Healthcare Provider Referral and Treatment Decisions Under Mixed Contracts

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Abstract

The literature examining how healthcare providers respond to the financial incentives introduced under capitation and fee-for-service contracts have done so in settings where contract types differ across patients, but not across services within a patient. We build on this literature by quantifying the extent to which providers' referral and treatment decisions respond to financial incentives when contract types and prices are determined between hospitals and insurers at the service level. We do so using the universe of claims for pregnant patients enrolled in the Colombia's national health insurance plan in 2011. We develop a two stage model of the primary care physician's referral of their pregnant patient to a hospital for delivery, and the delivering hospital's choice between performing a vaginal delivery and cesarean section. We show that primary care providers are more likely to refer a pregnant patient inside for delivery the higher is their expected profit. We also show that delivering providers are more likely to choose the delivery method with the higher fee-for-service price. These results indicate that mixed contracts do not ameliorate provider moral hazard.

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1 Introduction

In markets where public health insurance is supplied by private insurers, payments from insurers to providers are typically made under either capitation or fee-for-service (FFS) contacts. These forms of reimbursement are antithetical with respect to the incentives they present to providers. Capitation payments are ex-ante lump sum transfers that cover all of a patient's health care claims. Because providers bear the full cost of treatment beyond the capitation payment, reimbursement by capitation may incentivize providers to under-provide services, substitute toward cheaper care, or provide care more efficiently (Frakt and Mayes, 2002; Frank et al., 1995; Hillman et al., 1989; Stearns et al., 1992; Brot-Goldberg and De Vaas, 2018). Papers studying provider behavior under capitation have found evidence that they respond to these incentives without affecting quality of care or patient outcomes (Ho and Pakes, 2014a). Under a FFS reimbursement scheme, the insurer and hospital negotiate a price for each service that is paid to the provider each time the service is rendered. Because provider profits are proportional to the number of services rendered under FFS, this reimbursement scheme generates incentives to over-provide or substitute to more expensive treatments (Shafrin, 2010). Research has found that use of FFS contracts explains much of the rising healthcare costs in countries like the United States (RAND Corporation, 2019), Norway (Grytten and Skau, 2008), and China (Eggleston et al., 2004). The papers that examine provider responses to these polar contracts have focused on settings where one contract type is present between any insurer-provider pair. We contribute to this literature by studying provider incentives and behavior in a setting where contract type is determined at the service level between each insurer hospital pair. This paper provides an understanding of provider behavior in a context where incentives vary across both insurers and services, and studies the effect of this variation on referral and treatment decisions.

Our setting is the Colombian healthcare market, which is characterized by near universal coverage under a basic national health insurance plan. Individuals choose a private insurer through which to access the national plan. Those above a monthly income threshold pay a monthly contribution to the government for access to the national plan, while those below that threshold have their healthcare subsidized. Enrollees do not make payments to their insurers, and coinsurance rates, copays, and maximum out-of-pocket expenditures are set by the government. Insurers form networks of healthcare providers, and negotiate reimbursements for healthcare services. These negotiations entail determining both a contract type and price for each service. Almost 40% of all claims filed during 2010 were reimbursed under a capitation contract, while another 40% were reimbursed under a FFS contract. The government mandates that certain low complexity services with relatively high demand and low markups must be covered under capitation. While the government recommends that high complexity services be covered under FFS, the contract type is ultimately determined through negotiations between insurers and providers, and for many services there is variation across insurer-provider pairs in the type of contract that the service is reimbursed under. Additionally, the services required to treat a single patient might be reimbursed under different types of contracts. This raises the question of whether providers are still responsive to financial incentives in their referral and treatment decisions when there is variation across services in contract type for a single patient. Leveraging both the highly regulated nature of the setting we study as well as the detail of our claims data, which contains information on the contract type of each claim filed, we are able to quantify the profitability of any given claim, and relate that profitability to providers' treatment decisions and moral hazard.

In this paper, we examine the extent to which providers respond to the financial incentives introduced under mixed contracts in both their referral and treatment decisions. We do this by focusing on a subset of the population with a specific acute condition - pregnancy - for which there are two main treatments - vaginal delivery and cesarean delivery (c-section). We leverage the fact that referrals in the Colombian health system, including those to an OB/GYN, must be made by a primary care physician (PCP) and examine the PCP's decision to refer the patient to a specialist within their own hospital or to a specialist at another hospital given the contract types and prices of each delivery type negotiated with the patient's insurer. We also examine the delivering provider's decision to perform either a vaginal delivery or c-section given negotiated contract types and prices of each procedure. These prices and contracts will be different from those considered by the PCP if the referral was to a specialist outside their own hospital.

