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The effects of pension reforms on physician labour supply: Evidence from the English NHS

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The Effects of Pension Reforms on Physician Labour Supply: Evidence from the English NHS

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Abstract

We examine the labour supply response of senior doctors in England following a reform of the public sector pension system that moved employees from a final salary to a career average pension plan. Exploiting the staggered rollout of the reform across narrowly defined age groups, we find that doctors increased labour supply by just under 4% four years after exposure. This implies a labour supply elasticity with respect to pension wealth of -0.05, and with respect to current returns to work of 0.04. This indicates doctors' responses were small despite relatively large changes in financial wealth induced by the reforms.

Keywords: Doctor labour supply; Labour supply elasticity; Defined Benefit pensions; Public pension reform.
JEL Classification: H55, J22, J26, I10.

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1 Introduction

Concerns over the financial sustainability of pension plans, the result of rising life expectancy and low interest rates, have meant that in recent years generous defined benefit plans have either been reformed or scrapped in both the public and private sector in many countries (Hinrichs, 2021; Whiteford and Whitehouse, 2006). Such reforms are also intended to strengthen labour supply incentives at younger ages, by moving away from benefits that are strongly linked to final years in the labour market to those linked to earnings across the life cycle. But the responsiveness of labor supply to changes in pension incentives for individuals who are not yet at retirement age is an open question. Individuals often appear either not to be fully aware of the details of pension systems (Mitchell, 1988; Arenas de Mesa et al., 2006; Crawford and Karjalainen, 2020), over-discount the future (Laibson, 1997) or do not process financial information well (Banks and Oldfield, 2007; Banks and Crawford, 2022). This potentially impacts the responses to pension incentives (Chan and Stevens, 2008; Bottazzi et al., 2006; Mastrobuoni, 2011; Liebman and Luttmer, 2015). In addition, most research has focused on the responses to reforms of individual at or near retirement age (Blundell et al., 2016).

In this paper, we study the impact of a major reform to public sector pensions in the UK. We focus on the responses to this reform on a tightly defined group of highly skilled public sector workers: senior doctors working in the English National Health Service (NHS). The NHS pension plan had 3.4 million members in 2021 (NHS Pension Scheme, 2021) and, as part of wider reforms to pensions for all public sector workers in the UK, the NHS plan was reformed from a final salary defined benefit (DB) plan to a career average pension in 2015. While remaining a DB plan, for most NHS employees this change represented a fall in the generosity of their pensions and altered the link between labour supply and pension wealth at different points in the lifecycle.

This reform, and how it affected senior doctors, is of considerable interest for several reasons. First, the NHS reform was large and part of similar reforms applied across large parts of the UK public sector. It was thus both salient and well publicised by the various public sector pension providers. Second, the way the reform was implemented meant that it affected individuals sufficiently far away from retirement to be able to alter their labour supply. Third, the senior doctors we examine have flexibility in their labour supply to the NHS, may have generous outside options (in the private healthcare market) and are a highly educated group whose financial literacy is likely to be considerably higher than that of other employees (Banks and Oldfield, 2007). Thus they are able to alter their labour supply in response to changes in the incentives embodied in the pension reform. Finally, senior doctors play a central role in the delivery of healthcare, in the training of younger doctors and face increasing demand for their time due to rising population needs for healthcare. Understanding their response is therefore central to the delivery of healthcare in the UK and, more generally, to understanding how skilled labour may respond to pension changes.

In common with reform to many other pension plans, the reform involved a number of changes, including new accrual rates, retirement ages and reductions in total pension value. This means that the reform has an ambiguous theoretical impact on labour supply, in part because of the standard conflict between income and substitution effects. Whether such a reform increases or decreases labour supply, and the magnitude of such changes, is thus an open empirical question.

To estimate the effect of the reform on senior doctor labour supply to the NHS, we exploit the fact that the reform was announced and introduced for all public sector (including NHS) employees at a single point in time, but its implementation affected employees, including senior doctors, in a staggered fashion. The new pension plan was announced in 2012 and introduced in 2015. Most senior doctors were immediately moved to the new pension plan at its introduction but those sufficiently near to retirement were never moved. An intermediate group were moved onto the new plan over time in a staggered manner based on their date of birth. Using detailed administrative monthly payroll data, we exploit this staggered roll-out, restricting our sample to senior doctors born within a seven year time span. To avoid the well known issues when estimating models with two-way fixed effects and staggered treatment timings (De Chaisemartin and d'Haultfoeuille, 2018; Goodman-Bacon, 2021; Sun and Abraham, 2021; Borusyak et al., 2021), we estimate the impacts of the reform on the labour supply of senior doctors in this cohort using the imputation method proposed by Borusyak et al. (2021).

We find that being moved onto the new pension plan increased average full-time equivalent labour supply by 3 percentage points after four years, equivalent to a 3.5% increase on baseline labour supply. This was driven by an increase on the extensive margin: moving to the new plan increased the probability of working in the NHS four years later by 3.4 percentage points (3.7%). These effects persist and grow over longer horizons. By contrast, there was no impact on the intensive margin, with no significant effect on hours conditional on participation. In the pre-reform period, many doctors had started to drop out of the NHS at the stage of their career we examine. The increase in the extensive margin therefore suggests that the reform extended the number of years doctors worked in the NHS.

We examine heterogeneity in responses to the reform. We find that senior doctors with fewer outside opportunities for private sector work increased their NHS labour supply in response to the reform. Senior doctors with more outside opportunities did not, highlighting the importance of outside labour market opportunities when considering changes to remuneration of public sector workers. We find no difference in responses by the gender of senior doctors.

We then estimate the financial impacts of the reform and combine these with our labour supply estimates for male and female senior doctors to estimate labour supply elasticities. We estimate a labour supply elasticity with respect to pension wealth of -0.05 and a labour supply elasticity with respect to current returns to work of 0.04. These imply that the change in pension wealth was the main channel through which the reform affected labour supply, explaining about 74% of the total increase in labour supply. These elasticities are relatively small when compared to other estimates of doctor labour supply (e.g. Lee et al. (2019) found doctor wage elasticities ranging from 0.1 - 0.5), indicating that for mid-career doctors (those affected by the reform), changes in financial incentives may have relatively little effect. This lack of a large response may be because the reform and pension plans were relatively complex to understand or because doctors are less responsive to changes in delayed remuneration relative to changes in current wages.

The contributions of this paper are the following. First, we contribute to the literature on the impact of pensions on labour supply. Most of the literature focuses on retirement incentives for those at or near retirement (Blundell et al., 2016). From these studies, changes in retirement incentives have a large impact on retirement decisions and large implicit taxes often hinder older age employment (Gruber and Wise, 1999). But changing incentives for those further from retirement may have different effects than changing these for those close to retirement. A final salary plan such as the pre-reform NHS plan generates stronger work incentives at points in the lifecycle when wages are high (for the group we study almost always towards the end of the career) and weaker incentives when wages are low, than a career average or defined contribution plan. So we may expect to see different outcomes than for workers close to retirement.

There are two recent papers that examined similar reforms to public pensions, in European contexts, for workers not yet near retirement (French et al., 2022; Bovini, 2019). Both focus on average responses across employees in all occupations and sectors of the economy. We build on this literature by focusing on a set of highly skilled workers (who are also key to the health and production of the economy).

Second, we contribute to the literature on doctor labour supply. Perhaps surprisingly, there is a rather limited literature on the labour supply of doctors and much comes from the US context, which is characterised by very different employment contracts and incentives for doctors than many other healthcare systems (Nicholson and Propper, 2011; Lee et al., 2019). Much of this literature also has difficulties establishing causality. The UK evidence is particularly scarce (Ikenwilo and Scott, 2007; Lee et al., 2019) given the importance of the NHS as the dominant provider of healthcare and the large share of public expenditure accounted for by healthcare spending (21% in 2019-20, Institute for Fiscal Studies (2021)). Our contribution is to provide causal evidence on the labour supply of doctors in England using novel detailed administrative data by exploiting a reform that generates exogenous variation in pension compensation. We thus contribute to the understanding of the labour supply of doctors in countries where doctors are hospital or healthcare facility employees, as distinct from being self-employed (e.g. (Brekke et al., 2017; Andreassen et al., 2013; Broadway et al., 2017). Most of this literature focuses on current remuneration for doctors: our contribution is to show the importance of pensions, and more generally delayed remuneration, for labour supply.

Finally, as the reform we examine was for almost all public sector employees, it also affected other high skilled individuals in the UK public sector (judges, academics, senior public sector managers) for whom these is no evidence on their response to the changes. Our results may be useful for understanding changes for these groups.

The rest of the paper is organised as follows. Section 2 describes the institutional background, the pension reforms that we study, and how we might expect them to affect labour supply. Section 3 describes the data. Section 4 explains our empirical strategy. Section 5 presents the results of the labour supply analysis and uses these results to estimate labour supply elasticities. Section 6 concludes.

2 Background

2.1 Healthcare in England

The vast majority of healthcare in England is provided by the National Health Service (NHS). Care is free at the point of use and funded out of general taxation. Elective (pre-planned) and emergency care is typically provided by large, public hospitals with some provision of elective care by private hospitals.[1] NHS hospitals provide a wide range of services. Patients do not pay for care when treated under the NHS and hospitals are reimbursed by the government through a set of nationally agreed tariffs for a given treatment.[2] Elective care is rationed through waiting times and by the requirement to have a referral from a primary care physician. Emergency care is accessed through hospital emergency departments, which provide urgent care and admit patients for further treatment if required. There is also a small private-pay elective healthcare sector, specialising in elective care for which there is long NHS waiting lists. For this, patients pay out-of-pocket or through medical insurance.

2.2 Labour Supply in the NHS

The vast majority of staff in public hospitals are salaried public sector employees, with short-term shortages filled by external agency staff. Staff are contracted to an NHS 'Trust', comprised

[1] In 2017-18, 6% of publicly funded elective surgeries were conducted by private hospitals (Stoye, 2019).

[2] These prices are known as Healthcare Resource Groups, similar to Diagnosis-related Groups (DRGs) in the US.

of one or a small number of geographically close hospital sites.[3] We focus here on senior doctors in NHS hospitals, known as consultants. These doctors made up 42% of the total doctor workforce and 8% of the total qualified clinical workforce in the NHS in 2021 (NHS Digital, 2022b). Every treated patient has a named consultant who has overall responsibility for their care. Consultants lead medical teams to provide care in their given speciality. They may also have other management duties within a hospital. Henceforth we refer to consultants as senior doctors.

All doctors earn a basic salary depending on their role and experience, with this salary set by national pay scales. All senior doctors can receive additional pay, for example by working additional shifts or taking management responsibilities. This means that senior doctors have more ability to adjust their hours and income than many other salaried professions. Some of this additional pay is pensionable, including pay for permanent extra responsibilities, and some of it is not, including payment for hours worked over full-time contracted hours. Senior doctors can also apply for clinical excellence awards, based on achievements in their work, which can substantially increase their pay. Over most of this period, all such awards were pensionable.[4]

Senior doctors can also supplement their NHS salaries by doing additional work in private hospitals. To do this, senior doctors who are on full-time contracts are expected to provide additional hours to the NHS.[5] Senior doctors may alternatively choose to leave the NHS and work entirely within the private sector. Data on private earnings for doctors is difficult to obtain but historically, private earnings have been a significant percentage of total income for senior doctors because pay-per-hour in the private sector is often considerably higher than in the NHS and The availability of private work varies considerably across both region and clinical specialities, being particularly high in specialities for which there are long NHS waits and in regions where patient income is higher (Morris et al. (2008), Appendix Figure A1).

