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Abstract

The incomplete pass-through of exchange rates to prices is a well-documented phenomenon. Firms respond optimally to exchange rate shocks by adjusting margins and buying inputs from regions with more advantageous terms of trade. Consumers, in turn, substitute goods that become more expensive for relatively cheaper goods after an exchange rate shock. We use data from the market for new cars in Colombia to empirically analyze the determinants of incomplete pass-through after a large depreciation of the local currency. We estimate a structural oligopoly model that nests the optimal reactions of firms and consumers to assess their relative importance in explaining the lack of response of retail prices to the exchange rate shock. We find that, in relative terms, the most important factor explaining incomplete pass-through is consumer substitution, followed by strategic interaction between sellers.

Keywords: incomplete pass-through, oligopoly, trade.

JEL Classification: L13, L62, F14

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Pass-through de la tasa de cambio en el mercado de carros colombiano*

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Resumen

El pass-through incompleto de choques de tasa de cambio a precios minoristas es un fenómeno bien documentado. Ante un choque de tasa de cambio, las firmas responden óptimamente ajustando sus márgenes e importando bienes intermedios de regiones con términos de intercambio más favorables. Los consumidores, a su vez, sustituyen bienes que se encarecen por bienes relativamente más baratos. Usando datos del mercado de carros nuevos en Colombia, analizamos los determinantes de la incompletitud del pass-through luego de una gran depreciación de la moneda local. Estimamos un modelo estructural de oligopolio que anida las reacciones óptimas de firmas y consumidores para medir su capacidad de explicar la poca respuesta de los precios minoristas ante el choque de tasa de cambio. Encontramos que el principal factor a la hora de explicar este pass-through incompleto es la sustitución de los consumidores, seguido por la interacción estratégica entre vendedores.

Palabras clave: pass-through incompleto, oligopolio, comercio

Clasificación JEL: L13, L62, F14

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1 Introduction

The Colombian economy experienced a very large depreciation during 2014, after the collapse of the international oil prices. The nominal exchange rate went from around COP$1800 per USD in early 2014 to around COP$3000 per USD in mid 2015. (10) document that at the time of the depreciation, the pass-through to domestic prices was limited. The tepid response of local prices to external shocks is the norm rather than the exception, as (17) show using data from 21 industrialized countries. Even though the adjustment of domestic prices after a depreciation modulates the adjustment of the whole economy, it is usually taken as given in the macroeconomic literature (see (14) for a review of the literature).

In this paper, we use the Colombian market for new cars to study the microeconomic mechanisms at play in the adjustment of prices after cost shocks, such as the ones induced by depreciations. This market is highly exposed to exchange rate shocks because most vehicles sold in Colombia are imported, and even those locally assembled rely heavily on imported components. However, despite its high exposure to foreign cost shocks, the impact of the depreciation on average prices is small relative to the size of the depreciation.

We highlight three elements of the adjustment that mitigate the effect of the depreciation and render the pass-through incomplete. First, the adjustment of wholesale prices, which happens in the international markets. Second, the decrease in total demand and consumer substitution towards cheaper automobiles. And third, the adjustment of markups resulting from oligopolistic firms responding optimally to their rivals' reactions to the shock.

Our results show that these forces mitigate the effects of depreciation on the prices observed in the market. Even though individual prices adjust optimally after the shock, average prices are less responsive. We quantify the relative importance of the factors determining this lack of response. More generally, our work highlights the importance of accounting for how shocks to rival firms affect the reaction of a given firm to its own shocks. Even though this relationship is evident in the most basic oligopoly models, empirical works estimating pass-through seldom control for it.

We use information on sales and registrations at the level of individual cars and a standard model of pricing and demand for differentiated goods. Our model allows us to estimate wholesale prices and demands for each automobile. With the estimated model, we can compute counterfactual prices and shares, under assumptions that isolate the three elements described above. These counterfactual computations allow us to assess the relative importance of these three elements in limiting the price response to cost shocks.

The paper is organized as follows. In the second section, we discuss the related literature.

In the third section, we describe the data and the problem that we study. In the fourth section, we present our empirical model. In the fifth section, we develop our empirical analysis. The end of the fifth section concludes.

2 Literature

The literature on pass-through is too expansive to be covered entirely here, so we will focus on the work that more closely relates to ours. To guide our insights about the aspects of a market that determine the level of pass-through, we followed a number of conceptual works that show how the response of local prices to cost shocks varies with different features of the markets such as its structure ((13); (3); (11)), the curvature of the demand faced by the firms ((23); (6)) or the role played by local costs ((29), (8)).

A large portion of the empirical literature comprises works that inquire on the timing of pass-through, that is, the delay of price adjustment in response to cost shocks, as in (28) and (17). Another part of the literature, more aligned with our interests, studies how firm and consumer optimal behavior mitigates partially the effect of cost shocks on retail prices. For instance, (19) decompose retail prices into markups and a wholesale component to study the asymmetric pass-through observed in retail stores close to the US-Canada border, and find that retail prices respond to changes in costs in neighboring stores within the same country but not across the border. (1) find that exchange rate shocks exhibit less pass-through for firms that are large importers, relative to firms that are small importers, because the latter increase their markups. Similar results, albeit using a completely different methodology, are found by (12) who estimate markups from production data alone to assess the extent of pass-through following a liberalization of trade in India. They find that the decrease in costs that the liberalization brought about was not passed on to consumers because the firms increased their margins. In contrast, (15) find that emission costs in Spain are almost fully passed on to prices because Spanish firms have no incentive to alter their markups due to the inelastic demand they face. Similarly, (25) find that costs in the cement industry are more than fully transmitted to prices.