There is a large literature showing that c-section rates vary substantially across hospitals, even among women with similar health risks. Non-medical geographic factors including provider density and malpractice pressure have been shown to explain part of the variation in cesarean rates (Kozhimannil et al., 2013; Baiker et al., 2006). However, to our knowledge, there has been no examination of the role of provider moral hazard in explaining the decision to perform a c-section. Whether mixed contracts alleviate provider moral hazard is an important question generally, but is especially important in the specific case of delivery procedure choice. Procedure choice at the time of delivery has been shown to impact the rate of delivery injuries as well as rates of asthma, immune deficiencies, and breastfeeding among infants as summarized in Card et al. (2020). The determinants and consequences of delivery choice are also of keen interest to the many medical and international organizations that have called for regulation aimed at reducing the recent and uneven rise in global c-section rates (Teleki, 2020; World Health Organization, 2018; USA Today, 2020).

We develop and estimate a two-stage model of referral and delivery procedure choice for a pregnant patient. In the first stage, the PCP decides whether to refer the patient to a specialist inside or outside their own hospital. This decision is a function of the reimbursement that the PCP's hospital would receive if the patient were referred inside. The second stage takes the referral decision as given, and models delivering providers' treatment decision between c-section and vaginal delivery as a function of the reimbursements that the delivering provider's hospital would receive. We find that both referring and delivering providers are responsive to financial incentives: a one percent increase in expected reimbursement under FFS generates a 5.8 percentage point increase in the likelihood of a referral inside, while a one percent increase in the relative price of c-section under FFS generates a 11 percentage point increase in the likelihood of delivery by c-section. Referring and delivering physicians' decisions are also impacted by the expected out-of-pocket payments of their patients. In both stages, we control for the patient's suitability for each procedure, which we estimate non-parametrically using a random forest algorithm.

Our findings are consistent with other papers that study insurer and provider responses to financial incentives (McClellan, 2011; Hillman et al., 1989). Variation in FFS prices has been linked to the number and duration of PCP visits (Brekke et al., 2017), the likelihood of providing specialty care (Grant, 2009), and the likelihood of being prescribed a generic drug (Liu et al., 2009). The literature has also found evidence not only of under-provision of services under capitation (Stearns et al., 1992), but of insurer responses to referral choices. In particular, Ho and Pakes (2014a) and Ho and Pakes (2014b) find that insurers with a higher share of capitated physicians are more price sensitive and more likely to refer their patients to cheaper, further away hospitals. Other papers have studied provider behavior when multiple contract types are present across patients and have found providers to be responsive (Hennig-Schmidt et al., 2011). We contribute by showing that this responsiveness remains even when variation in contract types exists at the patient level, and that it plays an important role in the decision to perform c-sections.

2 The Colombian Healthcare System

The Colombian healthcare system is divided into two income-based regimes: the Contributory regime (CR) and the Subsidized regime (SR). The CR covers all individuals above a monthly income threshold, and these individuals pay a monthly contribution to the government for access to the national health insurance plan. Those below the monthly income threshold belong to the SR, and their healthcare is completely subsidized through tax revenue. Members of both regimes have access to the same national health insurance plan called POS by its Spanish acronym. The healthcare system has nearly universal coverage, approximately 51% of the population belonging to the CR, and the other 49% to the SR.

The design of the national health insurance plan is determined by the government. The plan covers a set of around 7 thousand procedures, services, and devices, as well as more than 700 prescription medications, all of which are chosen by the government. This plan is provided by private insurers, each of which forms its own network of providers with whom they engage in bilateral negotiations over contract terms and reimbursement rates. The government specifies the contract types that insurers and providers may use in determining reimbursements. These include capitation, FFS, fee-for-package, and fee-for diagnosis. Capitation and FFS are by far the most commonly used contract types, together accounting for over 80% of all claims filed in the CR in 2011. The government mandates that certain common, low-complexity services, like visits to the primary care provider (PCP), must be covered under capitation. For all other services, the contract type is decided by the insurer and the hospital. Access to any specialist or high-complexity service can only be obtained through a referral from a PCP. This referral may be to another physician within the PCP's own hospital or to a physician at a different hospital; we will refer to the former type of referral as an inside referral and the latter as an outside referral.

Those who enroll in the national health insurance plan do not pay premiums to their insurer. Instead, the government reimburses plans with risk-adjusted per-capita transfers. The risk adjustment formula controls only for sex, age category, and municipality of residence. The government also sets copays, coinsurance rates, and yearly maximum out-of-pocket expenditures. Theses prices vary across individuals based on their monthly income but do not vary across services, providers, or insurers. For enrollees who made less than 2 times the monthly minimum wage (MMW), the copay, coinsurance rate, and OOP limit in 2011 were 4,000 pesos, 11.5%, and 57.5%$\times$ MMW respectively. For those who made between 2 and 5 times the MMW, the copay, coinsurance rate, and OOP limit were 8,000 pesos, 17.3%, and 230%$\times$ MMW respectively. Finally, for those who made over 5 times the MMW, the copay, coinsurance rate, and OOP limit were 20,900 pesos, 23%, and 460% $\times$ MMW. These prices have remained unchanged for the past 20 years.[1]

