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Financial incentives and prescribing behavior in primary care

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Abstract

Many healthcare systems prohibit primary care physicians from dispensing the drugs they prescribe due to concerns that this encourages excessive, ineffective or unnecessarily costly prescribing. Using data from the English National Health Service for 2011–2018, we estimate the impact of physician dispensing rights on prescribing behavior at the extensive margin (comparing practices that dispense and those that do not) and the intensive margin (comparing practices with different proportions of patients to whom they dispense). We control for practices selecting into dispensing based on observable (OLS, entropy balancing) and unobservable practice characteristics (2SLS). We find that physician dispensing increases drug costs per patient by 3.1%, due to more, and more expensive, drugs being prescribed. Reimbursement is partly based on a fixed fee per package dispensed and we find that dispensing practices prescribe smaller packages. As the proportion of the practice population for whom they can dispense increases, dispensing practices behave more like non-dispensing practices.

KEYWORDS
drug expenditure, financial incentives, physician agency, physician dispensing, primary care

JEL CLASSIFICATION
I11, I18, L10

1 | INTRODUCTION

Pharmaceutical drugs are a cornerstone of modern medicine and a major contributor to population health (Buxbaum et al., 2020; Lichtenberg, 2012). Most drugs are prescribed in primary care, where they are used to treat a range of common health problems such as hypertension, diabetes or bacterial infections. However, patients may not benefit from pharmaceutical prescribing to the full extent if they struggle to have their medicines dispensed, for example, because they live far away from the closest community pharmacy. In order to facilitate patients' access to drugs, some countries permit primary care physicians to dispense the medication they prescribe through their own co-located dispensaries.[1] This form of vertical integration benefits patients, who incur lower travel costs. However, it may also harm the interests of patients and funders if dispensing status incentivizes excessive, ineffective or unnecessarily costly prescribing.

In this paper, we analyze the effect of dispensing rights on the prescribing behavior of primary care physicians (general practitioners (GPs)) in the English National Health Service (NHS) using detailed quarterly data from 2011 to 2018 on the cost, volume, and pack size (drug amount per prescription) of all types of drugs prescribed in every general practice in England. We exploit the unique regulatory environment in the UK that permits general practices to dispense medicines only for patients who live more than 1 mile (1.6 km) away from the nearest community pharmacy and who have asked their practice to dispense to them. These regulations create variation in dispensing status and intensity across practices, which we use to estimate the effects of physician dispensing at the extensive margin (comparing practices which do and do not dispense) and at the intensive margin (comparing practices with different proportions of patients to whom they dispense). This provides estimates of the effects of banning dispensing entirely and of varying the conditions necessary for patients to request that their practice dispense to them and so changing the proportion of patients for whom the practice can dispense.

We control for the potential endogeneity of the practice decision to dispense to patients who request it in two ways. First, we control for selection on observables by using detailed information on the characteristics of practice patients (age by gender mix, prevalence rates for 12 chronic conditions, deprivation) and practice organisation (list size, full time equivalent number of GPs, proportion of GPs who are profit sharing partners, proportion of GPs trained in the UK, GP age) to create entropy balanced (EB) samples of dispensing and non-dispensing practices. Second, to control for selection on unobservables, we capitalize on the dispensing eligibility rule to instrument for practice dispensing status with the rurality of practice location, arguing that if the practice is in a rural area then a higher proportion of the local population will qualify for dispensing status.

Our models (OLS, EB, and 2SLS) yield the same pattern of results. Based on our most conservative estimates, OLS, the prescribed drug cost per practice patient is 3.1% higher in dispensing than in non-dispensing practices. This is due to dispensing practices prescribing more often (19.1% more prescriptions per practice patient), and prescribing more expensive drugs (1.4% higher cost per standardized prescription; 0.5% more branded vs. generic drugs). English dispensing practices receive a fee for each item they dispense and we find that they respond to this incentive by reducing the volume of drugs in each prescription by 17.0% compared with non-dispensing practices.

At the intensive margin, we find that the effect of the share of patients for whom a practice can dispense is non-linear. As the proportion of patients to whom the practice can dispense increases, the differences in prescribing between dispensing and non-dispensing practices become smaller. This suggests that physicians take account of both practice profit and patient well-being in their prescribing. Practices with a smaller proportion of dispensing patients must generate more revenue per patient to cover the fixed costs of running a practice dispensary and so respond more strongly to the effects of their prescribing on practice profit.

Our study contributes to the literature on physician dispensing and the more general literature on physician agency and supplier-induced demand (e.g., Clemens & Gottlieb, 2014; McGuire, 2000). Previous studies find both positive (Burkhard et al., 2019; Chou et al., 2003; Kaiser & Schmid, 2016; Rischatsch, 2014) and negative or non-significant effects (Ahammer & Schober, 2020; Lim et al., 2011; Trottmann et al., 2016) of physician dispensing on drug expenditure.[2] Possible channels, through which physician dispensing may increase expenditure, include volume effects (Burkhard et al., 2019; Filippini et al., 2014; Park et al., 2005; Trap, 2002) or choice of drugs with higher profit margins (e.g., Iizuka, 2012; Liu et al., 2009). The existing economic literature has mostly focused on Switzerland (where dispensing is regulated at canton level) and Asia. For England, Morton-Jones and Pringle (1993) analyzed data from 108 practices in Lincolnshire and found prescribing expenditures to be 13% higher in dispensing practices. More recently, Goldacre et al. (2019) compared the probability of prescribing four categories of high cost drugs versus therapeutically equivalent low cost drugs. They found that dispensing practices were up to five times more likely to choose high cost drugs, and that this effect intensifies as the share of eligible dispensing patients in the practice increases.

Our study makes two innovations. First, it is the first comprehensive assessment of the effects of physician dispensing in the English NHS. Contrary to previous analyses, we cover *all* pharmaceutical prescribing and do not restrict ourselves to a small, regional sample of GP practices. Second, the existing international literature has studied the effect of physician dispensing at the extensive margin only, typically relying on before-and-after comparisons (e.g., due to national bans on physician dispensing) or regulatory, time-invariant differences across large, heterogeneous jurisdictions (e.g., cantons in the Swiss context). We exploit variation in dispensing status and intensity across practices in the same geographic areas to examine behavior at both the intensive and extensive margins.

The remainder of the paper is organized as follows: Section 2 provides the institutional background and the dispensing regulation in the NHS. Sections 3 and 4 describe the data and empirical methods. Section 5 presents the results and Section 6 concludes.

2 | INSTITUTIONAL SETTING

The English NHS has a list system in primary care: patients register with a single general practice that acts as the gatekeeper to most other NHS services, including non-emergency hospital care. Almost all general practices are small businesses owned and run by partnerships of GPs who share profits and losses. In 2018, there were 7148 general practices in England with an average list size of 8279 patients and 3.37 full time equivalent GPs.

The English NHS is funded almost entirely by taxation. There is a small patient charge (£8.80 in 2018/19) when a primary care prescription is dispensed, be it by a pharmacy or an on-site GP dispensary. Around half of the population are exempt from this charge on grounds of age (under 16, in full time education and under 18, or over 60), current or recent pregnancy, specified medical conditions, and low income (House of Commons Library, 2020). As a result, approximately 90% of prescriptions are dispensed without charge, so that GPs' choice of medication is unlikely to be affected by their concerns about affordability (Crea et al., 2019; Lundin, 2000). The prescription charges that dispensing practices collect on non-exempt prescriptions are not retained by the practice.

General practices have contracts with the NHS under which they are paid by a mixture of capitation payments, quality incentives, and fee-for-service payments for a small number of services such as vaccinations. They are reimbursed for the costs of their premises and information technology but meet all other costs, such as hiring practice staff, including salaried non-partner GPs, from their revenue. There are two main type of contracts. The General Medical Services (GMS) contract is negotiated centrally by the Department of Health and Social Care and the British Medical Association, the doctors' trade union. The most common non-GMS contract is the Primary Medical Services (PMS) contract, which is negotiated between individual practices and the local healthcare purchaser (Clinical Commissioning Group (CCG)).[3] Under PMS contracts, the practice receives a lump sum for providing a set of services similar to those required by the GMS contract plus additional services for particular groups of patients. GP practice payments do not vary with the number of patient consultations whatever contract the practice holds.