Our work closely resembles the work of (27) who analyze the determinants of incomplete pass-through using data from the coffee industry. They start by documenting the price response of retail prices to manufacturer and wholesale prices. Then they use a structural model of demand and supply to recover the parameters that govern the agents decisions when price is set statically. Using these fundamental parameters they estimate a menu cost model for the firms dynamic pricing problem. They use the estimated of the model to explain the timing of price changes observed in the data. Our work differs in two important ways. First, our focus is on dissecting the incompleteness of pass-through and assess the relative importance of its causes, rather than analyze the timing of the price changes. Second, we avoid dynamic considerations on both the pricing and demand side of our model.

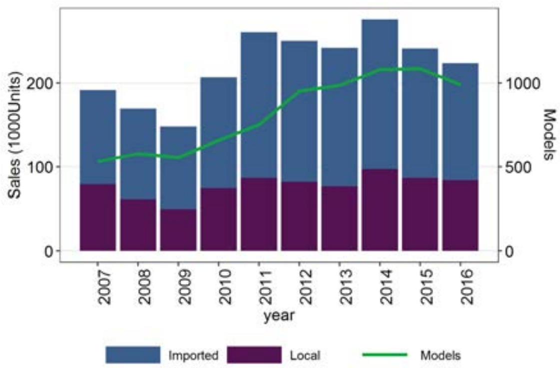
The identification of dynamic models of demand is based on the variation over time in the response of purchases to changes in measures of market-level quality, as first proposed by(24) (see also (9),(Hendel and Nevo),(30), (20)). Our preliminary analysis indicated that the correlation of purchase behavior and measures of market-level quality is stable, which implies that there is no evidence in the data that consumers are timing optimally their purchases. Therefore, we adopt a standard static choice model, which is equivalent to a dynamic choice model with stationary beliefs about the evolution of market-level quality and prices. On the supply side, car manufacturers and retailers adjust flexibly their prices. Price flexibility and static demand implies that pricing is static as in the standard models of markets for differentiated goods a la (7).

Since we are interested in analyzing how much of the incompleteness of pass-through is caused by firms responding to cost shocks and how much is caused by firms responding to their rivals, our work resonates with the work of (5), (2) and (26) who assess how much firms react to cost shocks and how much to rivals' decisions. Our endeavor is also similar to (4), as they exploit a sudden exchange rate appreciation in Switzerland to evaluate the impact of the sensitivity of retail prices to wholesale prices.

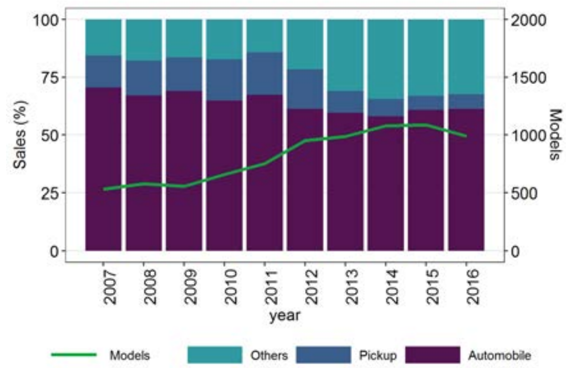
3 Data and descriptive analysis

We collect data on all new cars sold in Colombia during the years 2007-2016. The data were collected by an independent market research firm until 2013. For the years 2014-2016, the data come from the national administrative registry called RUNT (Registro Único Nacional de Tránsito), which includes data on all new registered vehicles. These data contain the quantities of specific models of cars sold. We obtain average yearly prices and the observed characteristics for each car model collected by an association of insurance companies (Fasecolda) which uses the price information for the adjustment of insurance policies. Finally, in order to account for the income of the households that purchase new cars, we use data from the Gran Encuesta Integrada de Hogares (GEIH) a household survey conducted by DANE (the Colombian national statistics agency), as we explain when we describe our model below.