3 Data

Our data consists of all of the claims filed by pregnant women enrolled in the national insurance plan in 2011. We retain all claims filed in the nine months preceding a claim for childbirth. We observe the ICD-10 diagnosis code for each claim, and obtain comorbidities by grouping ICD-10 codes into the following conditions according to Alfonso et al. (2013): genetic anomalies, arthritis, arthrosis, asthma, autoimmune disease, cancer, cardiovascular disease, diabetes, long-term pulmonary disease, renal disease, HIV-AIDS, transplant, tuberculosis, and epilepsy. We observe the hospital at which each service was provided, and can distinguish visits with specialists from visits with primary care physicians. We identify each patient's primary care physician as the last PCP she sees before her delivery. We can determine that a PCP referred a woman to an OB/GYN inside if the PCP's hospital is the same as the hospital associated with the childbirth claim. If the PCP operates at a different hospital than that at which the childbirth took place, then we conclude that the PCP referred the woman's childbirth to an OB/GYN outside. We observe the contract type under which each claim was reimbursed, and the price of each claim reimbursed under a FFS contract. We do not observe the lump sum payments made from the insurer to the provider for capitated services. In addition to her comorbidites, we also observe each enrollee's age and municipality of residence.

Our raw data consists of 114,167 childbirths. We drop deliveries that take place at hospitals that either perform fewer than 40 deliveries during the sample period, or that contract with fewer than two insurers. The former restriction ensures that the hospitals in our sample are those that regularly perform childbirths. The latter restriction implies dropping from our sample providers who face no potential variation with respect to contract type, reimbursement rates, or coinsurance payments across patients undergoing the same procedure. These restrictions amount to dropping the smallest providers in our sample: applying them results in dropping 83% of providers, but only 20% of deliveries, so that our analysis sample consists of 91,277 childbirths performed by 205 unique hospitals and covered by 11 unique insurers.

[1] The average exchange rate during 2011 was 1,847 COP/USD

Table 1: Characteristics of deliveries by referral and procedure type

	All	Referred inside		Referred outside	
		Vaginal	C-section	Vaginal	C-section
Number of deliveries	91,277	5,172	4,950	43,228	37,927
Share of deliveries, %	100	5.67	5.42	47.36	41.55
Financial characteristics					
FFS price†, mean (se)	3.56 (2.37)	1.22 (1.52)	2.44 (2.26)	4.27 (2.47)	3.22 (1.98)
Capitated, %	11.9	56.28	39.58	7.81	6.89
Patient characteristics					
Age, mean (se)	27.90 (5.66)	27.49 (5.64)	28.99 (5.83)	28.42 (5.74)	27.22 (5.47)
Diagnoses, %					
Arthritis	0.51	0.23	0.42	0.62	0.42
Asthma	1.25	1.16	1.47	1.38	1.08
Autoimmune_Disease	0.28	0.19	0.38	0.30	0.24
Cancer	11.03	5.99	9.96	12.81	9.83
Cardiovascular_Disease	6.18	3.63	6.75	7.74	4.67
Diabetes	0.62	0.39	0.95	0.82	0.37
Epilepsy	0.39	0.31	0.40	0.46	0.33
Genetic anomalies	1.25	1.10	1.39	1.38	1.11
HIV-AIDS	0.20	0.14	0.51	0.25	0.12
Long term Pulmonary Disease	0.47	0.37	0.34	0.59	0.37
Renal Disease	0.52	0.58	0.44	0.61	0.43
Transplant	0.01	0.00	0.02	0.01	0.01
Tuberculosis	0.09	0.14	0.06	0.09	0.09
Type of municipality, %					
Metropolitan	45.15	66.03	57.25	38.48	48.33
Normal	53.49	31.57	41.9	60.33	50.19
Peripheral	1.36	2.40	0.85	1.18	1.49

Note: This table shows summary statistics of the final sample separately by type of procedure and type of referral. The unit of observation is a delivery. † measured in 100,000 Colombian pesos.

We provide summary statistics for these 91,277 childbirths in table 1. 53% of all childbirths are vaginal deliveries, while the remaining 47% are c-sections. 11% of all childbirths are referred inside, while the remaining 89% are referred outside. The average FFS price for a c-section referred outside is 322 thousand pesos, and that for a vaginal delivery is 427 thousand pesos. We see that the average price for vaginal deliveries that are referred inside is lower than those performed outside, similarly for c-sections. One might initially take this as evidence against the hypothesis that PCPs are responding to financial incentives in their referring decisions. However, we note that the relevant price for a PCP considering whether to refer outside is the price established between the PCP's hospital and the patient's insurer. This price is not the price of delivery for the woman observed in the data if the woman is referred outside. These counterfactual prices can be obtained from the price data of other women enrolled with the same insurer who have their baby delivered at the same hospital as the PCP of the woman who was referred outside. Turning to enrollee characteristics, we see that 20% of women have at least one comorbidity. The most common comorbidity is cardiovascular disease, which affects 6% of women. Note that the rate of every comorbidity is higher among the set of women who receive c-sections than those who have vaginal deliveries. This is consistent with the use of c-section to prevent complications that arise in labor for high-risk births. It also highlights the importance of controlling for a woman's suitability for c-section with respect to her health status when evaluating the determinants of providers' procedure choice. We detail our measure of procedure suitability in section 5.