There is limited formal control over the prescribing behavior of GP practices. CCGs hold the prescribing budget for their local area and have to cover losses in the case of excessive prescribing. In contrast, GP practices do not have formal prescribing budgets. Any indicative budget limits set by their local CCG are, therefore, difficult to enforce.

2.1 | General practice dispensing

Most patients who receive a drug prescription from their GP must take it to a community pharmacy in contract with the NHS to have it dispensed. Patients who would have serious difficulty in accessing a pharmacy or who live in an area which has been designated as rural in character and who are more than 1 mile (1.6 km) away from a pharmacy, can ask their general practice to dispense drugs to them.[4] The practice decision on whether to dispense is all or nothing: if it agrees to dispense to one eligible patient it must dispense to all eligible patients who request it.

In the first quarter of 2018, 980 general practices in England (14% of all practices) had agreed to dispense to 3.1 m eligible patients (5.4% of the 58.1 m patients registered with general practices). Most dispensing practices are in rural areas, as shown in Figure 1, though there are some in urban areas where a small number of patients have claimed eligibility on grounds of serious difficulty in accessing community pharmacies.

Community pharmacies and dispensaries operate under the same regulations and generate income in the same way. For example, the English NHS does not permit pharmacists to dispense a generic drug when a branded drug was prescribed ('generic substitution') and this also applies to GP dispensaries. The only relevant difference between both types in the context of our analysis is that community pharmacies are not owned and operated by the GP practice, hence there is no potential mechanism by which pharmacists' profit objective can influence GPs' prescribing behavior.

Like pharmacies, dispensing practices receive two[5] main types of payments for dispensing:

(a) a fee per prescription they dispense that is independent of the type, cost, or quantity of the drug.6 Thus, a practice is paid more for dispensing two separate prescriptions each for a month's supply of a drug than for a single prescription for 2 months' supply of the same drug. The dispensing fee declines with the total number of prescriptions dispensed in the financial year. In October 2018, the maximum dispensing fee per prescription was £2.47 and the minimum was £2.18.
(b) reimbursement for the dispensed drugs bought by the practice or pharmacy. The reimbursement is based on the manufacturers' list price, known as the Net Ingredient Cost (NIC). Dispensing practices usually buy drugs from wholesalers at a discount, which depends on a number of factors such as volume purchased or temporary promotions. The NHS reduces the reimbursement by a fraction of the NIC, known as the "clawback". The clawback increases with the total NIC of all drugs dispensed and ranges from around 3%–11%, with most dispensing practices facing the full clawback of 11%. The maximum clawback is typically less than the discount that practices receive on the NIC.

There is indicative evidence that dispensing is profitable for practices. In 2017/18, partner GPs in dispensing practices with GMS contracts had a mean pre-tax income of £121,300 compared with £104,800 for partner GPs in non-dispensing GMS

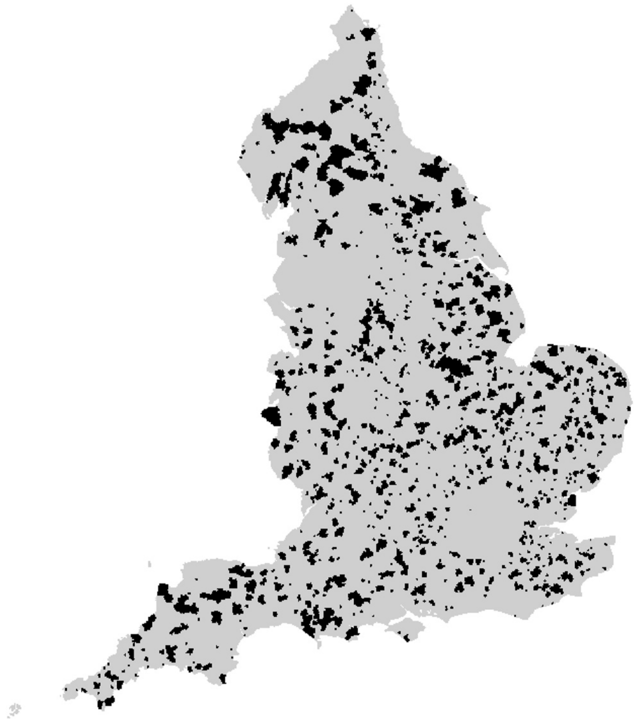

FIGURE 1 Geographic distribution of dispensing practices across England. Middle-layer super output areas (MSOAs) with at least one dispensing GP practice in Q1 2018 are in black. MSOAs with no dispensing practices are in gray (e.g., central London).

practices (NHS Digital, 2019). There is also evidence that GPs in dispensing practices have a higher hourly income (Gravelle et al., 2011). The profit margins for 20 English dispensing practices in 2010 were estimated to range from 9% to 13% using the more conservative Fully Allocated Costs (FAC) approach (PriceWaterhouse Coopers 2010).

2.2 | Physician incentives

We assume that GPs in dispensing practices, like those in non-dispensing practices, are partially altruistic (McGuire, 2000) and care about the effect of their decisions on their income and on the well-being of their patients. Practices must decide whether to dispense to all eligible patients requesting it or to none of them. GPs also decide what they prescribe and dispense to dispensing patients and what they prescribe to non-dispensing patients.[7] Patient utility depends not just on the prescriptions that they are given but also on the time, travel, and other costs of having their prescriptions dispensed in the practice or in a pharmacy. If their practice i has eligible patients and decides to dispense, the gain in utility in period t for an eligible patient h who requests that the practice dispense to them is $g^d_{hit} \geq 0$.

The utility gain G to practice i, which has eligible patients and decides to dispense, is

$$G_{it}\left(L^d_{it}\right) = \pi_{it}\left(L^d_{it}\right) - F_{it} + \alpha \sum_{h=1}^{L^d_{it}} g^d_{hit} \tag{1}$$

where $\pi_{it}\left(L^d_{it}\right)$ is the gross profit from dispensing to the L^d_{it} patients on the dispensing list, F_{it} is the fixed cost of running a dispensary and $\alpha > 0$ is a parameter reflecting GP altruism. A dispensing practice cannot control the size $\left(L^d_{it}\right)$ of its dispensing list: once it has decided to dispense, it must dispense to any eligible patient who requests it.

Gross profit from dispensing is

$$\pi_{it} = \sum_k \sum_\ell p_{it\ell k} n_{it\ell k} + r(n_{it}) + mL^d_{it} - c(n_{it}) \tag{2}$$

$p_{it\ell k}$ is the net reimbursement from the NHS for drug k dispensed in pack size ℓ: the net ingredient cost minus the clawback and the purchase price paid by the practice. $n_{it\ell k}$ is the number of dispensed prescriptions of drug type k and pack size ℓ. r (n_{it}) is dispensing fee income from dispensing $n_{it} = \sum_k \sum_\ell n_{it\ell k}$ prescriptions. m is payment per dispensing patient if the practice meets the quality standards of the Dispensing Services Quality Scheme. c (n_{it}) is the variable cost, such as additional staff, of dispensing n_{it} prescriptions.

A practice with eligible patients will choose to dispense if and only if $G_{it}\left(L_{it}^{d}\right) \geq 0$. The total utility gain to dispensing patients will increase with L_{it}^{d}. There are also likely to be economies of scale affecting total profit because of the fixed cost of setting up a dispensary. Practices can also achieve bigger discounts on larger drug purchases and use their specialist dispensary staff more productively. Thus, it is plausible that practices with more eligible patients are more likely to choose to dispense.