Figure 1: Sales of cars: number and type

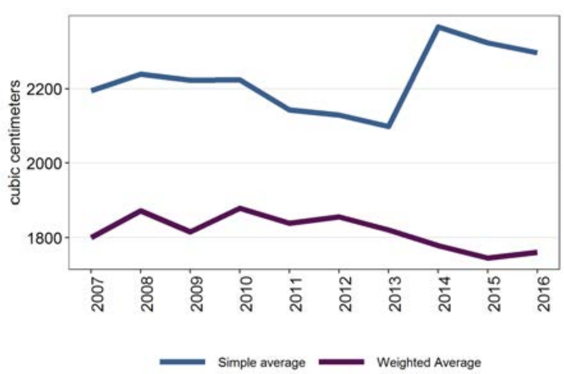


(a) Origin

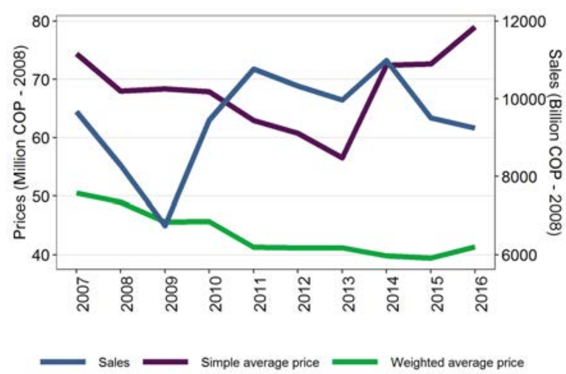


(b) Type

Figure 2: Engine Displacement, Prices and Sales



(a) Engine Displacement



(b) Prices

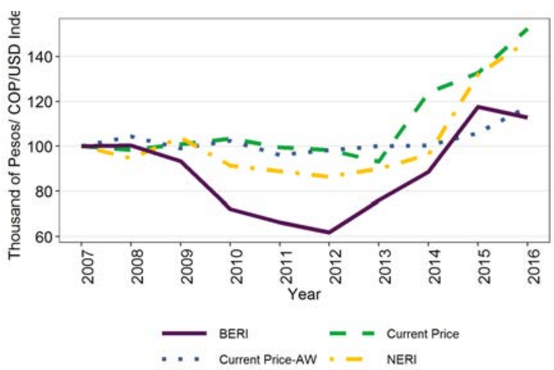
Figure 1 describes the number and types of cars sold yearly, while figure 2 shows how their average price and engine displacement evolved. Specific details are available in tables (3) and (4), respectively. During the sample period, the Colombian automobile market undergoes a significant transformation. While the number of different automobiles available to consumers almost doubled from 543 in 2007 to 1,018 in 2016, and sales increased from 192,000 units in 2007 to 277,000 units in 2014, the average price per car sold (weighted by sales) in constant COP fell every year-with 2016 being the only exception-as shown by the green line of figure 2(b). Even though the number of cars sold was 16% higher in 2016 than it was in 2007, the value of total sales in constant pesos fell by almost 5% during the same period.

An important driving force of the transformation of the market during these years was the evolution of the exchange rate. The nominal COP/USD exchange rate went from around COP$2,000 per dollar in 2007 to less than COP$1,900 per dollar in 2013 even though the cumulative inflation during these years was more than 20%. The large depreciation that started in 2014 took the exchange rate to more than COP$2,750 per dollar by the end of 2015 and to more than COP$3,000 per dollar by the end of 2016. During the years 2013-2016, the cumulative inflation was less than 20%.

Despite the large shocks to the exchange rate, and as shown by the purple line of figure 2(b), the simple average price of available cars, measured in constant 2008 Colombian pesos, fell from COP$75 million in 2007 to less than COP$60 million in 2013, and then increased to over COP$83 million in 2016. As pointed out before, the weighted average price of cars is more or less constant, which implies that consumers substitute across cars as their relative prices change.

The focus of our analysis will be the depreciation of the exchange rate between 2013 and 2016. In Figures 3(a) and 3(b), we show the evolution of the exchange rate and prices between 2007 and 2016. Specifically, Figure 3(a) shows yearly indices for the nominal exchange rate and the average nominal prices of cars. The figure shows indices for the COP/USD nominal exchange rate and for the average bilateral exchange rate with countries of origin, weighted by car imports. It also shows indices for the simple average price across available models, and the price average across models weighted by sales. As shown, the simple average price traces closely the COP/USD exchange rate, whereas the average price weighted by the observed sales grows more slowly after the depreciation. Moreover, the nominal exchange rate index, weighted by the shares of imports of specific countries, shows a much smaller increase after 2014. In other words, consumers substitute for cheaper cars from countries whose currencies

Figure 3: Prices and Exchange rates



(a) Nominal

Panel (a): BERI is weighted average bilateral exchange rates (local currencies per COP) index using sales as weights. Current price corresponds to an index of the average price of cars in current COP. Current price - AW is an index of the average price of cars in current COP using sales as weights. NERI is the nominal exchange (COP/USD) rate index.

(b) Real

Panel (b): Price 2008 is the average constant price deflated by CPI. Price 2008 - AW is a weighted average constant price using sales as weights and CPI as deflator. RERI: real exchange rate index (weighted average by sales) calculated using the rate between Colombia and the car's country of origin devaluation times, the ratio between the car's origin country, and the Colombia inflation rate.

exhibit a relatively low depreciation.

Figure 3(b) plots indices for real prices and real exchange rate. The average real price of cars closely follows the evolution of the real exchange rate. Interestingly, the weighted average real price of cars continues trending down after 2013 once more showing the important role played by consumer decision on determining the level of pass-through.

We can further explore the correlations between the average price of cars and the exchange rate in the microdata, using standard pass-through regressions. We run regressions of model-level prices on the nominal COP/USD exchange rate and model-fixed effects, as follows:

$$p_{jt} = \alpha_0 + \alpha_1 ER_t + \alpha_2 ER_{t-1} + u_{jt} \tag{1}$$

where p_{jt} is the price of model j at year t and ER_t is the nominal COP/USD exchange rate in year t. We include one lag in the regression, since more lags were not statistically significant.

We consider three different specifications of equation 1. In the first specification, the coefficients are constant across models up to a model-specific constant. In the second specification, we allow the coefficients to be correlated with the bilateral exchange rate with respect to each model's country of origin. In the third specification, the coefficients vary

Table 1: Reduced Form

	Dependent variable:				
	Price				
	(1)	(2)	(3)	(4)	(5)
TRM	-0.0196	-0.0260	-0.0222	-0.0221	-0.0229
	(0.0125)	(0.0213)	(0.0199)	(0.0200)	(0.0206)
Lag.TRM	0.0205***	0.0222**	0.0130*	0.0130*	0.0129*
	(0.00708)	(0.0102)	(0.00643)	(0.00644)	(0.00741)
BER-COP/LCU		0.0597	0.0164	0.0161	0.0173
		(0.0626)	(0.0573)	(0.0576)	(0.0583)
Lag.BER-COP/LCU			0.104**	0.104**	0.106**
			(0.0424)	(0.0428)	(0.0453)
Share				0.775	0.779
				(1.301)	(1.225)
Share × TRM					0.695
					(0.834)
Share × Lag.TRM					0.150
					(0.760)
Observations	4,631	4,631	4,631	4,631	4,631
r2	0.991	0.991	0.991	0.991	0.991

Notes: Cluster errors in parentheses * p<0.10, ** p<0.05, *** p<0.01.
All regressions include fixed effect of car.

with respect to the markets shares of each model. The aim of this analysis is to detect any possible correlation of the exchange rate pass-through with the bilateral exchange rates and the sales of each model. These two variables are themselves correlated with cost and relative demand, respectively, which, as we have pointed out, seem to have had an effect on the observed pass-through.