[3]For simplicity, we refer to these trusts as 'hospitals' throughout the text. In rare cases, individuals may be employed by two Trusts.

[4]Clinical excellence awards can be either local (allocated and funded by the employer trust) or national (allocated and funded nationally). National awards were pensionable during our sample period. From April 2018, local awards were no longer pensionable.

[5]A full time senior doctor does 10 sessions, and to work in the private sector, are required to offer 11 sessions. However, as doctors are paid salaries contracted hour enforcement varies considerably between Trusts.

2.3 The 2015 Pension Reform

In March 2011, the government's Independent Public Service Pensions Commission recommended that UK public sector pensions move away from their traditional final salary form (which typically averaged earnings of the last three years of employment) towards a career average revalued earning (CARE) plan. This was still a defined benefit plan, but with different features to the previous plan. These recommendations led to changes across all public sector pension plans, including plans for civil servants, teachers, police and firefighters and NHS employees.

2.3.1 How did the change of plan affect senior doctors in the NHS?

Prior to 2015, the NHS had two pension plans: the 1995 and 2008 plans. We focus on the former as almost all senior doctors we examine were in that plan.[6] This was a final salary defined benefit pension plan, where each year of service accrued 1/80th of the member's best salary over their final three years before retirement. Under the new 2015 plan the pension depended on average earnings rather than final salary. Each year a member would accrue 1/54th of their earnings in each year they worked in the NHS.[7] Thus the value of the 2015 plan depended much more on career rather than final (three year) earnings.

The 2015 plan had a number of other differences. The normal retirement age was 60 in the 1995 plan. This was raised to the state pension age in the 2015 plan, which was 67 for the senior doctors in our analysis. So the retirement age is substantially higher under the new plan. Both plans allowed early retirement in return for reduced benefits during retirement. Under the 1995 plan, those who joined before 2006 (most of those in our cohort) had an early retirement age of 50. Under the 2015 pension plan, the earliest early retirement age was 55. Moreover, since the normal pension age has increased under the 2015 plan, early retirement at the same age in the 2015 plan means a larger reduction in benefits than in the 1995 plan.[8]

[6]The 2008 plan was introduced in 2008 for new joiners, so any senior doctor that worked continuously in the NHS since before 2008 would still be in the 1995 plan. All of our cohort worked in the NHS in 2012. Our data does not go back further, but the mean age of our cohort in 2008 was 42 and so it is likely that almost all our senior doctors were working in the NHS prior to 2008. The 2008 plan was also a defined benefit plan, but with slightly different accrual rules and a later retirement age (65).

[7]Before retirement, each year's accrual would also be uprated at Consumer Price Index (CPI) inflation plus 1.5%.

[8]The 1995 plan also included a lump sum worth three times the annual pension value upon retirement. The

Despite these differences in their generosity, both plans have the same employee contribution rates. These depend on income and range from 5% for those on the lowest NHS incomes to 14.5% for those earning more than £111,377. The contribution rates for the employer (the NHS Trusts) are also the same under both plans, at 14.3% until March 2019 and 20.6% from April 2019. Changes to the pension plan therefore did not directly affect either the take-home pay of senior doctors or the costs for hospitals of employing senior doctors.

2.3.2 How might the reform affect labour supply?

The reform had several financial impacts, each of which could affect labour supply differently. In Appendix A, we develop a simple two-period model of labour supply to understand the impacts of the new pension plan. In this section, we discuss the intuition behind the formal results.

The first change is the relationship between current pay and pension value. In the pre-reform pension plan, current pay level did not affect the value of a pension until a doctor was within three years of retirement. Under the new pension plan, current pay affects pension value regardless of how close the doctor is to retirement. This increases the returns to additional pay for those far from retirement and decreases the returns for those within three years of retirement. The effect of the change in incentives is a priori ambiguous. This is the standard conflict between income and substitution effects at a higher wage. The higher current return gives a greater incentive to work in the NHS (substitution effect), but also increases total renumeration, reducing the incentive (income effect).

The second change is the change in the value of the pension. The overall value of a lifetime in the new plan has been estimated to be relatively similar to the old plan for an average NHS worker (Cribb and Emmerson, 2016; Danzer et al., 2016). But for most senior doctors previously in the old plan, the new pension is worth less than they expected as the delayed retirement age means they must pay into the plan for more years to receive fewer years of benefits (Cribb and Emmerson, 2016). This represents a negative wealth shock and a reduction in total remuneration. When there is no outside option, a reduction in pension wealth will increase labour

2015 plan did not include a lump sum upon retirement, but plan members can choose to take a lump sum in return for reduced subsequent payments.

supply in the NHS. Intuitively, without an outside option the only way the doctor can increase their now lower income in retirement is to work more in the NHS. With an outside option, the change in wealth has a more complex and ambiguous effect on labour supply. This is because a doctor will respond to a reduction in wealth by working more (and therefore increasing total pension wealth), but may choose to do this by working more in the outside option and less in the NHS, depending on the relative wages and pension contribution rates in each sector. It is therefore possible that with an outside option, the reduction in wealth will either reduce or not change NHS labour supply.

The third change is the increase in the minimum retirement age from 50 to 55. For individuals who had planned to retire between 50 and 54, they can no longer take their pension.[9] In response, doctors can either increase their labour supply to the NHS or retire earlier than allowed under the plan. For those with a sufficiently appealing outside option, the second option is possible. For those without such an outside option, this increase in the minimum retirement age will mechanically increase the length of labour supply as doctors continue to work until an older age.

Taken together, the labour supply effects of the reform are therefore ambiguous and the direction of any labour supply response remains an open empirical question. To examine this we exploit the staggered introduction of the plan.

2.3.3 The rollout of the plan

The new pension plan for NHS employees was announced in March 2012 and implemented from 2015 in a staggered fashion. In April 2015 all of those more than 13 years and 5 months away from retirement age (under their previous plan) in April 2012 were immediately moved to the new plan. When moved to the new plan the final salary link of the old plan was maintained. Rather than transferring the value of their pension in the old plan to the new pension plan, staff members maintained their old pension and started a new pension in the new plan. This meant that the accrual period under the old plan would not increase, but the final salary would update to reflect the final salary when the staff member retired. All new joiners to the NHS started in

[9]This does not fit directly into the simple model presented in Appendix A where there is no choice over when the doctor retires.

the 2015 plan.

Those within 13 years and 5 months of their retirement age in April 2012 received either 'tapered' or 'full' protection. Those within 10 years of their retirement age received 'full' protection, and were not moved onto the 2015 plan, but remained in their previous plan. Those between 10 years and 13 years and 5 months received 'tapered' protection, which meant they would spend additional time in their previous plan before being moved to the 2015 plan. In June 2015, those 13 years and 5 months away from retirement were moved to the 2015 plan, and in August 2015, those 13 years and 4 months away were moved. This pattern continued over time, with each subsequent month age group shifted every two months, until all were shifted by February 2022.[10]

3 Data

Our primary source of data is the Electronic Staff Record (ESR), the monthly payroll for all staff directly employed by the NHS.[11] It includes occupational codes, demographic characteristics, a breakdown of monthly pay and the number of hours or shifts worked for each employee. We identify senior doctors (consultants) using national paycodes in the data and only include senior doctors working in short term general (acute) hospitals. We use these data from April 2012 to August 2021.[12] In our analysis years are fiscal years (April to March).

We create a cohort of senior doctors who were affected by the reform. This cohort consists of any doctor who was employed as a senior doctor in an acute (short term general) hospital in April 2012 who was born between April 1962 and December 1969. These doctors were all affected by the staggered rollout. We discuss the reasons for this restriction in more detail in Section 4 and test robustness to using alternatively defined cohorts in Section 5.2. Defining the cohort in 2012 allows us to consider labour supply outcomes for three years prior to the reform

[10] The staggered rollout was subsequently ruled to have discriminated against younger members. As a result, the government has announced that members at retirement can choose whether they want their benefits from earnings between 2015 and 2022 to come from the old or the new pension plans. This was announced in 2021, and is still subject to some uncertainty. Therefore, for our sample period, senior doctors would have believed their pension benefits would come from the new 2015 plan upon being moved.

[11] This includes most hospital staff but excludes family doctors (General Practitioners) working outside of hospitals and staff employed by an external agency.

[12] Our sample period includes the Covid-19 pandemic, but our analysis includes time fixed effects which will absorb all common changes in labour supply related to the pandemic.

We define a number of labour supply outcomes. First, we measure total labour supply as the full-time equivalent (FTE) contracted hours of each senior doctor, including zeroes for those who have left the NHS. Second, we measure the extensive margin of labour supply using a dummy variable for whether the senior doctor is still employed by the NHS at time t. Third, we measure the intensive margin of labour supply as FTE contracted hours conditional on being employed by the NHS. Although not a measure of labour supply, we also measure pension plan membership to examine whether doctors reacted to the reform by leaving or joining the NHS pension plan.

There are 11,872 senior doctors in our cohort. Table 1 presents summary statistics for 2014, focusing on 2014 as this is the year immediately before the new pension plan was introduced. 32.6% of the senior doctors in our cohort were female and the average age in 2014 was 48. 93.9% were still working in the NHS (i.e. 6.1% had left the NHS between 2012 and 2014). 98.8% of those who were still working in the NHS were in the NHS pension plan. Appendix Figure C1 shows this very high participation rate is similar to that of younger senior doctors prior to the reform. This means that almost all senior doctors in our cohort would have been affected by the transition to the new pension plan.

Table 1: Consultant cohort summary statistics in 2014

	Mean	SD
Age	48.0	2.24
Female	32.6%	46.9%
NHS employment	93.9%	23.0%
NHS pay conditional on employment	£121,000	£33,600
NHS FTE conditional on employment	0.972	0.122
NHS pension plan membership conditional on employment	0.988	0.0982
N	11,872	

4 Empirical strategy

4.1 Cohort

To identify the impacts of the new pension plan on individual labour supply we exploit the staggered rollout of the plan. For our main analysis we restrict our cohort to senior doctors born between April 1962 and December 1969.[13] The vast majority of those in this plan were likely on the 1995 pension plan prior to the reform.[14] Those born between October 1966 and December 1969 were immediately moved to the new pension plan in April 2015. Those born between April 1962 and September 1966 were treated in the staggered fashion described in Section 2.3, with the youngest treated first from June 2015.[15] The oldest in this group had yet to be moved onto the new plan by the end of our sample period, but would eventually be moved.

Restricting our analysis cohort to this narrow group of birth years has a number of advantages for estimating the impacts of the reform. First, it means we only compare the labour supply of senior doctors born at most seven years apart. This means many other characteristics of these doctors are likely to be similar, as are their labour supply trends in absence of the reform. Second, our analysis only includes senior doctors who would be affected eventually by the reform. By not including older senior doctors who were never affected, we eliminate some common anticipation effects. In particular, the reform and its timing were announced to all of those in our cohort at the same time. By comparing only those who would eventually be treated, we eliminate any time-varying anticipation effects that were independent of treatment timing. For example, all of those in our cohort knew their retirement age would increase from 60 to 67, irrespective of when they were actually moved onto the new pension plan.

[13] In Section 5.2, we test for robustness using both a more narrowly- and more broadly-defined cohort.