Practices can increase revenue from dispensing in a number of ways. They can select drugs with higher markups ($p_{it\ell k}$) in clinical situations when more than one drug option is available (e.g., brand-name vs. generic formulations of the same molecule; or different molecules) (Iizuka, 2007; Liu et al., 2009). Second, they can increase the number of prescriptions ($n_{it\ell k}$) of a given drug of a given pack size. This will increase their reimbursement $p_{it\ell k}n_{it\ell k}$ and also their dispensing fee income $r\left(n_{it}\right)$. Third, since dispensing fee income $r\left(n_{it}\right)$ varies with the number of prescriptions dispensed, not the quantities of drugs, practices will increase their dispensing fee income if they prescribe several smaller packages (smaller ℓ) rather than a single larger package with the same total quantity of the drug.

In some of these decisions GPs will be trading off patient utility against greater income. For example, they may choose drug treatment over non-pharmacological alternatives even if the latter are at least as effective. Other responses may increase patient utility as well as practice profit. For example, patients may regard receiving a prescription as a validation of their decision to consult the GP and so will be more satisfied (Ashworth et al., 2016; Zgierska et al., 2012).

If they respond to these incentives dispensing practices will have different prescribing patterns compared to non-dispensing practices: they will prescribe more expensive drugs, they will prescribe a greater total quantity of drugs, and, on average, each prescription will be for a smaller amount. In the next section, we explain how we measure practice prescribing patterns and describe the data.

3 | DATA

We link administrative data to construct a quarterly panel of GP practices for 2011–2018. The panel covers all practices in England, but is unbalanced because of practice entries, exits and mergers. For each practice, we have data on organisational structure, characteristics of the patient population, and detailed information on prescribing. Online Appendix Table A1 lists the data sources and reporting frequencies.

Our initial sample contains 233,048 practice-quarter observations on 7970 practices with complete data. We exclude two practices with unusually high prevalence rates for chronic diseases and 122 very small practices (with less than 1000 patients in at least one quarter) since these are likely to be in the process of opening or closing and this may affect their prescribing behavior. We also exclude 95 practices where dispensing status fluctuates over time. These practices have very few patients for whom they can dispense and their dispensing status varies as these patients enter or leave the practice. Given the negligible proportion of practices with within-practice variation in dispensing status we use fixed effects for CCGs, rather than practices, to control for unobserved heterogeneity.[8] Thus, we further exclude practices in CCGs where all (35 practices) or none (3351 practices) of the practices dispense to ensure within CCG variation in dispensing status. The final sample has 129,520 practice-quarter observations from 4365 practices, of which 986 are dispensing, in 118 CCGs.

The number of practices in a CCG and the number of CCGs itself varies over time due to openings, mergers and closures. In Figure A3 in the Online Appendix we present descriptive statistics for CCGs in Q1 2014, which is the last quarter in our time series when all 118 CCGs were active. There is some variation in the number of practices operating within a CCG, reflecting differences in the population for which the CCG is responsible. Whereas some CCGs have less than 100,000 patients registered with their GP practices, others serve larger and/or more densely populated areas. There is also considerable variation in the proportion of GP practices that have dispensing rights.

3.1 | Prescribing measures

The data covers all medicines, dressings and appliances prescribed by English general practices and dispensed to patients anywhere in the United Kingdom. We use the shorthand "drug" to cover all types of prescriptions.

Drugs are labeled with a 15-digit British National Formulary (BNF) code that identifies the name of the drug, whether it is generic or branded, its formulation (e.g., capsule, tablet, liquid), its strength, and the quantity (e.g., number of pills, volume of liquid). For each BNF code the data reports, for each month for each practice, the total number of prescriptions dispensed, the total quantity, and the total NIC. The latter is based on the list price for the drug excluding VAT, and does not take account of discounts, dispensing costs, or prescription charges.[9] We aggregate the data to the quarterly level at which we observe practice list size and the number of dispensing patients.

The practice prescribing data do not differentiate between prescriptions for dispensing and non-dispensing patients, nor by whether the prescription was dispensed in a community pharmacy or practice on-site dispensary.[10] Our prescribing variables are therefore measured at practice level and are a weighted average of prescribing for dispensing and non-dispensing patients. Since we do observe the share of dispensing patients in each practice we use this to test our hypotheses about the effects of having dispensing patients on the prescribing outcomes (see the discussion of methods in Section 4).

Our discussion in Section 2.2 suggests that practices with on-site dispensaries are likely to have greater drug costs per patient because they gain financially by prescribing more expensive drugs and by prescribing a greater amount of drugs. Since they also receive a fee per prescription dispensed they have an incentive to write more prescriptions with smaller drug quantities. We construct six measures of practice prescribing to test these hypotheses (Detailed definitions of the measures are in Online Appendix Table A2.)

Three measures are related to practice prescribing volume. *Prescriptions per patient* is just the total number of prescriptions divided by the practice list size. GPs can prescribe different quantities of a drug (at a given strength and formulation) to cover longer or shorter intervals of medication. We refer to this as the 'pack size'. The relative pack size for a given drug type (i.e., molecule, formulation and strength) for a practice is the ratio of the average pack size (quantity) per practice prescription of that drug type to the modal pack size across all prescriptions of this drug type across all dispensing and non-dispensing practices in England. We calculate each practice's *relative pack size* as the weighted average of relative pack sizes across all drug types in this practice, where the weights are the practice proportions of each type of drug. We expect dispensing practices to prescribe smaller relative pack sizes. To allow for this when examining the effect of dispensing status on the number of prescriptions per patient we compute *standardized prescriptions per patient* as the sum of the per patient number of prescriptions of each drug type multiplied by the practice's relative pack size for that drug type.

The other three measures are related to prescribing costs. *Cost per standardized prescription* is total NIC per standardized prescription. *Proportion generic drugs* is the proportion of standardized prescriptions, which are for generic drugs. Generic drugs are usually cheaper than equivalent brand-name versions and GPs are encouraged by the NHS to prescribe generic drugs whenever possible. However, prescribing cheaper drugs is likely to reduce dispensing practice income and so we compare the proportion of generic prescriptions in dispensing and non-dispensing practices. Finally, *cost per patient* is total NIC per patient. This will be greater in dispensing practices if they have more standardized prescriptions per patient and higher cost per standardized prescription.

3.2 | Practice and patient characteristics

We have quarterly data on practice list size and the number of patients for whom practices can dispense. We measure practice organisational structure using annual data on the number of full time equivalent GPs, the proportion of them who are partners (and so residual claimants on practice profit), rather than salaried, their age, gender and whether they qualified in the UK or elsewhere. We also know the type of practice contract with the NHS (GMS vs. all other types).

To control for differences in patient case-mix across practices, we use data on patient demographics (14 age by gender categories). We attribute a measure of average patient deprivation to each practice by using the proportions of practice patients residing in each Lower Super Output Area (LSOA)[11] and the Index of Multiple Deprivation (IMD) for each LSOA. We have annual prevalence data for 12 chronic conditions treated in primary care, which are reported for each practice as part a national pay for performance program - the Quality and Outcomes Framework (QOF).

We classify practices as being in a rural area if the practice is located in a LSOA that is classified by the Office for National Statistics (2016) as being a rural town, or village, or hamlet, or containing mostly isolated dwellings.

4 | METHODS

We study the effect of GP dispensing on our prescribing measures both at the extensive margin, comparing practices that do and do not dispense, and at the intensive margin, comparing dispensing practices dispensing to different proportions of their list.

4.1 | Extensive margin

Our baseline regression model is

$$y_{ijt} = \beta_0 + \beta x_{it} + \delta D_{ij} + \omega_t + \gamma_j + \varepsilon_{ijt} \tag{3}$$

where y_{ijt} is the prescribing measure for practice i in CCG j in quarter t, x_{it} is a vector of practice and patient characteristics, D_{ij} is an indicator for practice dispensing status, ω_t are quarter t fixed effects, γ_j are CCG fixed effects, and ε_{ijt} is a zero mean error. The coefficient of interest is δ, which measures the average difference in prescribing behavior between dispensing and non-dispensing practices.