Specifically, in the first specification we let $\alpha_{0j} = \alpha_0 + \alpha_j$ and $\alpha_{rj} = \alpha_r$ for $r = 1, 2$. In this case, the coefficients are the same for all car models, except for the model-specific constant α_j which is estimated with a fixed effect. In the second specification $\alpha_{0j} = \alpha_0 + \alpha_j + \alpha_{0BER} BER_{jt}$ and $\alpha_{rj} = \alpha_r + \alpha_{rBER} BER_{jt}$ for $r = 1, 2$, so that the coefficients vary with respect to the time t bilateral real exchange rate BER_{jt} of Colombia and each j model's country of origin.

Finally, in the third specification the coefficients depend on the model's market share among all available cars at time t, denoted s_{jt/J_t}: $\alpha_{0j} = \alpha_0 + \alpha_j + \alpha_{0s} s_{jt}$ and $\alpha_{rj} = \alpha_r + \alpha_{sr} s_{jt}$, for $r = 1, 2$. Notice that all the specifications include fixed effects α_j that absorb the effect of the characteristics of each model that don't change over time, therefore the results are based on changes over time within each car model.

The coefficients $\{\alpha_1, \alpha_2\}$ in (1) measure the pass-through of the exchange rate to retail prices at the product level. In the first specification we assume that the coefficients are constant across products, i.e. $\alpha_{jr} = \alpha_r$ for $r = 1, 2$. In the second specification, we let the coefficients vary depending on the bilateral real exchange rates with the model's country of origin BER_{jt}, i.e. $\alpha_{jr} = \alpha_r + \alpha_{rBER} BER_{jt}$ for $r = 1, 2$. In the third specification, we let the coefficients depend on the model's market share among all available cars at time t, denoted s_{jt/J_t}: $\alpha_{jr} = \alpha_r + \alpha_{sr} s_{jt}$, for $r = 1, 2$.

Table 1 shows the results of these regressions. All variables are standardized, so that the coefficients are measured in terms of standard deviations of each variable. In column 1, we show the basic result with no interactions, which indicates that pass-through takes a year. One standard deviation increase of the COL/USD exchange rate is correlated with a statistically significant increase of around 0.12 standard deviation of car prices one year later. In other words, on average, there is incomplete pass-through of the nominal exchange rate to the final prices.

Columns 2-3 show the results that incorporate the effect on the pass-through of the real bilateral exchange rate of the COP vis-à-vis the currency of the countries of origin. As shown, the coefficient of the interaction of the bilateral exchange rate with the lagged nominal exchange rate is negative and significant, which means that the pass-through was lower precisely for the cars imported from countries that experienced a relative real depreciation of the exchange rate with respect to the Colombian peso. As expected, controlling for this interaction makes the coefficient of the lagged nominal exchange rate larger. Conditional on the real bilateral exchange rate, an increase of one standard deviation in the nominal US/COP exchange rate is associated with an increase of 0.24 standard deviations in the final price of the car. Even though the average pass-through is still incomplete, it is double the size as the unconditional estimate.

Letting the coefficients depend on the market shares of individual car models should show whether cars that become more popular have different pass-through than less popular cars. As shown in columns 4-5, the addition of the market shares to the regression does not have any effect on the estimated pass-through. In other words, there is no prima-facie evidence that the pass-through was lower for cars that became more popular after the depreciation.

These descriptive results show that price adjustment after the depreciation of 2014 was correlated with cost shifters, but not with crude demand shifters. This variation in the data will therefore allow us to estimate a structural model of demand and pricing that we can use to simulate counterfactual equilibria. We describe the model and its estimation in the following section.

4 The model

We are interested in understanding the adjustment of automobile prices after the large Colombian depreciation of 2014-2015. In particular, we want to estimate the effect that the depreciation had on wholesale prices, markups, and consumer behavior. Our strategy is to estimate a structural model of supply and demand and use the model to simulate counterfactual scenarios to isolate the effect of the different factors that determine the observed retail prices.

The focus of our analysis is the optimal prices p^* of car distributors in Colombia, which follow a pricing equation as follows:

$$p^*_{jt} = mc_{jt} + \upsilon^*_{jt}(Z_{jt}) \tag{2}$$

where $mc_{j,t}$ is the wholesale price (marginal cost) of car model j at time t. The optimal markup $\upsilon^*(Z_{jt})$ is a function of a set of state variables Z_{jt}, which depend on the strategic setup of the problem. For example, in a static Bertrand context, the state variables include the equilibrium cross-price elasticities of car models.

An exchange rate shock affects the wholesale price of cars which, in turn, determines the marginal cost faced by domestic retailers. The relationship between these marginal costs and the exchange rate is contained in the data and can be estimated. If an exchange rate shock affects cars differently depending on their country of origin and is distributed unevenly across countries, it will affect firms differently. Additionally, since price elasticities vary depending on equilibrium prices, markups should change differently across car models.