4 Model

In this section we present a model of referral and delivery type decisions by primary care providers and delivering hospitals, respectively. Suppose woman i whose health insurance is provided by carrier j becomes pregnant. She may have her baby delivered at hospital h by one of two procedures. Let

$$x_{ijh} = \begin{cases} 1 & \text{if} \quad \text{Caesection} \\ 0 & \text{if} \quad \text{Vaginal delivery} \end{cases}$$

and

$$l^x_{jh} = \begin{cases} 1 & \text{if} \quad x \text{ is covered under fee-for-service} \\ 0 & \text{if} \quad x \text{ is covered under capitation.} \end{cases}$$

Woman i's health condition makes her differentially suitable for each procedure. Let f^x_i denote woman i's suitability for procedure x.

Woman i's monetary cost of having a delivery of type x is summarized by her out-of-pocket payment, $OOP^x_{y(i)jh}$. The out-of-pocket payment varies across enrollees of different incomes y, because the coinsurance rates are income-specific, and across hospital-insurer pairs because it is at this level that prices are negotiated.

We assume that woman i's utility from delivery is additively separable in her health condition and monetary cost. The utility of woman i from receiving treatment x is

$$U_{ijh}^{x} = f_i^x + \omega_i[y_i - OOP_{y(i)jh}^{x}]$$

where ω_i captures the extent of moral hazard on the patient's side.

Sometime between woman i's becoming pregnant and her delivery, she visits a PCP at hospital h, who refers her to a specialist and a hospital at which to have her baby. The transfers made from woman i's insurance carrier to hospital h can be summarized by a lump sum payment per patient under a capitation contract, L_{jh}, and procedure-specific prices under a fee-for-service contract, p_{jh}^{x}.[2] The payoff to the hospital where the PCP works from treating woman i with procedure x is a weighted average of the woman's utility from delivery by procedure x and the profit to hospital h from performing procedure x,

$$W_{ih}^{xl} = U_{ijh}^{x} + \omega_h[L_{jh} + p_{jh}^{xl}1\{l_{jh}^{x} = 1\} - mc_h^x]$$

where mc_h^x is the marginal cost to hospital h of performing procedure x. Given this payoff, the PCP makes a referral decision. Specifically, the PCP decides whether to refer the woman to a specialist within or outside of their own hospital h.

To summarize, the timing of the model is as follows:

> Period 1: The woman becomes pregnant and visits the PCP. The PCP observes L_{jh}, p_{jh}^{xl}, and mc_h^x, and refers the woman to hospital h', where $h' = h$ implies a referral inside.
>
> Period 2: The woman's health status f_i^x is realized. Hospital h' observes f_i^x, $L_{jh'}$, $p_{jh'}^{xl}$, and $mc_{h'}^x$, and decides whether to deliver the woman's baby via c-section or vaginal delivery.

We solve this two stage model by backward induction. Let $x_{ijh'}^{*}$ be the optimal delivery type for hospital h' treating woman i covered by insurer j in the second stage, and let $\tilde{x} = 1 - x^*$. This choice by the specialist at hospital h' will satisfy the following inequality:

$$\begin{aligned} f_i^{x^*} + \omega_i[y_i - OOP_{y(i)jh'}^{x^*}] + \omega_h[L_{jh'} + p_{jh'}^{x^*l}1\{l_{jh'}^{x^*} = 1\} - mc_{h'}^{x^*}] \geqslant \\ f_i^{\tilde{x}} + \omega_i[y_i - OOP_{y(i)jh'}^{\tilde{x}}] + \omega_{h'}[L_{jh'} + p_{jh}^{\tilde{x}l}1\{l_{jh'}^{\tilde{x}} = 1\} - mc_{h'}^{\tilde{x}}], \end{aligned}$$

or

$$[f_i^{x^*} - f_i^{\tilde{x}}] - \omega_i[OOP_{y(i)jh'}^{x^*} - OOP_{y(i)jh'}^{\tilde{x}}] + \omega_h[p_{jh'}^{x^*l}1\{l_{jh'}^{x^*} = 1\} - p_{jh'}^{\tilde{x}l}1\{l^{\tilde{x}} = 1\} - mc_{h'}^{x^*} + mc_{h'}^{\tilde{x}}] \geqslant 0. \quad (1)$$

Equation (1) implies that a procedure is more likely to be performed if it is covered under a FFS contract,

[2]We take contracts and prices as given. How service-level contract types and prices are determined given the provider incentives they generate is an interesting avenue for future research.

and that the choice probability is increasing in its relative FFS price, and declining in its relative marginal cost. The size of these monetary effects is increasing in the hospital's moral hazard parameter, ω_h. Likewise, the likelihood of a procedure being performed is decreasing in its relative out-of-pocket cost to the patient, and the size of this effect is increasing in the patient's moral hazard parameter, ω_i. Finally, a procedure is more likely to be performed the relatively more suitable it is for the patient with respect to her health condition at the time of delivery. Importantly, we note that the capitation payments do not figure into the referral decision, as they are made to the provider regardless of which procedure is chosen.