A practice's dispensing status may vary over time due to changes in their patient population or local market entry of community pharmacies. However, during our study period, dispensing status was essentially time-invariant, with only 95 out of 7970 (1.2%) practices in our sample changing status over time. We therefore do not use practice fixed effects to control for time-invariant unobserved practice factors not picked up in x_{it} because, with very few practices changing dispensing status, the effect of dispensing status would be extremely imprecisely estimated. Instead, we model dispensing status as a time-invariant practice characteristic and exclude the 95 practices that switch dispensing status at any time in the study period. We use CCG fixed effects and drop CCGs where all or no practices have dispensing patients to ensure variation in dispensing status across the, on average, 40 practices within each CCG. The CCG fixed effects are expected to absorb a large part of unobserved heterogeneity. CCGs can influence the prescribing of its practices via its clinical governance procedures and local prescribing incentive schemes. Local hospital provision and policies can also affect practice prescribing. For example, practices in areas where patients wait longer for hip replacements may prescribe more pain killers. The CCG effect will also allow for local area characteristics, such as air quality, availability of open spaces and the quality of the housing stock, which may affect patient morbidity and, hence, prescribing. We cluster standard errors at CCG level.

The model includes a rich set of GP and patient characteristics in x_{it} to reduce concerns over differences in patient or GP characteristics that affect prescribing and the practices' decisions to dispense. However, there may still be residual differences in observed and unobserved characteristics between dispensing and non-dispensing practices in the same CCG that would bias our estimates. We use two separate strategies to deal with this.

First, we pre-process our data using Entropy Balancing (EB) (Hainmueller, 2012) to reduce imbalance in observable characteristics that may determine selection into treatment.[12] EB is a re-weighting approach in which the weights for each observation are chosen to approximately equalize pre-specified moments of the covariate distributions between the treatment and the control group. The pre-processed data are then analyzed using weighted least squares controlling for observable characteristics. The resulting estimates have been shown to have doubly-robust properties (Zhao & Percival, 2016), which reduces model dependence and misspecification bias (Robins, 1994). Assuming that observable and unobservable practice characteristics are highly correlated, EB yields unbiased estimates of the effect of treatment (dispensing status). We require the weighted data to exhibit balance in both the means and the variances of all covariates, including CCG membership. By definition, no set of weights can satisfy these requirements for practices in CCGs without any (or with only) dispensing practices, and practices in these CCGs are therefore dropped from the sample. Analysis of the re-weighted data using weighted least squares recovers the average treatment effect on the treated (ATT), that is, the consequences of a policy banning dispensing by practices. Inference is conditional on the estimated weights.

Second, we use an instrumental variable (IV) strategy to control for potential selection into dispensing status based on unobservable patient or practice characteristics. Note that the regulatory framework of the NHS prohibits practices that do not treat eligible patients (e.g., those located in urban areas with close proximity to community pharmacies) from opting into dispensing services.[13,14] To address endogenous selection, we estimate two-stage least squares (2SLS) models on our unweighted data using a binary measure of the potential local demand for physician dispensing that each GP practice faces as an instrument for observed dispensing status.[15] Specifically, our IV (Z_i) is an indicator for whether GP practice i is located in a rural area (see Section 3.2). Assuming that GPs are at least partially altruistic, we expect practices that are located in rural areas where the population lives further from community pharmacies to be more likely to dispense. Moreover, given the fixed cost of practice dispensaries, greater local demand for physician dispensing means that practices are more likely to at least break even financially, and so be more likely to dispense.

If patient health differs between rural and non-rural areas then rurality may have a direct effect on prescribing. However, our covariates include the practice-level prevalence rates for 12 chronic health conditions which will control directly for important aspects of health. We also include 14 practice patient age by gender proportions and a measure of deprivation that will pick up differences in prescribing associated with health conditions that vary with demography or deprivation. We therefore argue that the rurality instrument is likely to satisfy the exclusion condition.

4.2 | Intensive margin

Our practice prescribing measures are weighted averages of prescribing to dispensing and non-dispensing patients, where the weights are the proportions of dispensing patients in each practice i. Thus,

$$y_{ijt} \equiv s_{ijt} y_{ijt}^{d}(s_{ijt}) + (1 - s_{ijt}) y_{ijt}^{nd} = y_{ijt}^{nd} + s_{ijt}\left[y_{ijt}^{d}(s_{ijt}) - y_{ijt}^{nd}\right] = y_{ijt}^{nd} + \Psi(s_{ijt}) \tag{4}$$

where y^{d}_{ijt} and y^{nd}_{ijt} are the prescribing measures for dispensing and non-dispensing patients, s_{ijt} is the proportion of patients to whom the practice dispenses, and $\Psi(s_{ijt})$ is the effect on practice prescribing of having a proportion s_{ijt} of patients to whom it prescribes.

In the analysis at the extensive margin (3), the estimated coefficient δ on the indicator D_{ij} for being a dispensing practice recovers $E\left[\Psi(s_{ijt})|s_{ijt} > 0\right]$. We now seek to establish how $\Psi(s_{ijt})$ varies with $s_{ijt} \in (0, 1]$. For simplicity, we assume that Ψ_{ijt} is quadratic in s_{ijt}, so that

$$\Psi\left(s_{ijt}\right) = \psi_1 s_{ijt} + \psi_2 s_{ijt}^2 \tag{5}$$

$\psi_2 \neq 0$ would indicate that GP practices change their prescribing behavior for dispensing patients relative to non-dispensing patients as the proportion of dispensing patients in the practice varies. For example, as the proportion of dispensing patients increases, the fixed cost of operating a dispensary are spread over more patients and semi-altruistic practices have a reduced financial incentive to prescribe differently for dispensing patients and so $\psi_2 < 0$.

We estimate the intensive margin model on the sub-sample of practices with a positive number of dispensing patients $s_{ijt} > 0$ in all quarters. We exploit variation within these practices in the proportion of their patients to whom they can dispense drugs. This variation is exogenous within and between practices once a dispensary has been established since dispensing practices cannot exclude any eligible patients from drug dispensing services without stopping dispensing to all their dispensing patients. GP practice dispensing status is time-invariant in this sub-sample and so any inter-temporal variation in the number of patients receiving dispensing services is solely the effect of variation in local demand and not an effect of a practice's decision to dispense.

We use similar covariates as in the extensive margin model in Equation (3) but replace the binary dispensing status variable with the share of dispensing patients s_{ijt} and its squared value so that

$$y_{ijt} = \alpha_i + \beta x_{it} + \psi_1 s_{ijt} + \psi_2 s_{ijt}^2 + \omega_t + \varepsilon_{ijt} \tag{6}$$

where α_i is a practice fixed effect. Since we have limited within GP practice variation in s_{ijt}, we also estimate a model with CCG fixed effects instead of practice fixed effects. Standard errors are clustered at CCG level.

5 | RESULTS

5.1 | Descriptive statistics

Table 1 presents the descriptive statistics by practice dispensing status for the prescription measures, practice and patient characteristics as well as the distance measure for the extensive margin estimation sample. Figure A1 in the Online Appendix presents kernel density plots for the prescribing indicators.[16] Twenty-three percent (986) of practices dispense to eligible patients. These practices prescribe, on average, more and smaller packages than non-dispensing practices. They also have higher net ingredient costs (NIC) per patient. Dispensing practices also appear to be more homogeneous in their prescribing behavior as indicated by the lower variance of the prescribing indicators. Dispensing practices have slightly smaller list sizes, more GPs per patient, and a higher proportion who qualified in the UK. They also have somewhat older patients. Dispensing practices have higher rates of disease prevalence, except for chronic obstructive pulmonary disease and mental health problems, but their patients are less deprived than those in non-dispensing practices.

The average dispensing practice has dispensing rights for approximately 3200 patients, or 47% of their list in the final sample (Figure 2). There is substantial variation in the number of dispensing patients across practices, with some practices dispensing for over 10,000 patients. The share of dispensing patients in dispensing practices ranges from nearly 0% to 100% and has a bimodal distribution.