[14] This matters because the rollout was based on normal retirement age which is different in the 1995 and 2008 plans, and so different date of births were shifted at the same time depending on which plan they were in. Footnote 6 explains why almost all senior doctors in our cohort were likely in the 1995 plan. Any senior doctors in our cohort that were in the 2008 plan would not have been affected by the staggered rollout as they would have been too far from retirement. Instead, they would have all been immediately moved onto the new plan.

[15] The rollout actually grouped those born between the 2nd of one month and the 1st of the next month. For simplicity we refer to the month that the vast majority of those in the group were born in.

4.2 Estimation

To estimate the impact of the reform we model the labour supply of individual i in birth month group j (e.g. those born in October 1963) in month t as

$$y_{ijt} = \sum_{h=0}^{74} \beta_h \mathbf{1}(t = E_j + h) + \alpha_j + \delta_t + \gamma \text{ age}_{it} \times \text{gender}_{it} + u_{ijt} \tag{1}$$

where E_j is the month that each group is first treated, and so each β_h measures the effect of the new pension plan h months after being moved onto it. We include birth month fixed effects α_j and month fixed effects δ_t, as well as age (dummy variables for each year) by gender fixed effects.

We do not use OLS to estimate Equation 1 because of the well known issues when estimating models with two-way fixed effects and staggered treatment timings (De Chaisemartin and d'Haultfoeuille, 2018; Goodman-Bacon, 2021; Sun and Abraham, 2021; Borusyak et al., 2021). Instead, we use the imputation estimator proposed by Borusyak et al. (2021).[16] This is more computationally feasible than other proposed methods which aggregate many pairwise comparisons, such as that proposed by Callaway and Sant'Anna (2021), because of the large number of time periods our treatment is staggered over.

4.3 Identification and interpretation

The key identification assumption is that conditional on our controls, all other factors determining each senior doctor's labour supply are uncorrelated with their treatment timing. For this reason, we control for age and gender, since they are correlated with both labour supply and treatment timing via date of births. We assume that all other trends in labour supply are the same for all those in our cohort, since they were all born within a similar period.

We must also make assumptions about anticipation effects. There may be anticipation effects that are common to all of those in our cohort, since all are eventually treated. Since the policy is announced before the start of our sample period, any anticipation effects that are constant over time will be absorbed by our group (birth-month) fixed effects and will not

[16] We have repeated our primary analsis with OLS. The results are similar but less precise.

bias our estimated treatment effects. Moreover, any time-varying anticipation effects that are common to all in our cohort will be absorbed by our time period fixed effects and not bias our results. The threat to our empirical strategy is that there are time-varying anticipation effects that vary with treatment timing. We assume that there are no such effects and test for pre-trends using the methodology proposed by Borusyak et al. (2021).

Our estimated treatment effects should be interpreted as the impact of being moved onto the new pension plan, rather than the impact of the new pension plan *itself*.[17] If senior doctors behaved as fully rational, forward looking, economic agents they would have internalised the wealth and retirement age impacts of the new plan when it was announced in 2012. Our results would then only capture the impacts of the change in labour supply incentives. However, based on a large amount of evidence that individuals often lack key knowledge about pension systems and do not act as economic theory may predict when making pension decisions (Liebman and Luttmer, 2015; Laibson, 1997; Banks and Crawford, 2022), we think it is likely that most senior doctors did not behave in this way. Instead, it is likely that it was being moved onto the new pension plan that made the details of the new plan more salient to senior doctors. Our results will therefore may include parts of these other effects. However, any effects of the policy that are not time-varying, or are time-varying and common to all in our cohort, will be captured by our fixed effects.

5 Results

We first present our baseline labour supply results which we then subject to a number of robustness checks. We next examine heterogeneity between different groups of senior doctors based on their outside options and gender. Finally, we use our results to estimate labour supply elasticities with respect to wealth and financial incentives.

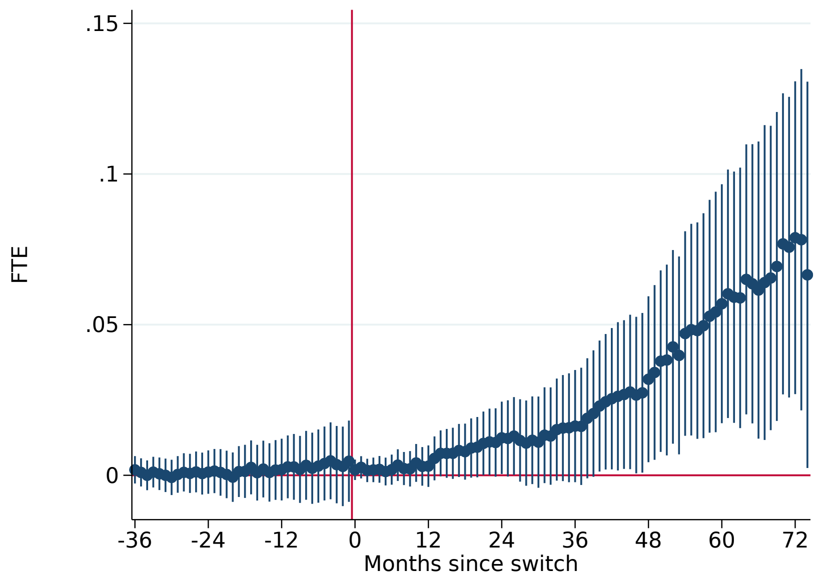
[17]Technically it is not being moved onto the new pension plan, since not all senior doctors are members of the plan, and therefore closer to an intention to treat (ITT) treatment effect. But since 99% were members pre-reform, for simplicity we interpret the estimated treatment effects as the effect of being moved.

5.1 Labour supply

We first consider total labour supply. Figure 1 shows the estimated effect of the reform on contracted FTE hours, including zeros. There is a clear upward trend in labour supply after being moved onto the new plan, which is statistically significant after three years.[18] Four years after being moved onto the new plan, senior doctors work 3% more of an FTE, and after six years they work 8% more. The average labour supply of those in our cohort is 0.91 of an FTE in 2014, prior to the introduction of the 2015 plan. So this is equivalent to a 3.5% increase after four years, and a 8.6% increase after six years.

Importantly, Figure 1 also shows that there is no statistically significant pre-trend in labour supply, with the point estimates all close to zero. This suggests that there are no time-varying anticipation effects between those moved earlier and later onto the plan that would bias our estimated treatment effects, or any differences in labour supply trends. This provides evidence against concerns that doctors change their labour supply immediately prior to being moved on to the new plan.

Figure 1: Total labour supply



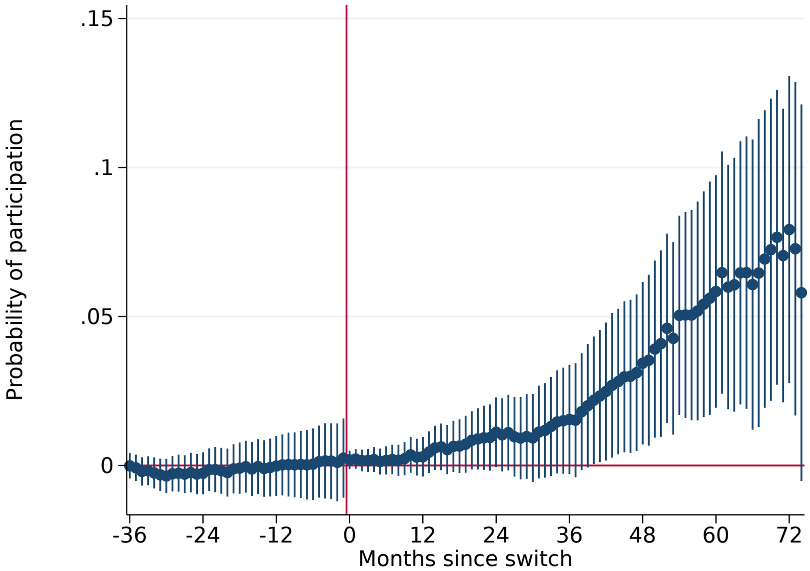
Note: The lines for each coefficient represent 95% confidence intervals.

We next decompose these changes in total labour supply into changes on the extensive and

[18] The confidence intervals grow over time because Borusyak et al. (2021)'s imputation method uses the not-yet-treated group to impute the time fixed effects, and this group gets smaller over time as more doctors are treated.

intensive margin. Figure 2 shows the extensive margin, which we measure using a dummy variable for working in the NHS as the outcome. There is again a sustained increase in labour supply after senior doctors are moved onto the new pension plan. After four years, senior doctors are 3.4 percentage points more likely to be working in the NHS, and after six years they are 7.9 percentage points more likely. Almost all (94%) of those in our cohort were working for the NHS in 2014 prior to the introduction of the plan, and so this is equivalent to a 3.7% increase after four years, and a 8.4% increase after six years. Since almost all of those in our cohort were working for the NHS prior to the reform, we interpret this increase in NHS employment as a reduction in leaving the NHS relative to the control group of doctors, leading to a *relative* increase in participation, rather than an *absolute* increase.

Figure 2: Extensive margin

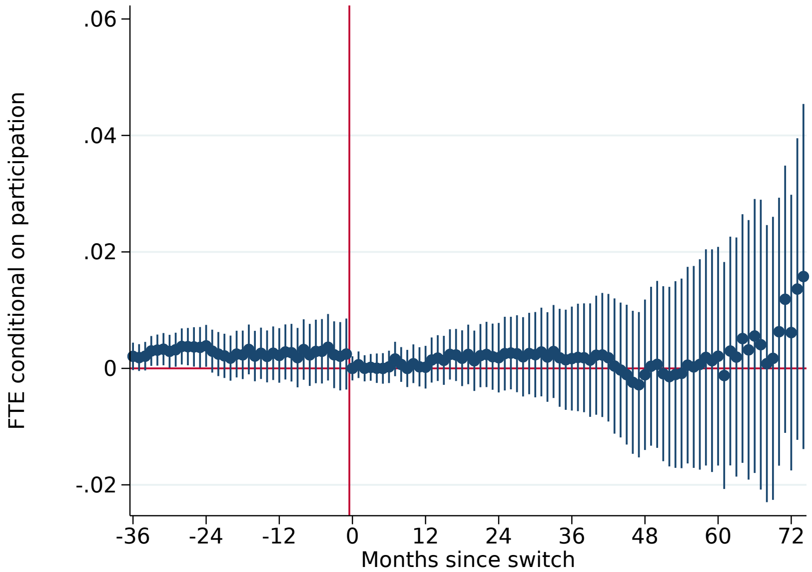


Note: The lines for each coefficient represent 95% confidence intervals.