In the first stage, the PCP at hospital h makes a referral decision by comparing the expected profit of referring the woman inside versus outside. Let

$$\begin{aligned}\text{Prob}(x_{ijh}=x) = \text{Prob}\Big(E\Big[&(f_i^x - f_i^{x'}) - \omega_i(OOP^x_{y(i)jh} - OOP^{x'}_{y(i)jh}) \\ &+ \omega_h(p^x_{jh}1\{l^x_{jh}=1\} - p^{x'l}_{jh}1\{l^{x'}=1\} - mc^x_h + mc^{x'}_h)\Big] \geqslant 0\Big), \quad \text{for } \; x \neq x'\end{aligned}$$

Then, the PCP will refer woman i inside if:

$$\text{Prob}(x_{ijh}=x)E[W^{xl}_{ih}] + \text{Prob}(x_{ijh}=x')E[W^{x'l}_{ih}] \geqslant \omega_h L_{jh}. \tag{2}$$

Note that we can write equation (2) as:

$$\begin{aligned}&\text{Prob}(x_{ijh}=x)E[U^x_{ijh} + p^{xl}_{jh}1\{l^x_{jh}=1\} - mc^{\bar{x}}_h] \\ &+ (1-\text{Prob}(x_{ijh}=x))E[U^{x'}_{ijh} + p^{x'l}_{jh}1\{l^{x'}_{jh}=1\} - mc^{x'}_h] + \omega_h L_{jh} \geqslant \omega_h L_{jh}.\end{aligned} \tag{3}$$

The capitation payments cancel out, and do not factor into the referral decision, as they are sunk profits.

5 Empirical specification

In this section, we describe the empirical analogues of the key elements of the model presented in the previous section. We describe our measure of each patient's suitability for c-section as well as our computation of negotiated prices. Then we present the estimating equations that will allow us to estimate the relationships between these elements and the treatment and referral decisions of providers.

5.1 Patient's suitability for c-section

We take a non-parametric approach to the measurement of each patient's appropriateness of c-section. In particular, we employ a random forest algorithm,

$$
\begin{aligned}
f_i^x &= f(X_i, D_i, t) \\
&= RandomForest(X_i, D_i, t)
\end{aligned}
$$

where X_i is a vector of demographic characteristics including sex, age, and department of residence; D_i is a vector of dummies for each 2-digit ICD-10 diagnosis code as well as for the ICD-10 disease groups listed in Alfonso et al. (2013); and t is an indicator for the calendar month when delivery occurs. We do not include reimbursement measures or non-medical patient characteristics, as our goal is to measure the medical risk of requiring a c-section free of financial incentives. After 10-fold cross-validation, we train the classification random forest model with 2,000 trees and 12 variables selected randomly at each leaf of the tree on a random sample of 70% of observations.

Figure 1 shows the ROC curve and area under the curve achieved by our model out-of-sample in the remaining 30% of observations. A perfect fit would suggest that women are always rendered the procedure that they are most suitable for. That the area under the ROC curve is well below 100 is consistent with physicians deviate from the most suitable treatment even after observing patient characteristics.

We use the entirety of our analysis sample when performing the random forest algorithm. In doing so, we implicitly assume that actual practice is reflective of a woman's true medical risk for c-section. We test the validity of this assumption by re-estimating the random forest algorithm restricting the sample to a subset of providers that have relatively low rates of negative outcomes related to childbirth. The differences between the measures of appropriateness for c-section generated using this subset of providers is compared to our main specification in the appendix. Currie and MacLeod (2017) employ a logistic regression model in their estimation of appropriateness for c-section. We compare the diagnostic of the random forest algorithm employed here to a logistic regression model in the appendix.