5.2 | Extensive margin

Table 2 presents the estimated effects of dispensing status on the prescribing measures.[17] The OLS results are consistent with the predictions in Section 2.1: dispensing practices prescribe more drugs, drugs that are more expensive, and in smaller pack sizes. They have 0.9 more prescriptions per patient and quarter with, on average, 16.9% (=100*(−0.22/1.29)) smaller packages compared to non-dispensing practices. After standardizing for package size, dispensing practices still issue 0.1 more prescriptions per patient and quarter. The average NIC per prescription is £0.10 higher than in non-dispensing practices and they prescribe fewer generic drugs that cost less than branded alternatives. Overall, the differences in prescribing behavior are

TABLE 1 Descriptive statistics by practice dispensing status for the final sample.

	Dispensing practices		Non-dispensing practices	
	Mean	**SD**	**Mean**	**SD**
Prescribing measures				
Prescriptions per patient	5.59	1.31	4.66	1.39
Relative pack size	1.11	0.16	1.29	0.23
Prescriptions (standardized) per patient	6.16	1.31	5.82	1.47
Cost per standardized prescription	6.73	0.71	6.69	0.75
Proportion generic prescriptions	0.80	0.06	0.79	0.06
Cost per patient	41.11	7.65	38.56	8.98
Organisational structure of practice				
List size	7819.70	4684.60	8255.10	4669.57
Full-time equivalent GPs per 1000 patients	0.52	0.30	0.46	0.26
GP partners (%)	0.69	0.24	0.69	0.28
UK-Trained GPs (%)	0.65	0.36	0.54	0.38
Age structure of GPs (proportion)				
Age <40	0.27	0.22	0.28	0.24
Age 40–59	0.66	0.25	0.60	0.28
Age 60+	0.07	0.16	0.12	0.24
Contract type				
GMS	0.75	0.43	0.62	0.49
other (Incl. PMS)	0.25	0.43	0.38	0.49
Located in rural area (%)	0.71	0.46	0.10	0.30
Patient characteristics				
Age-sex proportions				
Male - 0–4	0.02	0.01	0.03	0.01
Male - 5–19	0.08	0.01	0.09	0.01
Male - 20–44	0.13	0.02	0.17	0.04
Male - 45–59	0.11	0.01	0.10	0.01
Male - 60–74	0.10	0.02	0.08	0.02
Male - 75–84	0.03	0.01	0.03	0.01
Male - 85+	0.01	0.00	0.01	0.00
Female - 0–4	0.02	0.01	0.03	0.01
Female - 5–19	0.08	0.01	0.08	0.01
Female - 20–44	0.13	0.02	0.16	0.03
Female - 45–59	0.11	0.01	0.10	0.02
Female - 60–74	0.10	0.02	0.08	0.02
Female - 75–84	0.04	0.01	0.03	0.01
Female - 85+	0.02	0.01	0.01	0.01
Prevalence of chronic conditions (%)				
Coronary heart disease	3.78	0.91	3.47	1.06
Stroke	2.10	0.55	1.85	0.61
Hypertension	15.99	2.81	14.35	3.39
Chronic obstructive pulmonary disease	1.81	0.62	1.96	0.84

TABLE 1 (Continued)

	Dispensing practices		Non-dispensing practices	
	Mean	SD	Mean	SD
Cancer	2.92	0.77	2.29	0.83
Mental health problems	0.64	0.22	0.85	0.345
Asthma	6.45	0.96	6.15	1.15
Heart failure	0.85	0.34	0.78	0.35
Palliative care	0.35	0.37	0.30	0.31
Dementia	0.74	0.36	0.71	0.41
Atrial fibrillation	2.20	0.59	1.74	0.67
Cardiovascular disease (aged 30–74)	1.92	1.10	1.77	1.03
Index of multiple deprivation (2015)	0.09	0.03	0.14	0.07
Practices	986		3379	
Practice-quarter observations	30,171		99,349	

Note: Data: quarter-practice level 2011Q1 to 2018Q4. See Online Appendix Table A1 for sources. All prescribing measures, except prescriptions per patient and cost per patient, are standardized by relative pack size.

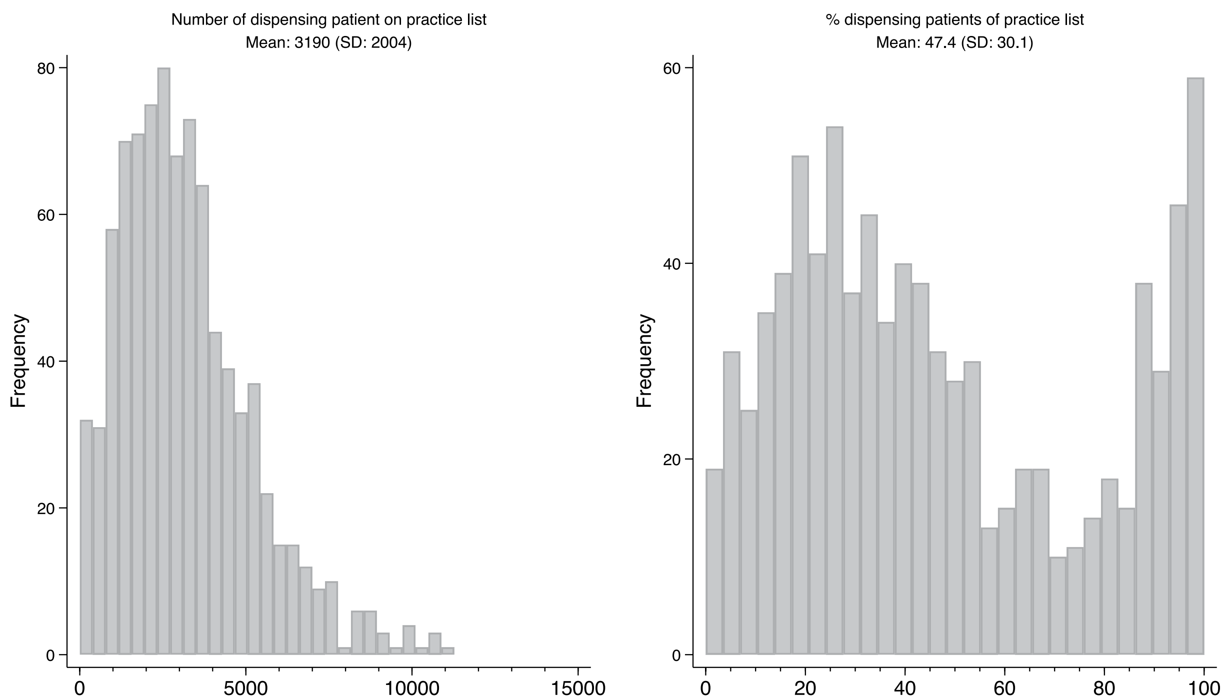

FIGURE 2 Number and share of dispensing patients in dispensing practices in the analysis sample.

associated with an additional expenditure of £1.18 per patient per quarter, or (100*(1.18/38.56)) = 3.1% of the mean quarterly expenditure per patient for non-dispensing practices. For a dispensing practice of average list size, this amounts to £36,914 of additional prescribing expenditure per year.

Some of the differences in observable characteristics between dispensing and non-dispensing practices may not be fully accounted for by OLS regression adjustment. EB equalizes the first two moments of the covariate distributions (see Online Appendix Table A4 for descriptive statistics). The resulting WLS estimates are generally in line with the OLS estimates, although the estimated effects of dispensing status on the prescription costs per patient and the number of (standardized) prescriptions issued are 35% and 44% larger than under OLS.

The 2SLS estimates allow for selection into treatment due to unobservable practice characteristics and identify LATEs. The IV is the rurality classification of the local area in which the GP practice is located (Section 4.1). It is a strong predictor of dispensing status with an effective F-statistic of 246.9 that exceeds the critical value of 37.4 as suggested by Olea and

TABLE 2 Effect of dispensing status at the extensive margin.