Figure 3 shows the intensive margin, measured as FTE contracted hours conditional on working in the NHS. There is no significant change in contracted hours at any point after being moved on to the new pension plan , suggesting that the main response was on the extensive margin.[19]

[19]This may suggest that the reform did not lead to an increase in the number of senior doctors working in the private sector alongside NHS work. To start working in the private sector, full-time senior doctors must first offer an additional four hours of work per week to their NHS hospital. We would therefore expect to see an increase in FTE if the reform pushed senior doctors to work in the private sector. However, it appears that this rule is not well enforced. In our data we see that only 1.8% of consultants in our cohort in 2014 working more than 1.1 of an FTE, far fewer than the share of senior doctors that Appendix Figure A1 suggests are working privately. It could alternatively mean that our payroll data is not recording the increase in hours but this would be surprising because

Figure 3: Intensive margin (FTE contracted hours)

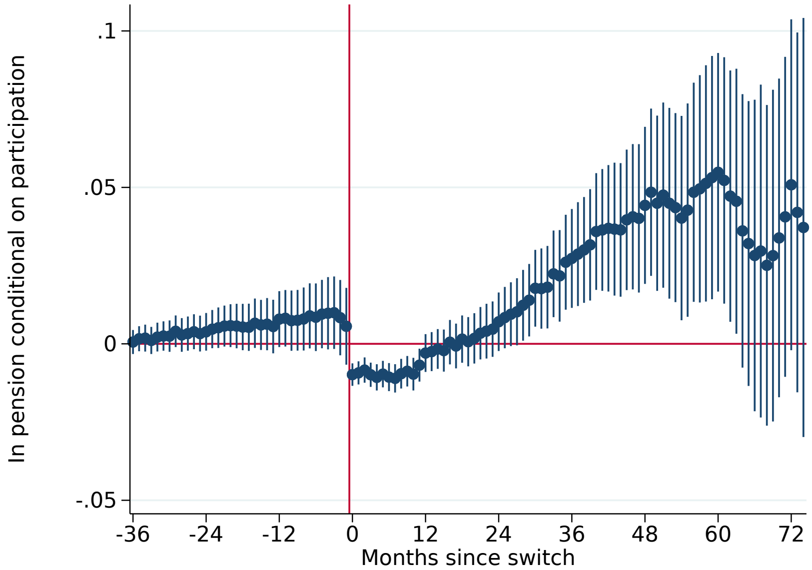


Note: The lines for each coefficient represent 95% confidence intervals.

Finally, we consider the impact of the reform on pension plan membership. Although senior doctors cannot adjust their pension contributions, we might expect them to change their membership if the pension has become substantially less generous. Figure 4 therefore shows the impact of the policy on a dummy variable for whether a senior doctor is a member of the pension plan, conditional on their NHS participation.

senior doctors would be paid for these additional hours. Appendix Figure D2 shows little change in total NHS pay conditional on participation, suggesting that there was not a large change in hours that our data is not capturing.

Figure 4: Intensive margin (Pension plan membership conditional on participation)



Note: The lines for each coefficient represent 95% confidence intervals.

There is an initial immediate drop in pension plan membership after the date of birth cohort is moved onto the new pension plan.[20] In particular, six months after being moved, there is a 1.1 percentage point reduction in the probability of being a member of the new plan. Since 99% of senior doctors were members of the plan in 2014, this is a very small reduction in membership although a large increase in non-membership. However, within a year of being moved, there is no significant difference in pension plan membership. And after two years, there is a significant increase in pension plan membership, with senior doctors 5.5 percentage points more likely to be a member five years after being moved.

The initial drop supports the view that doctors did not internalise the new plan until they were moved onto it and some reacted by moving out of the plan entirely. The subsequent increase in membership is large and possibly surprising, relative to the baseline of 99% participation in 2014. However, similarly to the results we find for the extensive margin, this increase in plan membership is likely driven by members of the new plan being less likely to leave than members of the old plans, rather than individuals rejoining the new plan. This is consistent with the change in pension rules. Under a final salary plan, it may be advantageous to leave the pension plan prior to retirement if income is expected to fall substantially, as this will lower

[20]For those that have already left the pension, the reform will have no effect. But it will matter if they decide to rejoin the pension plan.

the pension value by more than the additional year of accrual. Under the new career average plan, there is less of an incentive to do so, and so more doctors may have decided to remain in the plan until retirement. Appendix Figure C1 provides strong support for this interpretation. It shows that prior to the reform, senior doctors in their late fifties and older were much less likely to be members of the pension plan than younger senior doctors. Our results suggest that the reform reduced the size of this drop in participation, as would be expected given the change in rules.

Table 2 summarises our labour supply results. On average the new pension plan increased the labour supply of the senior doctors in our cohort, driven by an increase in labour supply on the extensive margin, rather than the intensive margin and led to an increase in pension plan membership. This change in the extensive margin of labour supply is likely caused by senior doctors on the new pension plan being less likely to leave the NHS, either directly because of the higher retirement age, or because of the reduced pension wealth. There are significant pre-trends on the intensive margin, but these are relatively small in magnitude (Figure 3) and we find no significant impacts of the reform on this margin. In comparison, there are no significant pre-trends for total labour supply or the extensive margin, where we do find major impacts of the reform.

Table 2: Summary of primary results

	(1) Total Labour Supply	(2) Extensive Margin	(3) Intensive Margin	(4) Pension plan Participation
36 months before	0.00182	-0.000111	0.00207*	0.000585
	(0.00232)	(0.00218)	(0.00120)	(0.00196)
24 months before	0.00106	-0.00261	0.00387**	0.00384
	(0.00367)	(0.00359)	(0.00183)	(0.00307)
12 months before	0.00190	-0.000172	0.00222	0.00790*
	(0.00523)	(0.00513)	(0.00239)	(0.00456)
0 months	0.00182	0.00188	0.00000422	-0.00983***
	(0.00173)	(0.00157)	(0.00106)	(0.00183)
12 months after	0.00303	0.00292	0.000203	-0.00294
	(0.00352)	(0.00338)	(0.00187)	(0.00308)
24 months after	0.0124**	0.0112*	0.00184	0.00706
	(0.00612)	(0.00596)	(0.00305)	(0.00477)
36 months after	0.0163*	0.0155*	0.00168	0.0273***
	(0.00950)	(0.00934)	(0.00455)	(0.00806)
48 months after	0.0319**	0.0343**	-0.00110	0.0443***
	(0.0140)	(0.0139)	(0.00659)	(0.0128)
60 months after	0.0569***	0.0584***	0.00209	0.0548***
	(0.0202)	(0.0199)	(0.00958)	(0.0195)
72 months after	0.0789***	0.0792***	0.00615	0.0508*
	(0.0265)	(0.0263)	(0.0121)	(0.0270)
Outcome Mean	0.880	0.910	0.970	0.962
N	1,317,792	1,317,792	1,198,717	1,198,717

Standard errors clustered at the doctor level in parentheses

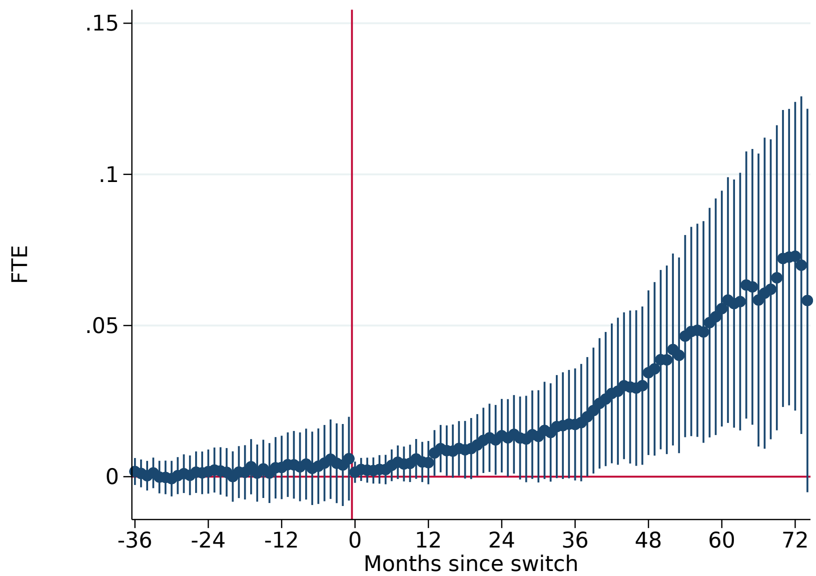
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Appendix Figure D1 estimates the total impact of the policy on our cohort. This total impact increases over time both because the estimated individual treatment effects grow over time (Figure 1) and because the staggered roll-out means that more senior doctors are moved onto the new plan over time. By the start of 2021, our estimates suggest that the reform had increased the number of FTE senior doctors working in the NHS by 666, out of a cohort of 11,900. Given the high pre-reform labour supply of senior doctors in our cohort, this increase was mainly driven by fewer senior doctors leaving the NHS than would have happened had the reform not occurred.

5.2 Robustness

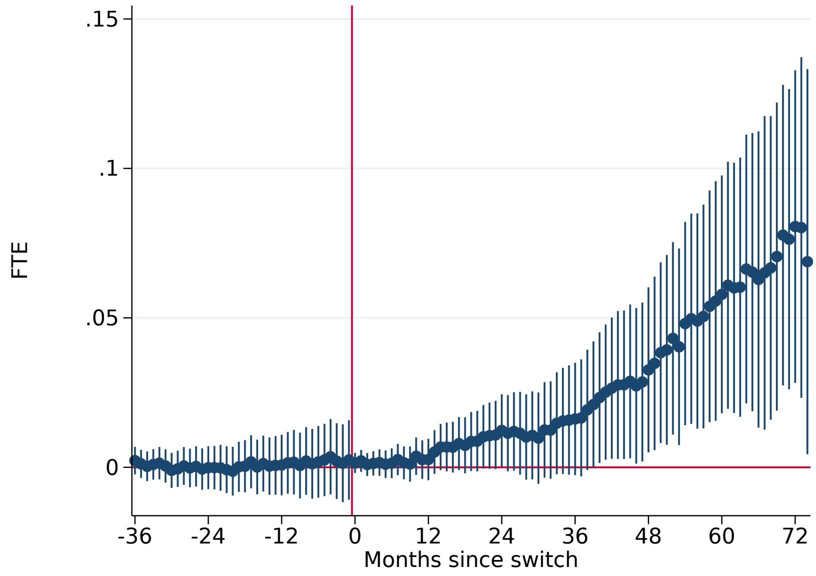
We begin by testing the robustness of our primary results to varying the definition of the treated cohort. For simplicity, we focus on our results for total labour supply. Our results above uses all senior doctors born between April 1962 and December 1969. Figure 5 shows the results if we shorten the definition of our cohort, and only include those born between April 1962 and December 1967. Figure 6 shows the results if we extend the definition of our cohort, and include those born between April 1962 and December 1971. In both cases, the results are very similar to our primary results, showing that they are not dependent on the precise boundaries of our cohort.

Figure 5: Total labour supply with a smaller cohort



Note: The lines for each coefficient represent 95% confidence intervals.

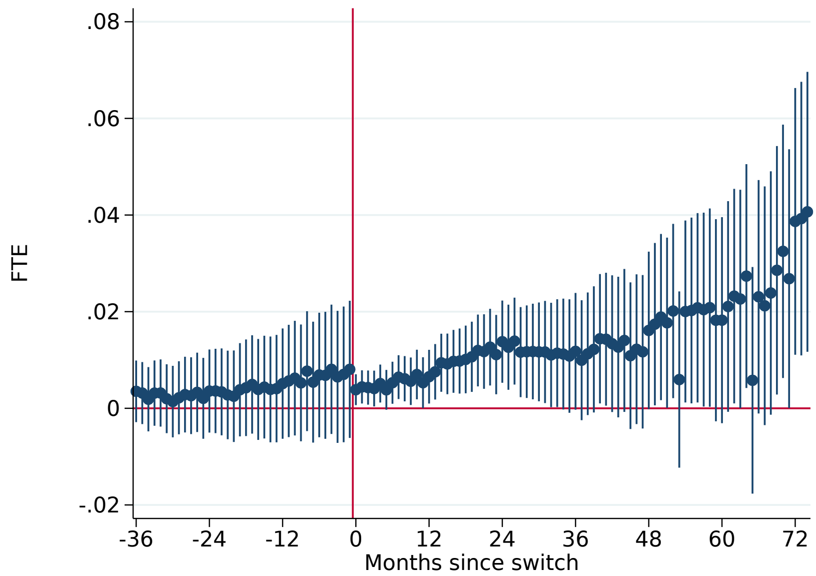
Figure 6: Total labour supply with a larger cohort



Note: The lines for each coefficient represent 95% confidence intervals.