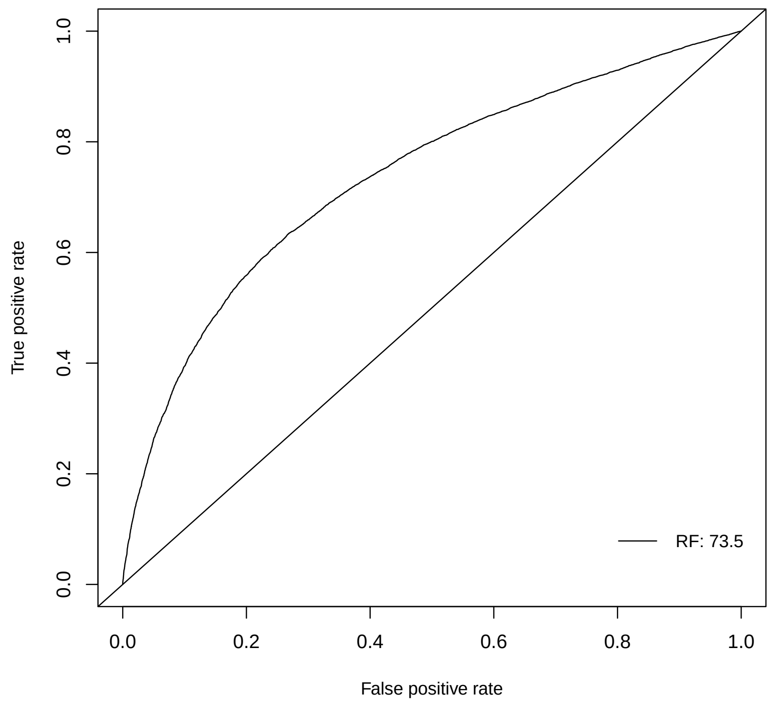

Figure 1: ROC curve for random forest specification

5.2 Constructing negotiated prices

Prices observed in the claims data may differ from prices at the hospital-insurer level. Childbirths for different patients may be reimbursed differently according to an arrangement determined by the hospital. Using observed claims prices under FFS associated to each delivery type, we construct negotiated prices as the average prediction of a linear regression of claims prices on patient characteristics and hospital fixed effects as in Gowrisankaran et al. (2015). Formally, we estimate the following regression via OLS, separately for each insurer j and procedure x:

$$p^x_{cjh} = \alpha_0 X_i + \lambda_h + \epsilon_{cjh}$$

Here c indexes a claim, X_i is defined as before, and λ_h are hospital fixed effects. We compute negotiated prices as the average prediction: $p^x_{jh} = (1/C^x_{jh}) \sum_c \hat{p}^x_{cjh}$, where C^x_{jh} is the number of claims for procedure x between hospital h and insurer j. The (unweighted) average R-squared across these regressions for c-section is 0.48 and for vaginal delivery 0.42.

5.3 Procedure choice

Our empirical specification for the second stage of the model in which the hospital chooses the type of delivery is:

$$\begin{aligned} x^*_{ijh'} &= \beta_0(f_i^{x^*} - f_i^{\tilde{x}}) + \beta_1 OOP^{x^*}_{y(i)jh'} + \beta_2 OOP^{\tilde{x}}_{y(i)jh'} + \beta_3 p^{x^*l}_{jh'} 1\{l^{x^*}_{jh'} = 1\} + \beta_4 p^{\tilde{x}l}_{jh'} 1\{l^{\tilde{x}} = 1\} + \eta_{h'} + \varepsilon_{ijh'} \\ &= \delta(OOP_{y(i)jh'}, p_{jh'}, \eta_{h'}; \beta) + \varepsilon_{ijh'}. \end{aligned} \tag{4}$$

Here, $x^*_{ijh'}$ is an indicator for woman i receiving a c-section at hospital h', the outside option being vaginal delivery. β_1 and β_2 measure the degree of provider altruism, while β_3 and β_4 measure the degree of provider moral hazard. $\eta_{h'}$ is a delivering hospital fixed effect that captures average marginal cost across procedures. Prices for c-section $p^{x^*l}_{jh'}$ and vaginal delivery $p^{\tilde{x}l}_{jh'}$ correspond to negotiated prices between the delivering hospital h' and the woman's insurance carrier j and are computed as detailed in the previous subsection. Both f^{x^*} and $f_i^{\tilde{x}}$ are computed using the results of the random forest algorithm described in section 5.1. We assume $\varepsilon_{ijh} \sim EVT1$ and estimate equation 4 via maximum likelihood.

5.4 Referral choice

As in equation 3, PCP's referral decisions are a function of the expected profits from an inside referral. Expected profits are given by the sum of profits to the PCP's hospital from c-section and vaginal delivery, weighted by the probability of each procedure being rendered in the second stage conditional on an inside referral. We therefore proceed by backward induction, estimating the second stage procedure choice model using the prices, contract types, and coinsurance rates of the referring hospital. Let

$$\hat{x}^*_{ijh} = \frac{exp(\delta(OOP_{y(i)jh}, p_{jh}, \eta_h; \hat{\beta}))}{1 + exp(\delta(OOP_{y(i)jh}, p_{jh}, \eta_h; \hat{\beta}))}$$

be the probability of hospital h delivering woman i's child by c-section conditional on an inside referral, and let z_{ijh} be a binary indicator that takes the value of one for an inside referral and zero for an outside referral. Our empirical model for the first stage is

$$\begin{aligned} z_{ijh} &= \gamma_0(\hat{x}^*_{ijh} f_i^{x^*} + (1 - \hat{x}^*_{ijh}) f_i^{\tilde{x}}) + \gamma_1(\hat{x}^*_{ijh} OOP^{x^*}_{y(i)jh} + (1 - \hat{x}^*_{ijh}) OOP^{\tilde{x}}_{y(i)jh}) \\ &\quad + \gamma_2(\hat{x}^*_{ijh} p^{x^*,l}_{jh} 1\{l^1_{jh} = 1\} + (1 - \hat{x}^*_{ijh}) p^{\tilde{x},l}_{jh} 1\{l^{\tilde{x}}_{jh} = 1\}) + \eta_h + \mu_{ijh} \end{aligned} \tag{5}$$

where η_h are PCP's hospital fixed effects and $\mu_{ijh} \sim EVT1$. We estimate equation 5 by maximum likelihood, bootstrapping the standard errors.