	Pooled OLS		EB		2SLS		Score test statistic
	Est	SE	Est	SE	Est	SE	
Prescriptions per patient	0.881***	0.043	0.891***	0.045	1.315***	0.100	33.26***
Relative pack size	−0.217***	0.011	−0.206***	0.015	−0.341***	0.026	42.16***
Prescriptions (standardized) per patient	0.096***	0.030	0.138***	0.037	0.027	0.079	1.17
Cost per standardized prescription	0.089***	0.023	0.108***	0.028	0.168***	0.052	3.22*
% Generic prescriptions	−0.004*	0.002	−0.006**	0.003	−0.002	0.005	0.16
Cost per patient	1.180***	0.200	1.599***	0.234	1.017*	0.565	0.10
Practice-quarter observations	129,520		129,520		129,520		
Effective F-statistic of excluded instrument	246.9						

Note: All models control for characteristics of the patient population and the organisational structure of the practice. Quarterly data 2011Q1 to 2018Q4. Standard errors are clustered over 118 CCGs. The robust score test (Wooldridge, 1995) is used to test for endogeneity of dispensing status.

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

TABLE 3 Extensive margin - alternative adjustments for selection on observables for the final sample.

	EB		NNM		IPWRA	
	Est	SE	Est	SE	Est	SE
Prescriptions per patient	0.891***	0.045	0.998***	0.009	0.927***	0.012
Relative pack size	−0.206***	0.015	−0.237***	0.002	−0.217***	0.003
Prescriptions (standardized) per patient	0.138***	0.037	0.124***	0.009	0.125***	0.012
Cost per standardized prescription	0.108***	0.028	0.173***	0.005	0.107***	0.006
Proportion generic prescriptions	−0.006***	0.003	−0.008***	0.001	−0.005***	0.001
Cost per patient	1.599***	0.234	1.896***	0.052	1.559***	0.064
Practice-quarter observations	129,520		129,520		128,600	

Note: Standard errors of EB and IPRWA estimates are clustered at CCG level. All models control for a full set of covariates for characteristics of the patient population and the organisational structure of the practice. Quarterly data 2011Q1 to 2018Q4 (Sources see Online Appendix Table A1). Estimates are ATTs. All estimations were performed using Stata's teffects routine.

Abbreviations: EB, entropy balancing; NNM, 1:1 nearest-neighbor matching without replacement with Abadie-Imbens SEs (Abadie & Imbens, 2006); IPWRA, inverse probability weighting with regression adjustment.

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

Pflueger (2013) (see Online Appendix Table A5 for first stage results). The resulting point estimates are broadly consistent with the OLS and EB estimates although they tend to be larger in magnitude.[18] However, the 2SLS estimates do not support the notion that dispensing practices prescribe a statistically significantly greater quantity of drugs after adjusting for pack sizes, or a lower share of generic drugs, or have a higher cost per patient. Furthermore, the robust score test (Wooldridge, 1995) fails to reject the null hypothesis of exogeneity conditional on other modeled covariates for the number of standardized prescriptions per patient ($p = 0.282$), share of generic prescriptions ($p = 0.686$), and cost per patient ($p = 0.753$). We, therefore, put more weight on the more efficient OLS and EB estimates to judge the effect of dispensing status on these three outcomes.

We conducted several sensitivity analyses. Table 3 shows that our results are robust to alternative adjustments for selection on observables, namely 1:1 nearest neighbor matching (NNM) without replacement and inverse probability weighting with regression adjustment (IPWRA) for the observations on the common support (128,600). Both methods allow calculation of the ATT under the assumption that practices do not select into dispensing based on unobservable characteristics. Online Appendix Tables A7 and A8 show that the results are robust to (i) restricting the sample to a balanced panel of practices that contribute data in all quarters of the data, and (ii) not restricting to CCGs with all or none of the practices dispensing.[19]

5.3 | Intensive margin

Table 4 presents our estimates of ψ_1 and ψ_2 from the intensive margin model (6). Most (97.5%) of the variation in the share of dispensing patients in our sample is between GP practices so that point estimates are poorly identified when GP fixed effects

TABLE 4 Effect at intensive margin - dispensing practices only.

	Pooled OLS		CCG fixed effects		GP fixed effects	
	Est	SE	Est	SE	Est	SE
Prescriptions per patient						
ψ_1	0.878***	0.106	0.914***	0.091	0.129	0.135
ψ_2	−1.424***	0.280	−1.239***	0.264	−0.472	0.320
Relative pack size						
ψ_1	−0.156***	0.025	−0.159***	0.023	−0.039	0.034
ψ_2	0.362***	0.054	0.302***	0.052	0.118	0.104
Prescriptions (standardized) per patient						
ψ_1	0.235**	0.097	0.238***	0.081	0.067	0.217
ψ_2	0.017	0.197	−0.041	0.199	−0.183	0.537
Cost per standardized prescription						
ψ_1	0.206***	0.067	0.115**	0.052	0.3030**	0.148
ψ_2	−0.655***	0.194	−0.348**	0.162	0.285	0.337
Proportion generic prescriptions						
ψ_1	−0.015**	0.006	−0.012**	0.006	−0.005	0.020
ψ_2	−0.047***	0.013	−0.035**	0.014	−0.067	0.050
Cost per patient						
ψ_1	2.259***	0.582	1.715***	0.477	1.315	1.078
ψ_2	−5.049***	1.573	−3.204**	1.470	2.502	2.278
Practice-quarter observations	30,171		30,171		30,171	

Note: All models control for a full set of covariates for characteristics of the patient population and the organisational structure of the practice. Standard errors are clustered over 118 CCGs. ψ_1 and ψ_2 denote the regression coefficients on the share of dispensing patients s_{ijt} and s_{ijt}^2, respectively. See Section 4.2 for further details.
***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

are included in the model. We therefore focus on the model with CCG fixed effects that capture unobserved differences at the regional level.[20] In line with the pooled OLS and EB + WLS results at the extensive margin (Table 2), we find that dispensing status increases prescribing costs, prescriptions per patient, and the cost per prescription but reduces pack size and % generic prescribing.[21]

In addition, our estimates of ψ_2 suggest a diminishing marginal effect of dispensing share on most prescribing measures. Put differently, GPs in dispensing practices prescribe more similarly to those in non-dispensing practices when the share of patients for whom they can dispense is higher. This might suggest that semi-altruistic practices open dispensaries despite having a small share of eligible patients and have a greater financial incentive to prescribe more dispensing patients to cover their fixed costs. However, this tendency is often small in magnitude and does not hold for the number of prescriptions (standardized) per patient, and the proportion of prescriptions for generic drugs.

Figure 3 plots the predicted values of parametric regression models assuming either a linear or quadratic relationship between s_{ijt} and the prescribing measures of interest. In addition, a spline model with 20 equally spaced knots serves as a non-parametric approximation of these relationships. See Figure 2 for the distribution of s_{ijt} in the sample.

6 | DISCUSSION

The English NHS is one of several healthcare systems that permit GPs to prescribe *and* dispense medicines under specific circumstances (Eggleston, 2012). GP practices in England are allowed to dispense prescriptions to patients who live more than 1 mile away from the nearest community pharmacy or who would otherwise struggle to access a pharmacy. Revenue in dispensing practices increases with the total cost of drugs dispensed and with the number of packs dispensed. Using the exogenous geographic variation in dispensing rights, we present evidence from the extensive margin analysis that, compared with practices which do not dispense, dispensing practices prescribe, on average, more and more costly drugs, which are provided in smaller pack sizes.