Another potential concern is that we exclude senior doctors that were never treated from our analysis. As explained in Section 4, we exclude these doctors from our primary analysis to ensure we are comparing a similar group of doctors and to eliminate some common pre-treatment anticipation effects. To test robustness to this choice, Figure 7 repeats our primary analysis including never treated senior doctors born between January 1959 and March 1962.

Figure 7: Total labour supply with never treated senior doctors

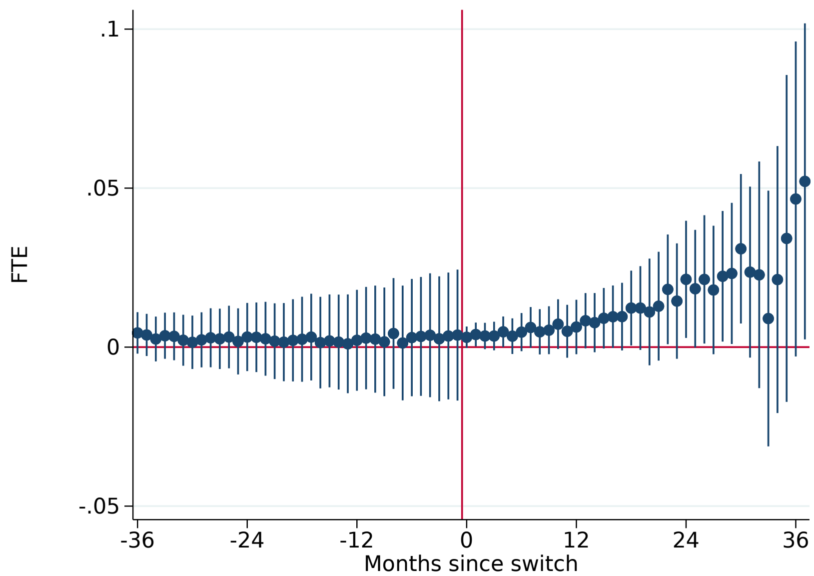


Note: The lines for each coefficient represent 95% confidence intervals.

The estimated treatment effects are similar to our primary results, although estimated somewhat less precisely: for example, four years after being moved onto the new pension plan, Figure 7 suggests that senior doctors are working 1.8% more, compared with 3.5% more in our primary analysis. However, there appears to be a small upwards pre-treatment trend in labour supply, although this is not statistically significant. This is consistent with our methodological concerns about including these never treatment senior doctors.

Second, to allow for potential trends in labour supply behaviour that are unrelated to the reform but vary across cohorts, we can include date of birth year by age fixed effects. Figure 8 shows that the inclusion of these trends eliminates these weak pre-treatment trends while still finding a qualitatively similar pattern of results. Importantly, though, these additional controls absorb some of the genuine treatment effect, since treatment is allocated based on date of birth. Moreover, due to the requirements of Borusyak et al. (2021)'s imputation estimator we can only estimate treatment effects for the first three years after being treated. This means that while the results still indicate increases in labour supply consistent with our initial results, the estimates are slightly smaller in magnitude while the standard errors are clearly much larger.

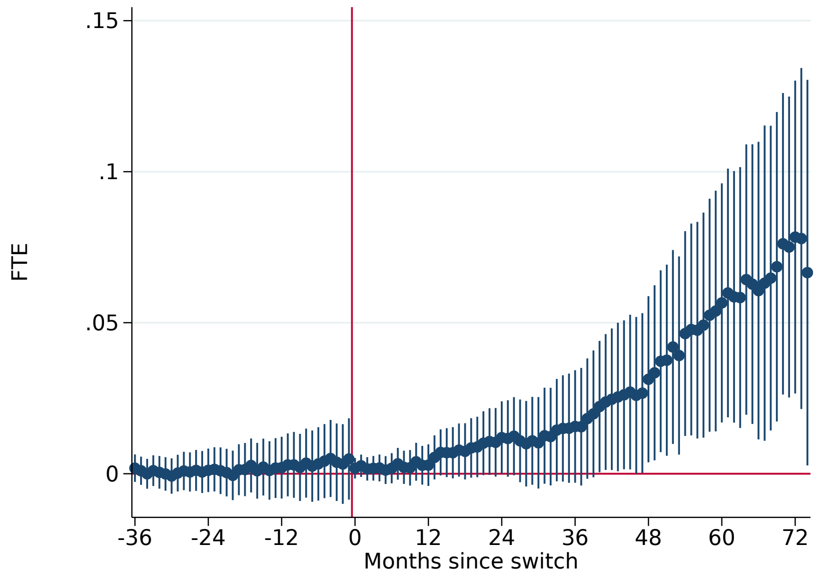
Figure 8: Total labour supply with never treated senior doctors and additional fixed effects



Note: The lines for each coefficient represent 95% confidence intervals.

Third, another potential concern is that our results may be influenced by the hospital or region in which senior doctors work. Figure 9 shows the impact of the reform on total labour supply conditional on hospital fixed effects. These capture both differences in the types of doctors working in each hospital and differences by local geography and region. The results are very similar to our primary results.

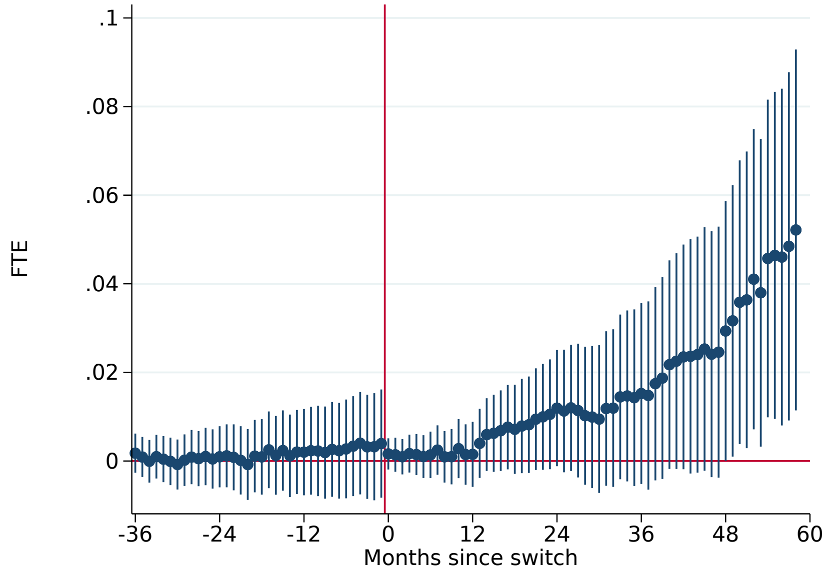
Figure 9: Total labour supply with hospital FEs



Note: The lines for each coefficient represent 95% confidence intervals.

One final potential concern is the impact of the Covid-19 pandemic, since our sample period extends to August 2021. Figure 10 repeats our primary analysis excluding March 2020 onwards from our sample. The results are qualitatively similar to our primary results, although slightly less precisely estimated. This suggests that are results are not being driven by changes in senior doctor labour supply during the Covid-19 pandemic.

Figure 10: Total labour supply excluding Covid-19 period



Note: The lines for each coefficient represent 95% confidence intervals.

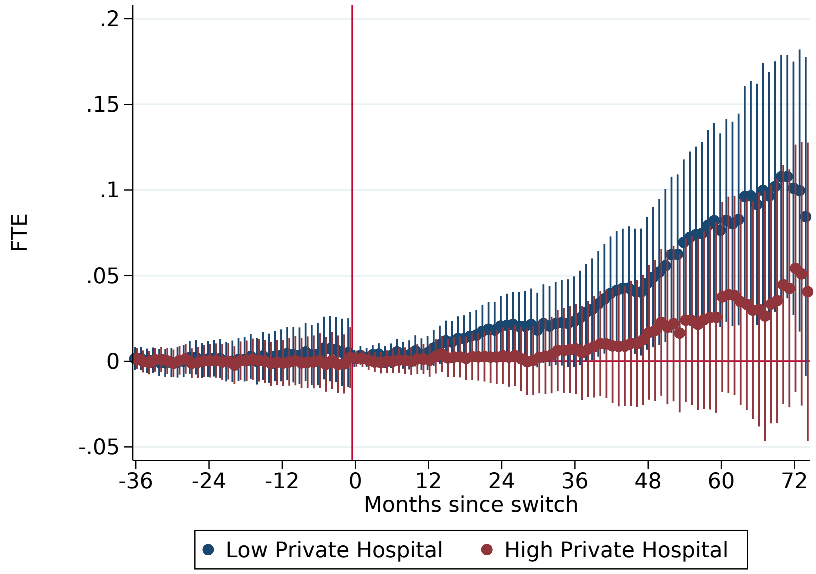
5.3 Heterogeneity

We now examine heterogeneity in the impact of the reform. One prediction of the model in Appendix A is that labour supply responses should differ by outside options. In particular, we would expect those with fewer outside options to increase their NHS labour supply in response to the reduction in retirement wealth, while the effect for those with more outside options is theoretically ambiguous.

To distinguish between these groups, we use the share of senior doctors working in the private sector in each hospital in 2022 as a measure of outside opportunities. Those with an above-median share of senior doctors working in the private sector are defined as 'high' opportunity hospitals, while those with a below-median share are defined as 'low'.[21] Data limitations mean we cannot construct this measure prior to the reform. Appendix B provides more details on the classification and data used.

[21]The distribution reflects geographical differences in the location of private hospitals and the demand for private healthcare.

Figure 11: Total labour supply by hospital private sector opportunities

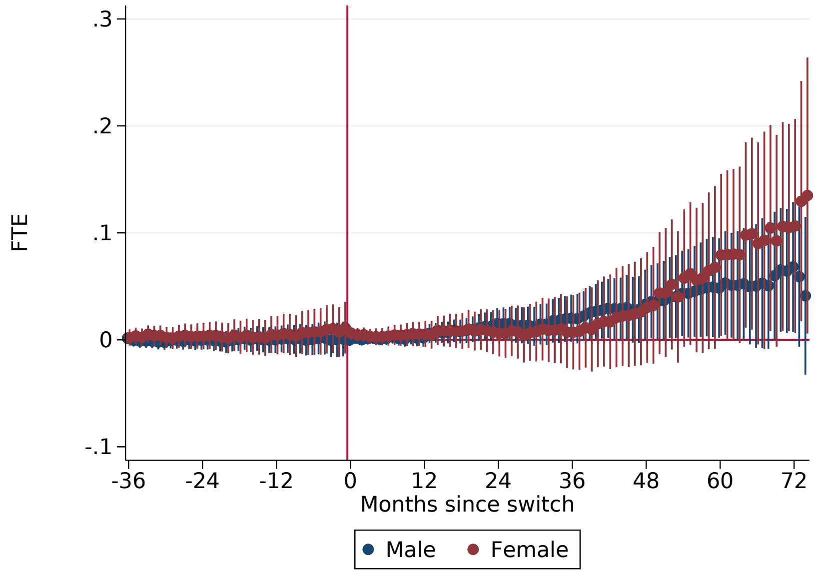


Note: The lines for each coefficient represent 95% confidence intervals. Excludes two small hospitals (3,441 observations) where private hospital data is not available.

