 %		1,294,012
	year 2	10.0 %		1,294,012
	year 3	10.0 %		1,294,012
	year 4	10.0 %		1,294,012
	year 5	10.0 %		1,294,012
	year 6	10.0 %		1,294,012
	year 7	10.0 %		1,294,012
	year 8	10.0 %		1,294,012
	year 9	10.0 %		1,294,012
	year 10	10.0 %		1,294,012
switch: non-exempt patient	Equals 1 if patient non-exempt from treatment	0.8 %		1,093,686

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... table 2 continued

Variable	Description	Mean	Std. Dev.	N
to salaried dentist	charges switched to salaried dentist			
switch: exempt patient to salaried dentist	Equals 1 if patient exempt from treatment charges switched to salaried dentist	0.4 %		1,093,686
switch: non-exempt patient to fee-for-service dentist	Equals 1 if patient non-exempt from treatment charges switched to fee-for-service dentist	12.5 %		1,093,686
switch: exempt patient to fee-for-service dentist	Equals 1 if patient exempt from treatment charges switched to fee-for-service dentist	5.8 %		1,093,686

Table 3: Results for utilisation of dental x-rays

	OLS	patient FE	dentist FE	patient and dentist FE
(exempt patient)* (fee-for-service dentist)	0.041*** (0.004)	0.161*** (0.008)	0.049*** (0.008)	0.094*** (0.021)
(non-exempt patient)* (fee-for-service dentist)	0.020*** (0.004)	0.126*** (0.007)	0.028*** (0.008)	0.060*** (0.021)
(exempt patient)* (salaried dentist)	-0.019** (0.008)	0.009 (0.012)	0.012 (0.008)	0.026** (0.012)
switch: exempt patient to salaried dentist	-0.073*** (0.009)	-0.036*** (0.011)	-0.021** (0.009)	-0.004 (0.012)
switch: non-exempt patient to salaried dentist	-0.044*** (0.006)	-0.009 (0.008)	0.016** (0.007)	0.023*** (0.012)
switch: exempt patient to fee-for-service dentist	0.097*** (0.002)	0.080*** (0.002)	0.099*** (0.002)	0.080*** (0.003)
switch: non-exempt patient to fee-for-service dentist	0.112*** (0.001)	0.101*** (0.001)	0.116*** (0.001)	0.102*** (0.002)
F-statistic (patients)	-	1.67***	-	1.46***
F-statistic (dentists)	-	-	16.49***	6.32***
F-statistic (combined)	-	-	-	1.79***
R^2	0.04	0.24	0.09	0.25
N (claims)	1,088,829			
N (patients)	145,550			
N (dentists)	3,077			
N (patient/dentist pairs)	276,544			

Here and in subsequent tables all models control for provider age & number of claims issued per month, patient age, deprivation category and duration since last visit; * denotes $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; Standard errors are in parentheses and are two-way (patient and dentist level) clustering in OLS model & two-way fixed effects model; one-way (patient, dentist or patient/dentist-pair level) clustering in all other models.

Table 4: Marginal effect of financial incentives on x-rays - percentage points

	Dentist fee-for-service	Dentist salaried
Exemption	3.4	2.6
	(2.2)	(1.2)
	Patient non-exempt	Patient exempt
Fee-for-service	6.0	6.8
	(2.1)	(2.2)