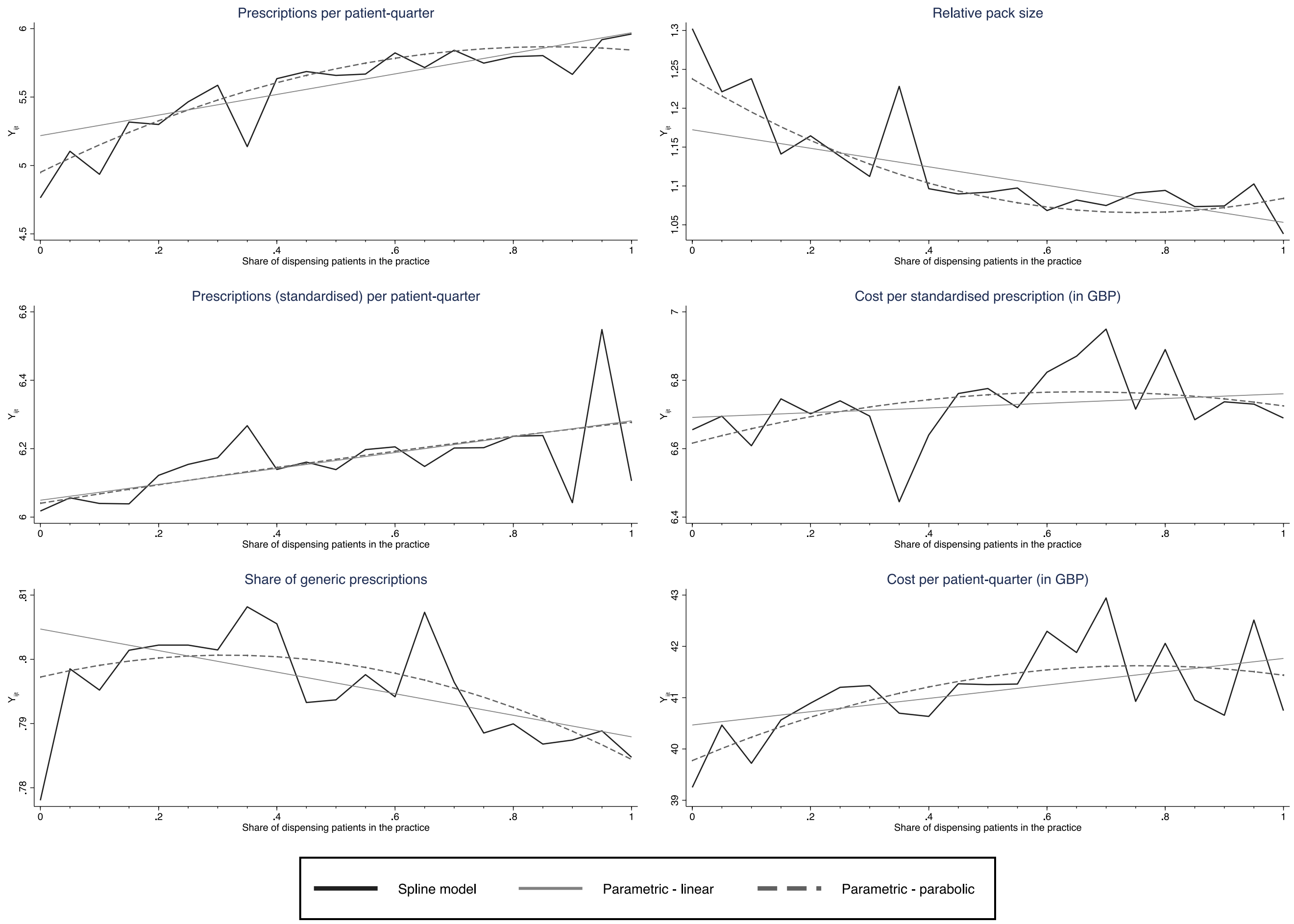

FIGURE 3 Prescribing outcomes at different proportions of dispensing patients in dispensing practices. The figure plots the predicted values of parametric regression models assuming either a linear or quadratic relationship between s_{ijt} and the prescribing measures of interest. In addition, a spline model with 20 equally spaced knots serves as a non-parametric approximation of these relationships. See Figure 2 for the distribution of s_{ijt} in the sample. [Colour figure can be viewed at wileyonlinelibrary.com]

We obtain broadly similar results from the analysis of the intensive margin, with drugs costs per patient, drug costs per prescription, and prescriptions per patient being higher, and pack size and share of generic prescribing lower in dispensing practices with a higher proportion of dispensing patients. The effects of physician dispensing on prescribing diminishes as the share of dispensing patients increases. While our data do not allow us to unpick this finding further, we note that it is consistent with a more altruistic interpretation of practice motivation, in which practices provide dispensing services in the interests of patients while seeking to recover the fixed costs of running a dispensary.

There are a number of potential limitations to our study. First, because the data do not distinguish between prescriptions for dispensing and non-dispensing patients, our prescribing outcomes are practice level averages across dispensing and non-dispensing patients weighted by the share of dispensing patients in the practice. This means that we cannot tell whether practice level differences between dispensing and non-dispensing practices are due to GPs in dispensing practices prescribing more, and more expensively, to all patients or only to dispensing patients.[22] If dispensing GPs prescribe differently to dispensing patients our results from the analysis of the extensive margin are a conservative estimate of the impact of physician dispensing on GPs' prescribing behavior toward patients to whom they can dispense.

Second, our practice-level data also do not permit us to examine whether the effect of dispensing status varies with other patient characteristics such as chronic morbidity. For example, patients with chronic health conditions may require more frequent prescriptions so that travel costs are more important for them and they may also be more knowledgeable about their disease and its treatment. Both these may limit the scope for opportunistic prescribing behavior if they qualify for dispensing status. Patient-level data would be required to test for heterogeneous effects of dispensing status by disease status.

Third, it is possible that, although we control for physician gender, age, and the proportion of profit sharing physicians in the practice, unobserved physician characteristics, such as their mix of profit orientation and altruism, lead them to join a dispensing practice, influence the practice decision to open a dispensary, *and* affect their prescribing. Similarly, although we have data on the age and gender mix of patients and on practice disease prevalence rates, and the choice of practices is smaller in rural areas, there may be endogenous selection into dispensing practices by eligible patients, especially those who expect to require more prescriptions. Although our IV for practice dispensing status (practice location in a rural area) is a very strong predictor of dispensing status, we cannot test whether it satisfies the exclusion requirement that it is uncorrelated with prescribing outcomes conditional on all covariates. In supplementary analysis, we found that the rurality IV is correlated with some of our outcome variables when included as an independent regressor in the OLS model but led to only small changes in the coefficient on dispensing status compared to the OLS results in Table 2 (see Online Appendix Table A10). However, these results cannot be interpreted as evidence for or against the validity of the IV (see Wooldridge (2019)).

Fourth, practice dispensing status may alter the behavior of dispensing patients as well as their GPs. The greater convenience of having a dispensary at the practice is likely to increase the proportion of prescriptions for eligible patients that actually are dispensed. Since non-dispensing patients must take their prescriptions to a community pharmacy there should be no effect on the proportion of their prescriptions that are dispensed. We have six outcome measures and five of them capture changes in GP, rather than patient, behavior. The volume of prescriptions (N/L) per practice patient is higher in dispensing practices and this is compatible with either causal route. However, dispensing practices have smaller pack sizes: they prescribe a given total amount of a drug in a larger number of prescriptions for smaller quantities. We argue that this is due to them receiving a fee for each item they dispense, irrespective of the price of the drug or the total cost of the prescription. There is no obvious reason why patients in dispensing practices would prefer smaller pack sizes. We find that dispensing status has a positive, small, and statistically insignificant effect on the per patient number of prescriptions standardized by the size of prescriptions (N^A/L). Dispensing practices will probably have larger profits if they prescribe more expensive drugs and we also find that the average cost per standardized prescription (C^A/L) is greater than in non-dispensing practices. Generic drugs have lower prices than therapeutically equivalent proprietary drugs and so are probably less profitable for dispensing practices in absolute terms. It seems unlikely that dispensing patients would be less likely to choose to have their prescription for generic, rather than proprietary, drugs dispensed. We find that the percentage of generic prescriptions is smaller in dispensing practices, though the difference is not statistically significant. Finally, the cost per patient (C/L) is larger in dispensing practices. This could be because dispensing patients are more likely to get their prescriptions dispensed or because they receive prescriptions for more expensive drugs. However, $C/L = (C/N^A)\ (N^A/L)$, and we find that both cost per standardized prescription (C/N^A) and the number of standardized prescriptions per patient (N^A/L) are larger in dispensing practices, suggesting that the higher cost per patient in dispensing practices is due to changes in GP behavior rather than to changes in behavior of patients eligible for dispensing.