Figure 11 shows how labour supply responses differed between senior doctors working in hospitals with high private sector opportunities and those working in hospitals with low private sector opportunities. Only senior doctors working in hospitals with low private opportunities have a statistically significant increase in total labour supply after being moved onto the new pension plan. The changes for senior doctors working in hospitals with higher private opportunities are statistically indistinguishable from zero. This is broadly consistent with the predictions of our model and highlights the importance of outside opportunities in the private medical sector for labour market responses of senior doctors in the NHS. Appendix Figure D3 shows that these results are robust to inclusion of hospital fixed effects and thus are not driven by differences in the geographical location of private opportunities.

We also examine whether the are are differences in the impact of the reform by gender. Figure 12 presents estimates from our primary analysis undertaken separately for male and female senior doctors. Overall, there is little evidence of a meaningful difference in response by gender. The point estimates for the two groups are very close (with the exception of the final few months of our estimated treatment effects) and are always well within the standard errors for each group.

Figure 12: Total labour supply by gender



Note: The lines for each coefficient represent 95% confidence intervals.

Taken together, our heterogeneity results suggest that senior doctors with greater outside opportunities increased their labour supply to the NHS by less than those with fewer outside opportunities. This is consistent with the predictions of our simple model and highlights the importance of accounting for outside labour market opportunities of medical staff when considering the impacts of changes in remuneration or other job qualities. However, we find no large differences in response to the reform by the gender of senior doctors.

5.4 Estimating labour supply elasticities

We can use our estimates of the labour supply changes to derive labour supply elasticities by treating the reform as a source of exogenous financial changes. In order to do this, we must first quantify the financial impacts of the reform. Under the assumption that the financial impacts of the reform affected labour supply in a linear and additively separable way, we then estimate elasticities by relating our estimates of the financial impacts of the reform to our estimate of the total change in labour supply in response to the reform. Appendix E has full details on the methodology used in this section.

As discussed in Section 2.3, the reform had two main financial impacts which we quantify in this section. First, it reduced the value of pension wealth, primarily by increasing the retirement age by seven years and reducing the generosity of the lump sum payments upon retirement. This is partly offset by a higher annual payment on retirement under the new plan. We measure this net reduction in pension wealth as the change in the discounted value of the pension benefits.

Second, the move from a final salary to career average pension plan increased the returns to labour supply for those more than three years away from retirement. We measure this as the discounted additional return to pension wealth of earning an additional pound during employment. This can be viewed as an increase in the effective wage rate.[22]

Because there are two financial changes, to separately identify the effect of each, we must compare the labour supply outcomes of (at least) two groups that faced different financial changes because of the reform. We therefore compare the labour supply responses and financial impacts of the reform separately for male and female senior doctors.[23] The financial impacts of the reform differed by gender for two reasons. First, women have a higher life expectancy. This means female senior doctors have a larger increase in returns to current labour supply for their pension because their pension is paid for more years on average. This higher life expectancy also means the percentage reduction in pension wealth, primarily driven by the seven year increase in retirement age, is smaller for female senior doctors because the number of years they receive their pension over is reduced by a smaller percentage. Second, male senior doctors may have different earnings profiles to female senior doctors, which means they have different wealth effects since the two pensions plans depend on earnings profiles very differently.[24] By comparing the different financial impacts on male and female senior doctors, we can therefore separately identify the effects of the two financial changes.

Table 3 summarises our estimated financial effects of the reform for those in our treatment sample. Our estimated financial impacts are large. We estimate that the value of the pension fell by 41% for male doctors and 39% for female doctors. This is mainly driven by the loss of the first seven years of pension entitlement, which is particularly costly because of discounting

[22] In both cases, we do not take into account additional pension contributions for the financial effects. This is because the reform itself did not affect the pension contribution rate.

[23] In Section 5.3 we also examine differences in labour supply responses by private sector opportunities. However, we cannot use these two groups for this analysis, because they are likely to have very different labour supply elasticities given the difference in outside labour market opportunities.

[24] In practice, this mostly but not fully offsets the difference in life expectancies.

and survival risk. We estimate that the increase in financial incentives from the higher effective wage rate was 17% for male senior doctors and 19% for female senior doctors. This means that for each additional pound earned at least three years from retirement, senior doctors now receive an additional £0.17-0.19 into their pension.

Table 3: Estimated financial effects of the reform by gender

	Male	Female
Wealth effect	-40.9%	-39.3%
Incentive effect	17.2%	19.3%

In the previous section, we examined labour supply responses to the reform by the gender of senior doctors (Figure 12). Despite the different financial impacts, there were no substantial differences in labour supply response between male and female senior doctors, and so in this analysis we assume that both groups responded equally to the reform. This implies that the differences in the change in financial incentives for men and women offset each other when impacting labour supply. Aggregating over the whole treatment horizon, we estimate that the reform caused both male and female senior doctors to increase their total labour supply by 3.0% on average, with a 95% confidence interval of 0.7% to 5.2%.

We can now combine these treatment effects with our estimates of the financial impacts of the reform to estimate labour supply elasticities, following a similar approach to French et al. (2022). This requires two simplifying assumptions. First, we assume that the underlying labour supply elasticities are the same for both male and female doctors. In general, labour supply elasticities can differ by gender, particularly between men and married women and single mothers (Meghir and Phillips, 2010). But in our case, we expect male and female senior doctors to have similar labour supply elasticities because they have the same age, occupation and level of education, and similar income and wealth. Second, we assume that the two types of financial impacts affect labour supply in an additively-separable way.

Under these assumptions, we can relate labour supply (y) to current income net of pension contributions (I), pension wealth (κ) and the returns of current labour supply to pension wealth

(τ) (the incentive effect) , where β are the responsiveness of labour supply to each component.

$$y = \beta_I I + \beta_\kappa \kappa + \beta_\tau \tau \tag{2}$$

We can use the reform as a source of exogenous variation in these financial values. To do this, we re-write Equation 2 to be in terms of percentage changes in y, I, κ and τ.[25] This eliminates income net of pension contributions (I) because the reform did not directly affect income or pension contribution rates. Since the equation is in terms of percentage changes, the responsiveness of labour supply to each component β, is replaced by the elasticity of labour supply to each component, ϵ.

$$\%\Delta y = \epsilon_\kappa \%\Delta\kappa + \epsilon_\tau \%\Delta\tau \tag{3}$$

This equation holds separately for each gender. The left hand side is the same for both, but since the financial impacts are different by gender, the coefficients on the elasticities on the right hand side are different. Since we have two equations and two unknowns (each elasticity), we can solve for the elasticities directly. Table 4 presents the results , with 95% confidence intervals in brackets. We calculate these confidence intervals by repeating our methodology to estimate elasticities but replacing our point estimate of the change in labour supply (3.0%) with the lower and upper bounds of its 95% confidence interval (0.7%, 5.2%).

Table 4: Estimated elasticities

	Estimated elasticity
Wealth, ϵ_κ	-0.0544
	[-0.0951, -0.0137]
Incentive, ϵ_τ	0.0428
	[0.0108, 0.0749]

The wealth elasticity is negative, so higher pension wealth reduces labour supply. The incentives elasticity is positive, so higher returns to current income for pension wealth (the effective wage rate) increase labour supply. We can also use these elasticities to decompose the labour

[25]We do this by first taking a first difference, then dividing by y and using the standard elasticity definition.

supply response to the reform by multiplying the average change in wealth (incentives) for all doctors by our estimated wealth (incentives) elasticity. This suggests that the reduction in pension wealth explains 74% of the total increase in labour supply, while the increase in incentives explains 26% of the total increase. This indicates that the wealth effect was the main driver of the increase in labour supply, both because the magnitude of the decrease in pension wealth was greater than the increase in incentives and because doctors were more responsive to it.

Previous work has estimated doctor wage elasticities from 0.1 to 0.5 (Lee et al., 2019). For example, Baltagi et al. (2005) estimated a short-run wage elasticity of 0.3 for male doctors in Norway. Our incentive elasticity (0.04) is very similar to a wage elasticity, and is low relative to the findings of other studies. This may be because doctors are less responsive to changes in delayed remuneration, even after discounting, relative to current wage changes. It may also be that, because of the complex nature of the pension plans and the reform, many doctors did not realise or underestimated the extent to which their current incentives had changed.

French et al. (2022) estimate a labour supply elasticity with respect to the net return to work of 0.44 for Polish employees aged 51-54 using a reform to the public pensions system. Their definition of net return to work is similar but not directly comparable to our incentive elasticity. Their estimated elasticity (0.44) is much larger than our elasticity (0.04), suggesting that doctors are less responsive to pension incentives than the whole population of workers.

Our wealth elasticity (-0.05) is more in line with findings from other studies on wider populations of workers. For example, Becker et al. (2022) estimate a wealth elasticity of -0.22 using a pension reform in Germany, with elasticities close to zero for those under 55 and much higher for those within a year or two of retirement. Banks et al. (2023) find that wealth (including pension wealth) has a positive but insignificant effect on subsequently leaving the labour market for those in work aged 50-74 in England.

Taken together, our estimated labour supply elasticities are small relative to labour supply elasticities in the literature, suggesting that our cohort of senior doctors are relatively unresponsive to changes in pension financial incentives. This low responsiveness explains why we estimate that the reform increased labour supply by only around 3.0%, a relatively small increase, despite the very large changes in financial incentives, including a reduction in pension wealth of around 40%. But as our estimates of the impact of the reform show, if changes in financial incentives are large enough, there can still be non-marginal changes in labour supply.

6 Conclusion

This paper examines the consequences of a pension reform in the English NHS on the labour supply of senior doctors. The new pension plan involved a number of changes and the reform has a theoretically ambiguous impact on labour supply. To estimate the impact of the reform, we exploit the staggered rollout of the new plan and focus on a narrow group of senior doctors born in the same period. We find that despite opposition to the reforms by doctor unions, the effect was to increase the labour supply of senior doctors. This was driven by an increase on the extensive margin, the result of both a reduction in pension wealth and an increase in current labour supply incentives.

Our results indicate that reforms to public sector pension plans do not necessarily reduce the labour supply of these key senior public sector workers even if total remuneration has fallen. Changes in total remuneration or financial incentives may therefore affect doctor labour supply in potentially unexpected ways. In our case we ascribe this to the fact that these doctors have spent many years specialising in the provision of NHS care and in many cases have few outside options, as there are limited other opportunities to practice as a doctor outside of areas with high levels of private practice. As a result, our results may also apply to other senior public sector workers, who also have specialised in provision of public sector work and/or have relatively few other opportunities to work outside the public sector (such as judges or senior members of the military or police).

Finally, we note that while our robust design means we are able to estimate the impact of the reform in detail for a set of experienced doctors, we are unable to estimate the effect on doctors starting their careers. For these individuals, the pension changes may induce less entry, less effort to attain high salaries at the end of their careers or more movement out of the NHS earlier in their careers, any of which could reduce total labour supplied to the NHS.

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A Appendix: Model

A.1 Model setup

To formalise the potential impacts of the new pension plan, we introduce a simple two-period model of labour supply. In the first period, a senior doctor chooses their NHS labour supply y_1 and their outside (private sector) labour supply y_2. The wage for labour supply in the NHS is normalised to 1, and the wage for outside labour supply is w_2. In the first period, senior doctors consume their income. In the second period, senior doctors are retired and consume the value of their pension. The value of the pension is defined as

$$P = \kappa + \tau_1 y_1 + \tau_2 w_2 y_2 \tag{A.1}$$

where τ_1 and τ_2 are the NHS and outside accrual rates, and κ is the lump-sum value of the pension, based for example on past accumulation in either sector.