Equation 5 is estimated using the subset of childbirths for women whose PCP is affiliated with an institution at which childbirths take place. Women whose PCPs are affiliated with institutions at which childbirths do not take place will always be referred outside. There are over a thousand unique institutions at which the women in our sample receive primary care. 131 of these are hospitals at which childbirths take place. These 131 hospitals account for 7,738 of the childbirths in our sample. Table 2 provides summary statistics for this sample. Restricting the sample to providers who perform primary care visits increases the rate of inside referrals to over 80%. Rates of capitation are much higher among these providers than among the sample as a whole. The subsample is also more urban than the full sample.

Table 2: Characteristics of deliveries by referral and procedure type for subsample of primary care providers

	All	Referred inside		Referred outside	
		Vaginal	C-section	Vaginal	C-section
Number of deliveries	7,738	2,971	3,236	728	803
Share of deliveries, %	100	38.4	41.8	9.4	10.4
Financial characteristics					
FFS price †	1.86 (2.27)	1.40 (1.69)	2.72 (2.48)	1.51 (2.80)	0.48 (1.25)
Capitated, %	52.05	54.90%	38.41%	66.76%	83.19%
Patient characteristics					
Age	27.87 (5.70)	26.82 (5.31)	28.69 (5.80)	29.08 (6.05)	27.39 (5.60)
Diagnoses, %					
Arthritis	0.39	0.17	0.53	0.82	0.25
Asthma	1.41	1.45	1.64	0.82	0.87
Autoimmune_Disease	0.26	0.27	0.19	0.69	0.12
Cancer	9.28	7.47	12.82	6.87	3.86
Cardiovascular_Disease	6.07	4.17	6.92	9.75	6.35
Diabetes	0.66	0.34	0.93	0.82	0.62
Epilepsy	0.37	0.13	0.53	0.55	0.50
Genetic anomalies	1.20	0.84	1.21	2.75	1.12
HIV-AIDS	0.17	0.24	0.12	0.27	0.00
Long term Pulmonary Disease	0.40	0.47	0.25	0.96	0.25
Renal Disease	0.50	0.50	0.43	1.24	0.12
Transplant	0.01	0.00	0.03	0.00	0.00
Tuberculosis	0.10	0.20	0.06	0.00	0.00
Type of municipality, %					
Metropolitan	53.04	50.69	44.00	74.31	78.83
Normal	45.10	45.88	54.73	26.69	21.05
Peripheral	1.86	3.43	1.27	0.00	0.12

Note: This table shows summary statistics of the subsample of observations associated to hospitals at which both PCPs are affiliated and deliveries take place. The uni of observation is a delivery. † measured in 100,000 Colombian pesos. For continuous variables, the mean and standard deviation in parenthesis are presented.

6 Identification

Here we outline the variation required to identify the parameters in our empirical model, and present a summary of the availability of this variation. First, we require price variation within hospitals to identify the coefficients on vaginal delivery and c-section prices. This variation will come from variation in negotiated procedure prices across the insurers that each hospital contracts with. We summarize the availability of such variation in table (3) with the distribution of residuals obtained from a regression of negotiated prices on hospital fixed effects. We see important variation in the c-section price residuals ranging from -1.2 to 1.8 million pesos and in the residuals from vaginal delivery prices ranging from -0.7 to 0.7 million pesos.

Table 3: Summary of data elements relevant for identification

	Mean	SD	Min	p10	p25	p50	p75	p90	Max
C-section price residuals	0.00	0.78	-11.12	-0.14	-0.02	0.00	0.01	0.13	18.08
Vaginal delivery price residuals	0.00	0.47	-6.79	-0.11	-0.01	0.00	0.00	0.07	7.36
C-section coinsurance residuals	0.00	0.09	-1.28	-0.02	0.00	0.00	0.00	0.03	2.08
Vaginal delivery coinsurance residuals	0.00	0.07	-1.29	-0.01	0.00	0.00	0.00	0.01	0.85
Observations	91,241								

Note: Summary statistics of the distribution of residuals from a linear regression of procedure prices on hospital fixed effects. Prices and coinsurance payments are measured in 100,000 Colombian pesos.

There are two additional sources of variation that would enable identification of the coefficients on both the price and coinsurance variables. The first is variation in income across patients within a hospital. Income variation would enable identification of the coinsurance coefficients since coinsurance rates are a function of the patients' income group. But because 99.89% of our sample made less than 2 times the MMW and therefore belong to the same income group, we cannot leverage this variation. The second source of identification stems from the fact that while variable reimbursements for capitated services are zero, coinsurance payments are not. The procedure choices of hospitals for which both c-section and vaginal delivery are capitated therefore help us identify the coinsurance payment variables.

7 Results

In this section, we present the logistic regression estimates for equations 4 and 5. Estimates for equation 4 are presented in table 4. The likelihood of delivery by c-section is increasing in the reimbursement for c-section and decreasing in the reimbursement for vaginal delivery, suggestive of substantial provider moral hazard in the choice of procedure. These estimates imply that a one percent increase in the relative price of c-section increases the likelihood of delivery by c-section by 11 percentage points, while a one percent increase in the price of vaginal delivery decreases the rate of delivery by c-section by 14 percentage points. The likelihood of c-section is also sensitive to the patient's coinsurance payments. We find that a one percent increase in the out-of-pocket expenditure for c-sections, decreases the likelihood of c-section by 54 percentage points, while a similar increase in vaginal delivery coinsurance payments increases the rate of c-sections by 46 percentage points.