We can use our estimates to provide a back-of-the-envelope calculation of the additional expenditure due to physician dispensing in the English NHS. Based on our OLS estimates (which have smaller effects than those from the 2SLS model and the models adjusted for selection on observables), we calculate that a dispensing GP practice of average size (i.e., approx. 7820 patients) has additional revenue of £42,288 per year, on average, of which £32,850 (78%)[23] is due to additional prescribing expenditure and the remaining £9438 (22%) reflect dispensing fees linked to additional prescribing (assuming all prescriptions to dispensing patients are dispensed on-site and practices receive the lower dispensing fee of £2.18 per item). Aggregated over the 980 dispensing practices in the English NHS in 2018, this amounts to an additional expenditure of approximately £36m per year, or the equivalent of 0.4% of total NHS drug expenditure (NHS Business Services Authority, 2020).

Our analysis only provides a partial picture of the full consequences of physician dispensing and we cannot, therefore, assess whether these additional costs are offset by the benefits of dispensing. For example, we do not know whether the additional expenditure generates health benefits,[24] nor how much physician dispensing reduces travel time for patients and how this is valued. Furthermore, we do not observe the cost of operating an on-site dispensary to GP practices and the degree of rent extraction. We, therefore, caution against drawing inference about the welfare implications of the English physician dispensing policy from our results.

Our general finding, that dispensing increases drug expenditure, is in line with previous studies in the economic literature. However, our estimated increase in drug expenditure of 3.1% per patient is an order of magnitude smaller than those reported in the most recent studies for Switzerland, where Burkhard et al. (2019) and Kaiser and Schmid (2016) found dispensing status to increase drug expenditure per patient by 52% and 34%, respectively. These marked differences may reflect differences in institutional features such as the way in which GPs are reimbursed (e.g., Swiss GPs earn a fee for every patient contact whereas GPs in England receive capitated payments) or the degree of monitoring. They do, however, serve as a reminder that empirical findings from one healthcare system should be validated in other systems before they can serve to inform local policy decisions.

In summary, our analysis provides evidence that English GPs modify their prescribing behavior in ways that are consistent with a profit motive when they are permitted to dispense medications. These behavioral differences are unlikely to be explained by differences in the health care needs of their local patient populations. It is possible that dispensing by English GPs increases overall welfare by reducing access costs and improving health for dispensing patients. Future patient-level studies are required to examine the consequences of GP dispensing for population health, access to care, and health to permit a more comprehensive assessment of costs and benefits.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

All data are available at the sources listed in Appendix Table A1. Data are provided under data sharing agreements and cannot be shared further without permission from data holders.

ETHICS STATEMENT

The study uses publicly available, secondary datasets that do not identify individuals. No ethics approval was required for the conduct of this study.

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ENDNOTES

1 For example, physician dispensing is permitted in Canada, parts of Switzerland, most US states, and many Asian countries but is banned in Germany and much of Scandinavia. In some countries, such as Austria, France and the United Kingdom, physicians are only allowed to dispense in areas where patients have greater difficulty in accessing community pharmacies. See Eggleston (2012) for a review of the history of PD and an economic analysis of factors that give rise to integration or segregation of prescribing and dispensing in different healthcare systems.

2 See Lim et al. (2009) and Eggleston (2012) for systematic reviews of earlier literature.

3 Prior to 2012/13, healthcare was purchased by Primary Care Trusts. We use the term CCG for both types of purchasers.

4 There are regulations restricting the entry of new pharmacies into rural areas (Department of Health, 2012) and attempts to enter are strongly resisted by local dispensing general practices.

5 In addition, dispensing practices can earn up to £2.58 per dispensing patient per year if they meet various process requirements of the Dispensary Services Quality Scheme. The scheme aims to ensure minimum competency standards for dispensing staff by mandating training requirements and standard operating procedures for dispensaries. It also requires practices to review prescriptions for 10% of their dispensing patients each year.

6 We define a prescription as a specified amount (pack size), dosage and pharmaceutical form of one drug. The prescription *form* given to the patient by a GP could contain more than one prescription, for example, for two different drugs.

7 A proportion of prescriptions are never dispensed: the patient may subsequently decide that they have recovered and do not need the drug or that it is not worth paying the prescription charge if they are not exempt (Beardon et al., 1993). We assume that GPs allow for this in their decisions on prescribing and whether to open a dispensary.

8 Section 4.1 sets out our estimation strategy.

9 Note that markups are likely to differ between combinations of dispensaries and wholesalers. Because markups are commercially sensitive, they are only reported to the Department of Health and Social Care for the calculation of the clawback rate but are not observed by researchers.

10 As we noted previously, some prescribed drugs are never dispensed so that the outcome measures are based on drugs dispensed. We continue to refer to "prescriptions" rather than use more cumbersome terms like "dispensed prescriptions".

11 There are 34.753 LSOAs in England with a mean population of 1500 (ONS, 2012).

12 We use the user-written Stata command ebalance (Hainmueller & Xu, 2013) to estimate EB weights.

13 Kaiser and Schmid (2016) face a situation with potential *one-sided non-compliance* in their analysis of physician dispensing in Switzerland. Physicians are allowed to dispense in some but not all cantons and they use this as an instrument for actual dispensing status. In our case practices can

only choose to dispense if they have patients who are eligible and request the practice to dispense. Practices in urban areas may dispense to patients who would have serious difficulty in accessing a pharmacy (see Section 2.1). Hence, we face potential *two-sided non-compliance*.

[14] It is possible that more altruistic or more profit-oriented physicians with eligible patients who would request dispensing are more likely to select into dispensing practices. We argue that this does not violate the exclusion restriction since the practice rurality instrument is correlated only with the local number of patients entitled to request dispensing and will not, conditional on the patient covariates, directly affect prescribing to dispensing patients.

[15] We follow Angrist and Pischke (2009, p. 191) and estimate the first stage with a binary endogenous variables as outcome using a linear specification.

[16] Online Appendix Table A3 has descriptive statistics, and Figure A2 has plots of the number and share of dispensing patients in dispensing practices, for the initial sample of practices including those in CCGs with no, or only, dispensing practices in any quarter.

[17] Full regression results are available in Online Appendix Tables A11-A13.

[18] We also estimate models where we replace dispensing status, D_{ij}, with the share of dispensing patients in the practice, s_{ijt}, over the interval $s_{ijt} \in [0, 1]$. The results are presented in Online Appendix Table A6 and show similar patterns to those presented in Table 2.

[19] We additionally estimated correlated random effects specifications with time-averaged GP practice variables included as regressors and GP practice random effects using the full sample of GP practices. The results are very similar to those with CCG fixed effects and standard errors clustered at CCG level presented in Table 2 (for our original sample of GP practices) and in Online Appendix Table A8 (all practices but without inclusion of cluster means). Results are available upon request.

[20] On average CCGs in our sample have 40 GP practices.

[21] Online Appendix Table A9 reports the regression coefficients of a model assuming that prescribing behavior is linear s_{ijt} ($\psi_2 = 0$).

[22] GP practices' contracts with the NHS prohibit such discrimination. However, this contractual obligation would be difficult to enforce given the challenge of establishing need for pharmaceutical treatment across heterogeneous patient populations.

[23] Estimated additional prescribing expenditure per dispensing practice is £36,910 and we assume an average clawback of 11% (£4060), resulting in net prescribing revenue of £32,850.

[24] There is some evidence to suggest that dispensing is associated with improved hypertension control (Gomez-Cano et al., 2021) but also with a higher rate of potentially inappropriate medication in the elderly that are associated with adverse outcomes (Blozik et al., 2015). We are not aware of studies that have established the effect of dispensing on long-term health outcomes.

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