Doctors have T hours available for work in the first period. Utility in each period is a function of consumption and leisure $u(c, l)$. We assume that utility is increasing and concave in both leisure and consumption. Utility over both periods is defined as

$$U(y_1, y_2) = u(y_1 + w_2 y_2, T - y_1 - y_2) + \beta u(\kappa + \tau_1 y_1 + \tau_2 w_2 y_2, T) \tag{A.2}$$

The first change from the reform is the relationship between current pay and pension value which can be modelled as a change in τ_1. The second change is the change in the value of the pension which can be modelled as a reduction in κ. We now derive the responsiveness of current labour supply (y_1) to these two financial changes. We first consider the simpler case when the doctor has no outside option, equivalent to $w_2 = 0$. We then consider the more complex case when the doctor has an outside option, equivalent to $w_2 > 0$.

A.2 Results with no outside option, $w_2 = 0$

The doctor faces the following optimisation problem

$$\max_{y_1} U(y_1, y_2) = u(y_1, T - y_1) + \beta u(\kappa + \tau_1 y_1, T) \tag{A.3}$$

The first order condition is

$$U'(y_1^*) = G(y_1^*, \tau_1, \kappa_1) = u'_{c,1} - u'_{h,1} + \beta\tau_1 u'_{c,2} = 0 \tag{A.4}$$

where, for example, $u'_{c,1}$ is the marginal utility of consumption in the first period and $u'_{h,1}$ is the marginal utility of leisure in the first period. Using the implicit function theorem,

$$\frac{\partial y_1^*}{\partial \tau_1} = -\frac{\partial G/\partial \tau_1}{\partial G/\partial y_1^*}, \quad \frac{\partial y_1^*}{\partial \kappa} = -\frac{\partial G/\partial \kappa}{\partial G/\partial y_1^*} \tag{A.5}$$

$$\frac{\partial G}{\partial y_1^*} = u''_{cc,1} + u''_{hh,1} - 2u''_{ch,1} + \beta\tau_1^2 u''_{cc,2} \tag{A.6}$$

$$\frac{\partial G}{\partial \tau_1} = \beta u'_{c,2} + \beta\tau_1 y_1 u''_{cc,2} \tag{A.7}$$

$$\frac{\partial G}{\partial \kappa} = \beta\tau_1 u''_{cc,2} \tag{A.8}$$

And so the labour supply responsiveness to the change in pensions are

$$\frac{\partial y_1^*}{\partial \tau_1} = -\frac{\beta(u'_{c,2} + \tau_1 y_1 u''_{cc,2})}{u''_{cc,1} + u''_{hh,1} - 2u''_{ch,1} + \beta\tau_1^2 u''_{cc,2}} \tag{A.9}$$

$$\frac{\partial y_1^*}{\partial \kappa} = -\frac{\beta\tau_1 u''_{cc,2}}{u''_{cc,1} + u''_{hh,1} - 2u''_{ch,1} + \beta\tau_1^2 u''_{cc,2}} \tag{A.10}$$

Equation A.6 will be negative since it is the second derivative of U and y_1^* is a maxima. The sign of A.7 is ambiguous since $u'_c > 0, u''_{cc} < 0$. By assumption $\beta, \tau_1 > 0$, $u''_{cc,2} < 0$ so A.8 will be negative. Taken together, this means that Equation A.9 has an ambiguous sign and Equation A.10 is negative.

This means that when there are no outside options, the increase in incentives for those more than three years from retirement has an ambiguous effect on labour supply. On the other hand, the reduction in pension wealth will unambiguously increase labour supply. The overall impact of the reform is therefore ambiguous.

A.3 Results with outside options, $w_2 > 0$

The doctor faces the following optimisation problem

$$\max_{y_1, y_2} U(y_1, y_2) = u(y_1 + w_2 y_2, T - y_1 - y_2) + \beta u(\kappa + \tau_1 y_1 + \tau_2 w_2 y_2, T) \tag{A.11}$$

The first order conditions are

$$U_1'(y_1^*, y_2^*) = G_1(y_1^*, y_2^*, \tau_1, \kappa) = u'_{c,1} - u'_{h,1} + \beta \tau_1 u'_{c,2} = 0 \tag{A.12}$$

$$U_2'(y_1^*, y_2^*) = G_2(y_1^*, y_2^*, \tau_1, \kappa) = w_2 u'_{c,1} - u'_{h,1} + \beta \tau_2 w_2 u'_{c,2} = 0 \tag{A.13}$$

We assume that there is an interior solution ($y_1 > 0, y_2 > 0$) which requires

$$u'_{c,1} + \beta \tau_1 u'_{c,2} = w_2 u'_{c,1} + \beta \tau_2 w_2 u'_{c,2} \tag{A.14}$$

The case where $y_1 > 0, y_2 = 0$ pre- and post-reform is the same as the no outside option discussed in the previous section. The case where $y_1 = 0, y_2 > 0$ is not relevant because our paper focuses on those initially working in the NHS.

Using the implicit function theorem,

$$\begin{pmatrix} \frac{\partial y_1^*}{\partial \tau_1} \\ \frac{\partial y_2^*}{\partial \tau_1} \end{pmatrix} = - \begin{pmatrix} \frac{\partial G_1}{\partial y_1^*} & \frac{\partial G_1}{\partial y_2^*} \\ \frac{\partial G_2}{\partial y_1^*} & \frac{\partial G_2}{\partial y_2^*} \end{pmatrix}^{-1} \begin{pmatrix} \frac{\partial G_1}{\partial \tau_1} \\ \frac{\partial G_2}{\partial \tau_1} \end{pmatrix}, \begin{pmatrix} \frac{\partial y_1^*}{\partial \kappa} \\ \frac{\partial y_2^*}{\partial \kappa} \end{pmatrix} = - \begin{pmatrix} \frac{\partial G_1}{\partial y_1^*} & \frac{\partial G_1}{\partial y_2^*} \\ \frac{\partial G_2}{\partial y_1^*} & \frac{\partial G_2}{\partial y_2^*} \end{pmatrix}^{-1} \begin{pmatrix} \frac{\partial G_1}{\partial \kappa} \\ \frac{\partial G_2}{\partial \kappa} \end{pmatrix} \tag{A.15}$$

Assuming invertibility of the Hessian of U,

$$\frac{\partial y_1^*}{\partial \tau_1} = \frac{\frac{\partial G_2}{\partial y_2^*} \frac{\partial G_1}{\partial \tau_1} - \frac{\partial G_1}{\partial y_2^*} \frac{\partial G_2}{\partial \tau_1}}{\frac{\partial G_1}{\partial y_1^*} \frac{\partial G_2}{\partial y_2^*} - \frac{\partial G_1}{\partial y_2^*} \frac{\partial G_2}{\partial y_1^*}} \tag{A.16}$$

$$\frac{\partial y_1^*}{\partial \kappa} = \frac{\frac{\partial G_2}{\partial y_2^*}\frac{\partial G_1}{\partial \kappa} - \frac{\partial G_1}{\partial y_2^*}\frac{\partial G_2}{\partial \kappa}}{\frac{\partial G_1}{\partial y_1^*}\frac{\partial G_2}{\partial y_2^*} - \frac{\partial G_1}{\partial y_2^*}\frac{\partial G_2}{\partial y_1^*}} \tag{A.17}$$

These are complex terms and we focus on their sign, rather than solving for explicit formulae.

1. The denominator of both terms is positive. Since (y_1^*, y_2^*) is the maxima of U, the Hessian of V will be negative semi definite. The denominator of both terms is the determinant of the Hessian, which will be positive since the matrix is negative semi definite.

2. The negative semi definiteness of the Hessian also means that $\frac{\partial G_1}{\partial y_1^*}$ is weakly negative. Combined with the positiveness of the determinant and Young's theorem $\left(\frac{\partial G_1}{\partial y_2^*} = \frac{\partial G_2}{\partial y_1^*}\right)$, this means that $\frac{\partial G_2}{\partial y_2^*}$ is also weakly negative.

3. The remaining terms are

$$\frac{\partial G_1}{\partial \tau_1} = \beta u'_{c,2} + \beta \tau_1 y_1 u''_{cc,2} \tag{A.18}$$

$$\frac{\partial G_1}{\partial \kappa} = \beta \tau_1 u''_{cc,2} \tag{A.19}$$

$$\frac{\partial G_2}{\partial \tau_1} = \beta \tau_2 w_2 y_2 u''_{cc,2} \tag{A.20}$$

$$\frac{\partial G_2}{\partial \kappa} = \beta \tau_2 w_2 u''_{cc,2} \tag{A.21}$$

Equation A.18 has an ambiguous sign. Equations A.19 - A.21 are all negative.

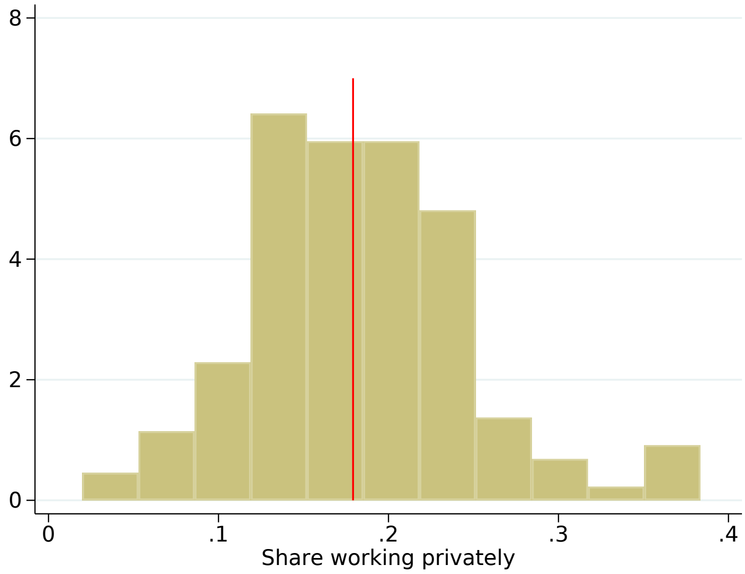
Taken together, this means that both Equations A.16 and A.17 have an ambiguous sign. Therefore, the two financial changes from the reform have ambiguous effects on labour supply, meaning the overall impact is ambiguous.

B Appendix: Additional data details

We construct the share of senior doctors in each hospital working in the private sector using two public datasets. First, we use data provided by the Private Healthcare Information Network (PHIN), an independent government-mandated organisation that publishes information about private hospitals and doctors in England (Private Healthcare Information Network, 2022). PHIN publish a list of senior doctors working in private practice, as well as their medical registration numbers. We combine this with data available from NHS Digital on senior doctors working in NHS hospitals using medical registration numbers (NHS Digital, 2022a). We use this to calculate the share of senior doctors working in each NHS hospital that are recorded as working privately. We use PHIN data from 8th November 2022 and NHS Digital data from 16th December 2022.