Our objective is to estimate the model (6) and compute the equilibrium under counterfactual assumptions. The estimation of the model yields estimates of the marginal costs that can be correlated with the exchange rate, country of origin, and other car characteristics. We can then use the estimated model to run a set of counterfactual assumptions to simulate equilibria with different exchange rates.For example, to assess the equilibrium pass-through of the observed exchange rate shock, we could simulate the model under the assumption that the exchange rate is constant. To do so, we have to estimate a demand system and a pricing model. We adopt a standard model of demand and pricing for differentiated goods that we discuss in more detail below. We take as given the set of products available in the market to abstract from entry/exit issues. We then use the estimated model to simulate optimal prices under counterfactual assumptions regarding the path of exchange rates.

4.1 Demand

We follow the standard literature on the estimation of demand for differentiated goods and assume that consumers have preferences over the attributes of cars as described by the utility function:

$$u_{ijt} = \delta_{jt}(x_{jt}, p_{jt}, \xi_{jt}) + \mu_{ijt}(x_{jt}, p_{jt}, \epsilon_i) + \varepsilon_{ijt}, \tag{3}$$

where the choice of a consumer i depends on the mean utility that each car model j generates to all consumers at time t, δ_{jt}, which in turn depends on the car's observed characteristics x_{jt}, its price p_{jt}, and an unobserved product attribute ξ_{jt}. We assume that there is an outside option $j = 0$ that corresponds to not purchaseing any car in the new car market, with a normalized mean utility $\delta_{0t} + \mu_{i0t} = 0$ which is constant across consumers and over time. The fact that this outside utility is exogenous and constant over time implies that consumers face a static problem each period.

The addition of consumer-specific tastes $\mu_{ijt} + \varepsilon_{ijt}$ in (3) generates market-level demand functions that depend on the observed characteristics and prices of all available car models:

$$s_{jt} = s(x_{jt}, \xi_{jt}, p_{jt}) \equiv \int \text{Prob}(u_{ijt} \geq u_{ikt}) dF(\mu_{ijt}, \varepsilon_{ijt}) \, \forall k \neq j \tag{4}$$

for $r = 0, 1, ..., J_t$, with J_t being the set of cars available to consumers at any given period. The demand is given by the share s_{jt} of all potential buyers at time t that choose model j over any other alternative model k. This share is the integral of the PDF describing a potential buyer i purchasing model j at time t over the distribution of the consumer-specific taste randomness $\{\mu_{ijt}, \varepsilon_{ijt}\}$. Since the demand of all models depends on the characteristics and prices of all models at time t, it is convenient to rewrite the demand system in matrix form:

$$S_t = S(X_t, \Xi_t, P_t) \tag{5}$$

where S_t, Ξ_t and P_t stand for the time t demand, unobserved attributes and price vectors, respectively; X_t is the matrix with the stacked vectors of the observed characteristics of all products. This demand system can be estimated directly using standard techniques based on the properties of the product and time-level model specific shocks ξ_{jt}. Alternatively, the demand system can be estimated jointly with the pricing model that is the focus of this paper and that we describe below.

4.2 Pricing

We assume that each car manufacturer b sets prices to maximize profits over a time horizon, taking as given the set of available models. Therefore, a manufacturer's problem is to set prices to maximize their profits:

$$\sum_{t=1,\ldots,T} \pi_{bt} = \sum_{t=1,\ldots,T} \sum_{j \in \Im_{bt}} (p^*_{jt} - mc_{jt}) s_{jt} M_t,$$

where each firm's b flow of profits at time t, denoted as π_{bt}, is the sum of product-level profits over the set $\Im_{bt}$ of products sold by the firm at time t. For each product j, profits are given by their markup times demand, which is the product of firm b´s model j market share and the number of potential consumers in the market M_t. Notice that by assumption, the characteristics of all available cars are taken as given.

We follow standard empirical models of product differentiation and assume that firms maximize each period's profits in a static environment. In this context, for each car model

l sold by firm b at time t, optimal prices solve the following problem a la Bertrand:

$$p^*_{l \in \Im_{bt}} = \arg\max \sum_{j \in \Im_{bt}} (p_{jt} - mc_{jt}) s_{jt} M_t, \tag{6}$$

where it is assumed that the marginal cost of each car mc_{jt} does not depend on the number of units sold. The first order conditions of this optimization problem imply that prices are equal to the marginal cost, plus a markup which depends on the own- and cross-price elasticities of the cars so that each car's price accounts for its effect on its demand and the demand of other models sold by the same firm. In matrix form, the equilibrium prices solve the following equation:

$$P^*_t = MC_t + \Upsilon(X_t, \Xi_t, dS_t/dP'_t), \tag{7}$$

where MC_t is the time t vector of model-level marginal cost and dS_t/dP'_t is the $J_t \times J_t$ matrix of price derivatives across cars available at time t. The vector Υ contains the markups of each model as a function of the characteristics of all models and the derivative of demand with respect to all prices. Notice that each model's markup depends on the characteristics of all models, since the demand for each model and its elasticities depend on the demand for all models.

The pricing equation (7) can be used to estimate marginal costs, given estimates of the demand described by equation (4). Alternatively and as indicated above, equations (4) and (7) can be estimated jointly. In our estimation, we parameterize marginal costs as linear functions of the observed characteristics and an unobserved cost shock ω_{jt} as follows:

$$mc_{jt} = X_{jt}\Gamma + \omega_{jt},$$

where the estimation of Γ is based on the statistical properties of ω.