Table 4: Estimates for second stage regression model of procedure choice

	Coefficient	Standard error	Marginal effect × 100
C-section price	0.668***	0.021	11.261
Vaginal delivery price	-0.848***	0.029	-14.311
C-section coinsurance	-3.192***	0.250	-53.832
Vaginal delivery coinsurance	2.759***	0.328	46.538
Suitability for c-section	2.603***	0.023	43.900
Observations	91,032		
Pseudo R^2	0.265		

Note: This table presents results from a logit model of procedure choice. The decrease in sample size comes from losing observations that are completely determined by the hospital fixed effect and by missing values in some of our explanatory variables. Includes hospital and department fixed effects. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Estimates for equation 5 are presented in table 5. We see that providers are responsive to the expected profit of retaining a pregnant patient: a 100,000 pesos increase in the expected profit results in a 5.8 percentage point increase in the likelihood of a referral inside. This implies that a standard deviation increase in the expected profit of an inside referral increases the likelihood of an inside referral by 12 percentage points. These results indicate that provider moral hazard is a determinant of referral choice even after controlling for a patient's expected suitability of c-section under mixed contracts. The expected procedure suitability is maximized when the most suitable procedure is the one most likely to be rendered by the delivering provider. We find that referring providers are more likely to refer inside if the more suitable procedure is more likely to be chosen in the second stage. Finally, our results show that referral choices decrease with higher expected out-of-pocket payments to the patient.

Table 5: Estimates for first stage regression model of referral choice

	Coefficient	Standard error	Marginal effect × 100
Expected price	0.654***	0.108	5.802
Expected coinsurance	-4.294***	1.015	-38.084
Expected procedure suitability	1.329***	0.403	11.790
Observations	6,577		
Pseudo R^2	0.517		

Note: This table presents results from a logit model of referral choice. The decrease in sample size comes from losing observations that are completely determined by the hospital fixed effect and by missing values in some of our explanatory variables. Includes hospital and department fixed effects. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Appendix A Random forest model

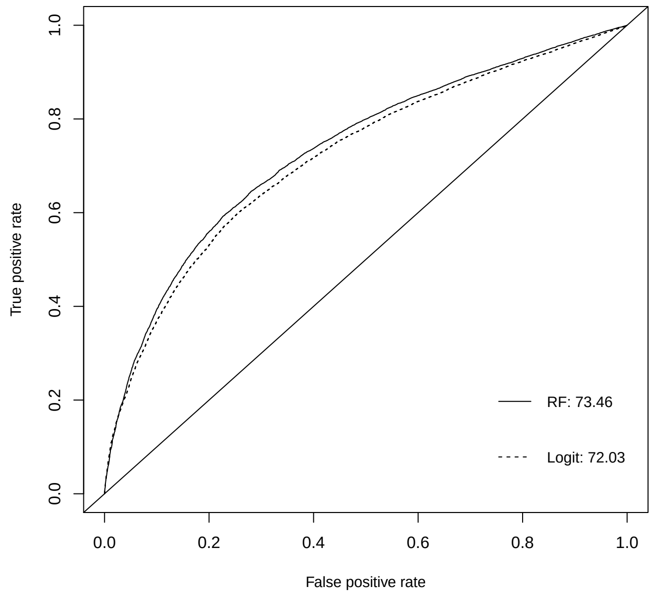

Figure 2: Comparison of random forest and logit model for appropriateness of c-section

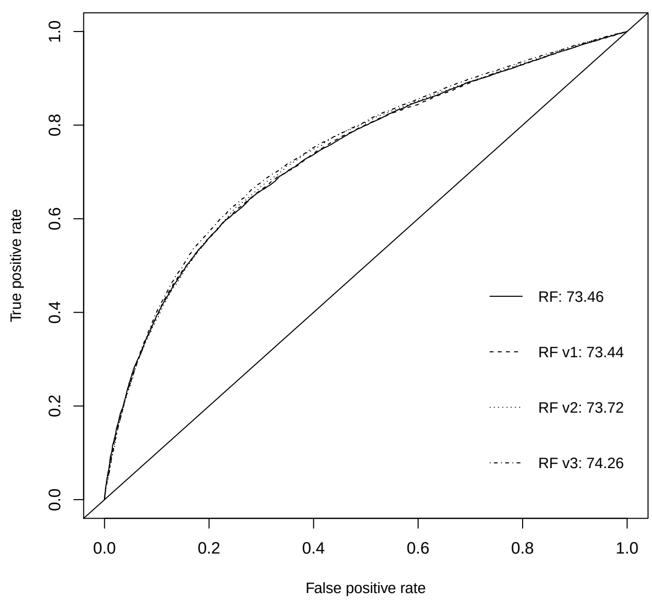

Figure 3: Comparison of random forests on subsamples with and without deliveries that end-up in bad outcomes

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