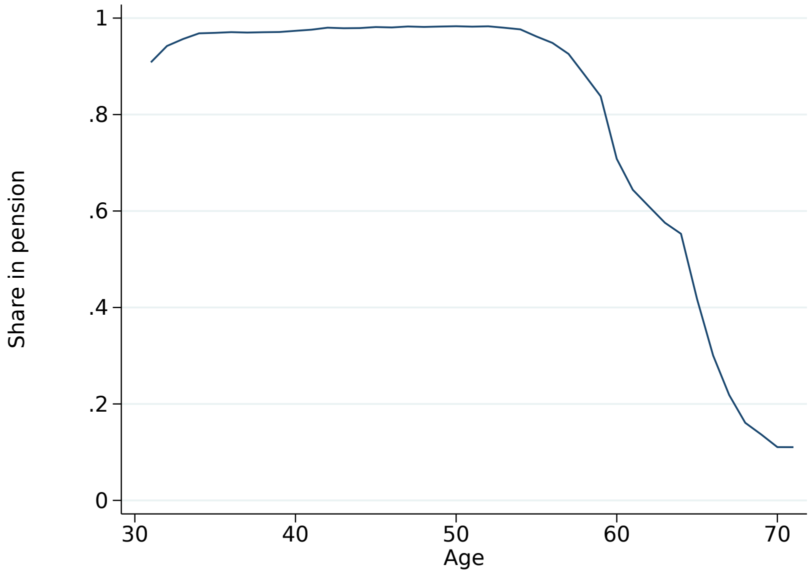
Figure A1 shows the distribution of the measure. The red line shows the median share, 17.9%. We define a hospital as having low private opportunities if their value is below the median, and as having high private opportunities if their value is above the median.

Figure A1: Distribution of share of senior doctors working in private hospitals in 2022



C Appendix: Additional descriptives

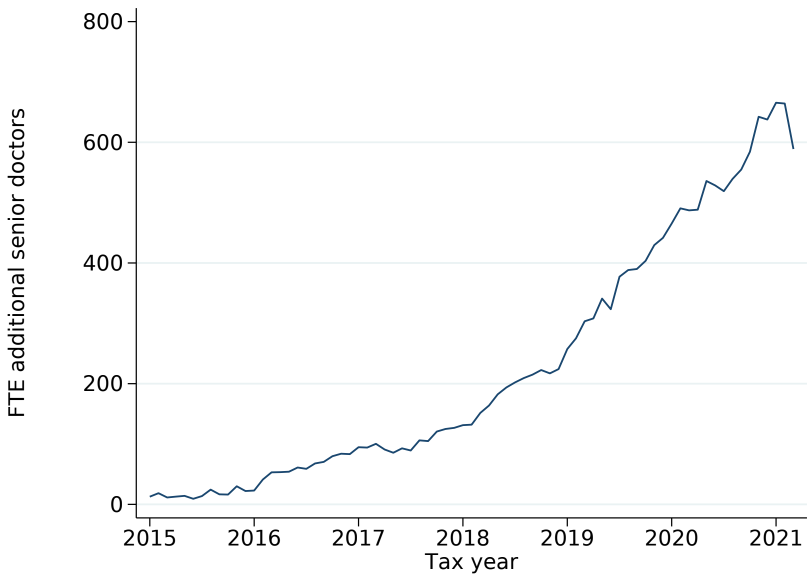
Figure C1: Average pension plan participation by age 2012-2014 conditional on NHS participation



Note: Average share of senior doctors in the NHS pension by year of age in each month between 2012-2014. Excludes ages with less than 1,000 senior doctor month observations.

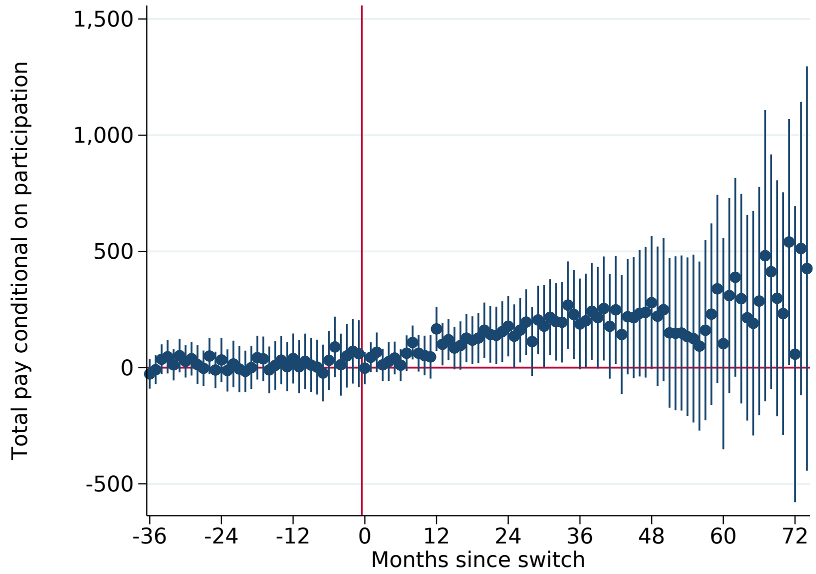
D Appendix: Additional results

Figure D1: Estimated total impact of policy



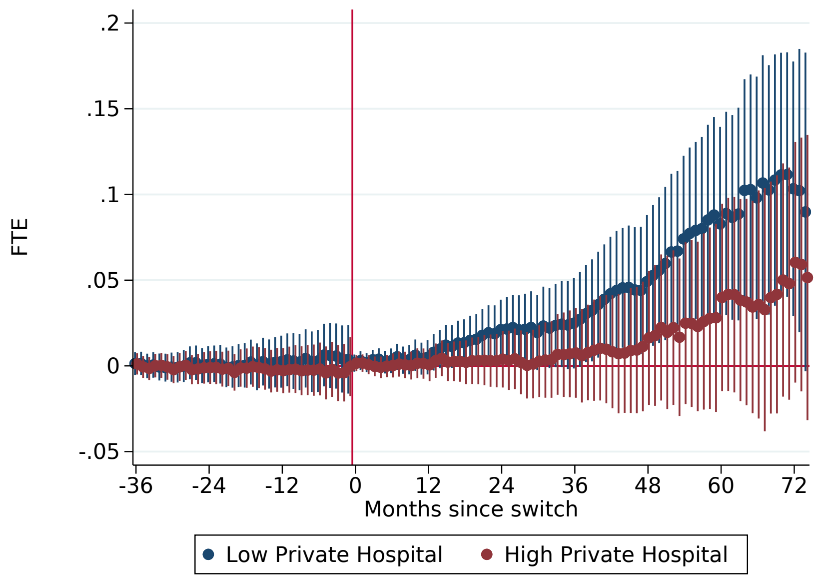
Note: Total effect in each period is calculated as the sum of each treatment coefficient multiplied by the number of senior doctors that number of months after treatment.

Figure D2: Intensive margin (Total monthly NHS pay)



Note: The lines for each coefficient represent 95% confidence intervals.

Figure D3: Total labour supply by hospital private sector opportunities with hospital FEs



Note: The lines for each coefficient represent 95% confidence intervals. Excludes two small hospitals (3,441 observations) where private hospital data is not available.

E Appendix: Calculating financial impacts of the reform

Table D1: Key parameters

Parameter	Value	Details
Real discount rate	3.0%	Superannuation Contributions Adjusted for Past Experience (SCAPE) rate in 2015. This is the discount rate used for public sector pension plans.
Expected inflation rate	2.0%	Bank of England inflation target.
Expected nominal earnings growth rate	0.5%	Growth in nominal senior doctor pay bands between 2012-13 and 2014-15.

Estimating counterfactual earnings paths. For doctors prior to treatment, we use actual earnings. For doctors after treatment, we estimate counterfactual earnings. We estimate counterfactual earnings paths using both doctors in our estimation sample prior to treatment and older doctors who were never treated (since we need earnings at older ages). We use this sample to calculate average pensionable pay for each month and year of age by gender cell. Since we are aggregating pay from different years, we deflate this pay by nominal earnings growth in NHS doctor pay bands prior to calculating this average. We then assume that nominal pay was expected to grow at the same rate as in 2012-13 to 2014-15, which was 0.5% per year.

Estimating pension values. We estimate the annual value of a pension upon retirement using the plan rules. In all cases, this depends on our assumed counterfactual earnings $\hat{y}$. For the old final salary plan, we additionally assume that doctors joined the NHS aged 25. The estimated annual value of a pension in the old plan is

$$\frac{\text{age} - 25}{80} \times \max\{\hat{y}_{\text{age}}, \hat{y}_{\text{age}-1}, \hat{y}_{\text{age}-2}\} \tag{A.22}$$

For the new career average plan we assume that CPI was expected to be constant at the Bank of England target of 2%. The estimated annual value of a pension post-reform, if you were treated at age *treat* is:

$$\frac{\text{treat} - 1 - 25}{80} \times \max\{\hat{y}_{\text{age}}, \hat{y}_{\text{age}-1}, \hat{y}_{\text{age}-2}\} + \sum_{a=treat}^{age} \frac{1}{54} \times \hat{y}_a \times (1.035)^{age-a} \tag{A.23}$$

Strategic drop-out of the final salary plan. We observe that many doctors previously would drop out of the final salary plan at least several years prior to retirement. To account for this, we estimate the probability of dropping out in the same way we estimate counterfactual earnings. We assume that nobody drops out before 55 and then there is a group specific linear drop-out curve. When then calculate the annual value of the pension as the weighted average

$$\sum_{a=55}^{age} P(\text{est. drop out at age } a)\frac{a-25}{80} \times \max\{\hat{y}_a, \hat{y}_{a-1}, \hat{y}_{a-2}\} \tag{A.24}$$

We assume there is no strategic drop-out of the new plan. In part, this is because we have no data to estimate this on as nobody in the treated group has yet reached the new retirement age. Our results also suggest that pension plan membership conditional on NHS employment has increased, suggesting there is less strategic drop-out far from the new retirement age.

Life expectancy. We use ONS life expectancy data for 2017-2019. This is for the whole population, because we do not have occupation-specific life expectancy estimates. We assume that all live to 60.

Estimating pension wealth. We estimate the entitlement value of the pension as the discounted value of the annual payment at age 60 in age 60 prices. Note that these values are held constant in real terms each year. For the old pension estimated pension wealth is

$$\sum_{age=60}^{100} P_{age}\frac{\text{old annual value} * (1+\pi)}{(1+\delta)^{age-60}} \tag{A.25}$$

For the new pension that is

$$\sum_{age=67}^{100} P_{age}\frac{\text{new annual value}/(1+\pi)^6}{(1+\delta)^{age-60}} \tag{A.26}$$

We adjust the new and old annual values in the first year of retirement to account for the lump sum values of the pension. To calculate the change in pension wealth we calculate

$$\frac{\text{PDV new pension} - \text{PDV old pension}}{\text{PDV old pension}} \tag{A.27}$$

Estimating changes in incentives. The value of earning an additional pound at age *age* is

$$\frac{1}{54} \times \frac{(1.035)^{66-age}}{(1+\pi)^{66-age}} \times \sum_{a=67}^{100} P_a \frac{1}{(1+\delta)^{a-age}} \tag{A.28}$$

The equivalent value is zero under the old plan. This can be interpreted as the percentage increase in wage rate.

Estimating elasticities Solving the simultaenous equations gives us the following equations

$$\epsilon_\kappa = \bar{\%}\Delta y \frac{\%\Delta\tau_f - \%\Delta\tau_m}{\%\Delta\kappa_m \%\Delta\tau_f - \%\Delta\kappa_f \%\Delta\tau_m} \tag{A.29}$$

$$\epsilon_\tau = \bar{\%}\Delta y \frac{\%\Delta\kappa_m - \%\Delta\kappa_f}{\%\Delta\kappa_m \%\Delta\tau_f - \%\Delta\kappa_f \%\Delta\tau_m} \tag{A.30}$$