4.3 Pricing and exchange rate pass-through

The estimation of the demand and pricing model above yields estimates of COP-denominated time- and model-level marginal costs. Since most cars that are sold in the country are imported, the marginal costs faced by car brands in Colombia correspond roughly to the wholesale price of cars, i.e. the price that the manufacturer charges the local dealerships for each car. Moreover, since the Colombian market is relatively small in the context of the global car market, the assumption that marginal costs do not depend on quantities or any other market-level demand shock is reasonable.

In order to infer the effect of exchange rate on prices, we first analyze the relationship between the estimated marginal costs and the real exchange rate of the Colombian peso. We assume that the model-level natural logarithms of marginal costs are linearly related to the country-specific exchange rates e_{jt}:

$$\ln mc_{jt} = \phi e_{jt} + \nu_{jt}, \tag{8}$$

where ν_{jt} is an error term and ϕ is a vector of parameters that we estimate. We will be more specific about the exchange rate measures that we use when we get to the estimation below. We consider this equation structural in the sense that it is stable across counterfactual exchange rate paths.

We can estimate the parameters ϕ using OLS, under the assumption that ν is independent of the exchange rate shocks, as we explain in more detail below. Let $\widehat{MC}(E_0)_t \equiv \{\widehat{mc}_{t=1,\ldots}\}$ be the vector of estimated marginal costs under a given set of observed exchange rates E_0. The pricing equation (7) can be used to obtain predicted prices under any set of exchange rates. For example, the baseline prediction $\hat{P}_t^0(E_0)$ of the estimated model would be obtained from the following equation:

$$P_t^0 = \widehat{MC}_t(E_0) + \hat{\Upsilon}_t(P_t^0)$$

where $\hat{\Upsilon}_t(P_t^0)$ is the estimated vector of markups, which itself depends on equilibrium prices. Similarly, we can use the estimated model to compute the predicted price vector $\hat{P}_t'$ associated with any counterfactual set of exchange rates E' or any other counterfactual scenario of interest.

In this context, the pass-through of the exchange rate would be given by the predicted differences in prices given the change in the exchange rates: $\frac{\hat{P}' - \hat{P}_0}{E' - E_0}$. Notice that this pass-through has two components. First, there is a direct effect on marginal costs; and second, there is an indirect effect on prices via optimal markups that respond to changes in demand across car models. Moreover, equilibrium markups respond to demand adjustment across car models due to the change in relative prices. However, as we show below, there are other important mechanisms at play affecting pass-through, like the set of cars that sellers decide to sell in response to the exchange rate shock and consumer substitution.

5 Estimation and results

5.1 Specification of the empirical model

We need to estimate the demand equation (4) and the pricing equation (7) simultaneously. To obtain an estimable demand equation, we parameterize the components of equation (3) as follows:

$$\delta_{jt}(x_{jt}, p_{jt}, \xi_{jt}) = X_{jt}\beta + \xi_{jt} \tag{9}$$

where β is a vector of parameters to be estimated and X_{jt} is a vector containing two continuous characteristics of the car (engine displacement measured in cubic centimeters and number of doors), a set of dummies for other discrete characteristics of the car (air conditioner, brand, type of vehicle and country of origin) and a second set of dummies to control for model and year fixed effects. Finally, the mean utility depends on a model-level unobserved attribute ξ_{jt}, which will serve as the market-level regression error term. This first term represents the mean utility generated by car model j across consumers at time t.

$$\mu_{ijt}(x_{jt}, p_{jt}) = \sigma^{cc}\epsilon_i^{cc}x_{jt}^{cc} + \sigma_{doors}\epsilon_i^{doors}x_{jt}^{doors} + \alpha\left(\ln[y_{it}] - \ln[p_{jt}]\right) \tag{10}$$

The second term in (3), explicitly written in equation (10), includes the components of utility that vary systematically across consumers. The price of model j at time t, p_{jt}, affects utility through its effect on the relative income of individual i, y_{it}. To model the consumers' income we randomly draw, every year, $1,000$ individuals without repetition from the household survey. The marginal utility of income depends on the coefficient α, the price of the car and the realization of income for individual i. In the portion of the utility that varies between individuals we include $\sigma_{doors}\epsilon_i^{doors}x_{jt}^{doors}$ which accounts for the fact that an ϵ_i-type individual has persistent taste for cars with more doors.

Finally, utility depends on an idiosyncratic shock ε_{ijt} that varies across models, individuals and years, and which is assumed to follow an iid Type I Extreme-Value distribution. This formulation of demand is similar to standard demand models that are mapped to market-level data, without micro-level data matching purchasing decisions with individual characteristics. The specified model generates a demand system as follows

$$s_{jt} = \int \frac{e^{\delta_{jt}(\cdot,\xi_{jt};\beta)+\mu_{ijt}(\cdot,\epsilon;\alpha,\sigma)}}{\sum_{l\in J_t} e^{\delta_{lt}(\cdot,\xi_{lt};\beta)+\mu_{ilt}(\cdot,\epsilon;\alpha,\sigma)}} dF_t(\epsilon), \tag{11}$$

where the integral is taken with respect to the distribution of the individual-level error term $\epsilon = \{\epsilon_{it}^{inc}, \epsilon_{it}^{cc}, \epsilon_{it}^{doors}\}$. We can use (11) in (5) to compute the market-level demand shock ξ for any vector of parameters β , α and σ. As it is usual in this type of estimation, we compute the integral via simulation and assume that the error terms ϵ follow an iid standard normal distribution.

On the supply side, we assume that the marginal cost is given by the following equation:

$$\begin{aligned} \ln mc_{jt} = \gamma_{cc} x_{jt}^{cc} + \gamma_{doors} x_{jt}^{doors} + \gamma_{model} x_{jt}^{model} + \gamma_{AC} x_{jt}^{AC} + \\ \gamma_{brand} x_{jt}^{brand} + \gamma_{type} x_{jt}^{type} + \gamma_{country} x_{jt}^{country} + \omega_{jt} \end{aligned} \tag{12}$$

where the variables that affect costs are the same variables that affect utility. In this specification, the effect of the changes in the bilateral real exchange rate are fully absorbed by the dummy variables $x_{jt}^{country}$, which vary across car models and over time depending on the country of origin of the car. The marginal cost is also affected by a model- and time-specific unobserved state variable ω_{jt}, which will be the econometric error that we will use to estimate the coefficients γ.

Replacing demand and cost in the pricing equation (7), we obtain the following estimable equation:

$$P_t^* = MC_t(\cdot, \omega; \gamma) + \Upsilon(X_t, \Xi_t, dS_t/dP_t'; \alpha, \sigma), \tag{13}$$

where the markup $\Upsilon(.)$ depends on the demand parameters. Notice that, conditional on all the parameters of the model, the unobserved shock ω can be calculated directly.

We estimate both demand and supply simultaneously. For any vector of parameters $\theta_0 = \{\alpha_0, \beta_0, \gamma_0, \sigma_0\}$, the unobserved states $\{\xi(\theta_0), \omega(\theta_0)\}$ can be computed and interacted with instruments to construct a criterion function that we minimize numerically:

$$G(\theta) = [\{\xi(\theta_0) : \omega(\theta_0)\}'Z]'\Omega[\{\xi(\theta_0) : \omega(\theta_0)\}'Z], \tag{14}$$

where Ω is a weighting matrix and Z is a matrix of instruments. We use as instruments the distance in the characteristic space between each car and other of available cars in the choice set, as described in (16). Specifically, we use the engine displacement, the type of car, and interactions between both. Moreover, we use the bilateral exchange rate with respect to the origin of each car, and the import tariffs imposed on the cars imported from each car's country of origin.

5.2 Estimation results and goodness of fit

We show the estimated coefficients of our preferred specification in table 2. The given specification identifies a negative price effect on demand (i.e. positive value for α). The estimated taste and cost coefficients for engine size are positive, while the taste and cost coefficients for the number of doors are negative. This indicates that all demand and supply effects associated with the size of the cars are absorbed by engine size. Similarly, the coefficients for the air conditioner dummy on both the supply and demand sides of the model are negative. This anomalous result is caused by the fact that air conditioning is not uniformly valued in the country, since it is not needed in some of the richest cities (including Bogotá and Medellín, which account for more than 20% of the country's population). So our model accommodates large shares of expensive cars in those cities that have no AC by estimating a negative parameter on the taste for AC.

Table 2: Estimates

	Demand	**Supply**
α	10.239***	
	(0.000)	
CC	6.430***	0.502***
	(0.001)	(0.000)
$Doors$	-6.920***	-0.006***
	(0.005)	(0.000)
σ_{do}	5.058***	
	(0.003)	
Air	-0.565***	-0.029***
	(0.000)	(0.000)
BER		0.073***
		(0.000)

Note: We only report the parameters of interest but the equations for demand and supply include model, year, country of origin and type of vehicle fixed effects too. The standard errors for the coefficients of the non-linear part of the specification, α, σ_{cc} y σ_{do} are obtained from the variance-covariance matrix of the GMM and the standard errors for the estimates on displacement (CC), doors and AC are obtained via bootstrapping.

We use this specification to analyze the pass-through of the exchange rate to prices and quantities. To do so, we compute counterfactual equilibria that we compare with the baseline estimation. Before we do so, we assess the goodness-of-fit of our model by comparing observed prices and shares to prices and shares predicted by our model under a baseline scenario. In the baseline scenario, we use the estimated demand and supply to compute an equilibrium in which firms and consumers respond optimally to the observed state of the world.

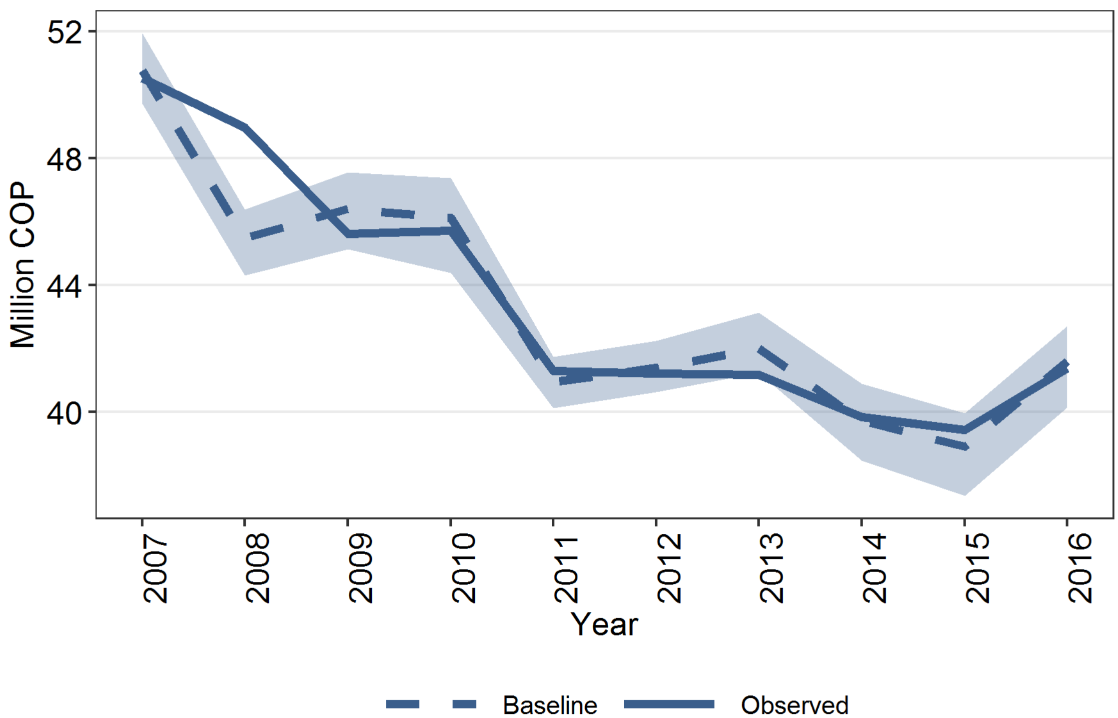
We start by looking at prices. Figure 4 shows the evolution over time of the average price of cars sold in Colombia between 2007 and 2016, weighted by the market shares of each year. The continuous line shows the observed average prices, while the dashed line (and its 95% confidence interval which is always under 10% of the price of the car) shows the baseline average price predicted by our model. The prices predicted by our model follow closely the observed prices. Moreover the 95% confidence interval generated by our baseline prices includes the observed average prices every year except for 2008 when the observed price is above the upper limit of the interval.

Similarly, figure 5 depicts the evolution of the weighted average markups, which range between 6.0% in 2007 and 4.3% in 2015. As before, the dashed line corresponds to the markups under the baseline scenario and the continuous line corresponds to the observed markups -calculated as observed price minus estimated marginal cost. Our model accurately replicates the average prices of cars after 2010. For every year in this period the 95% confidence intervals implied by our model contain the observed average markups. Our model, however, underestimates the average markup for 2009 and overestimates the average markups of 2008 and 2007.

After establishing that our model accurately captures the strategic decisions of firms, we turn our attention to gauge how it captures the decisions of consumers. In figure 6, we plot the share of consumers that purchase a new car every year among all consumers. As before, we show the baseline share of consumers buying new cars in our baseline scenario as a dashed line and the share of people purchasing a new car in the data as a continuous line. The share of consumers buying a new car every year predicted by our model follows closely the observed share, the baseline scenario slightly predicts fewer people buying new cars the first and last two years of our sample period. The fit of the model is not surprising, since the estimation is based on the equality between observed and predicted market shares.

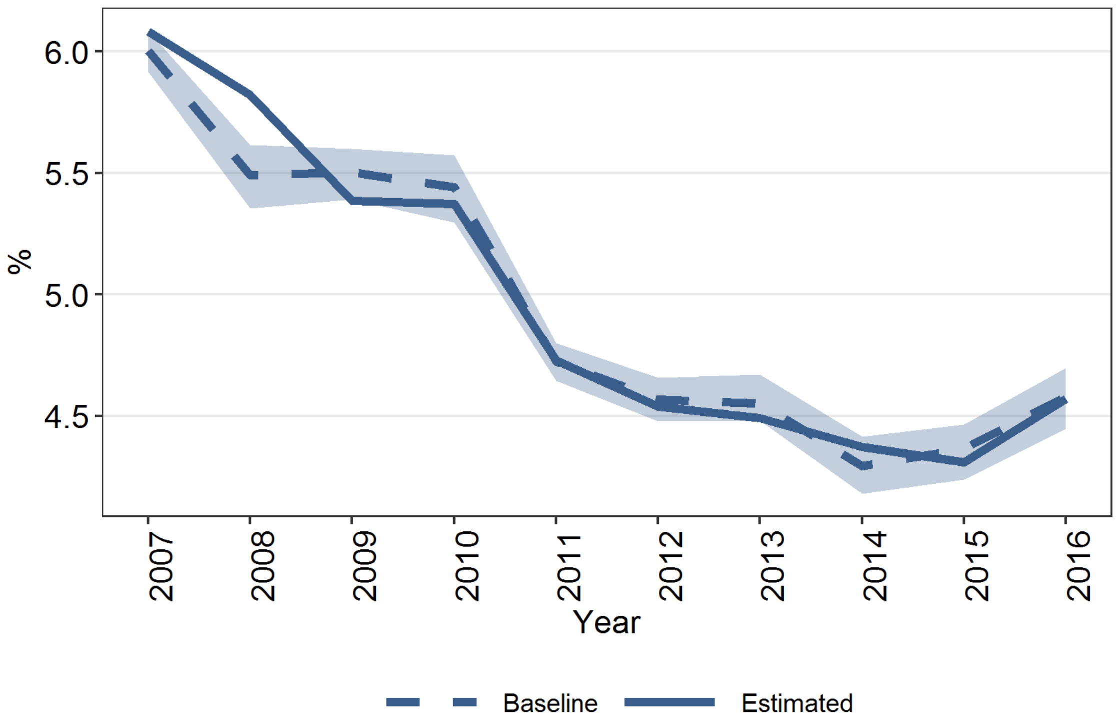
Conditional on purchasing a car, consumers must decide the type of car they buy. For instance, consumers might tend to buy cars with more powerful engines when cars are cheap. To assess the ability of the estimated model to replicate this this kind of substitution, we

Figure 4: Average price of new cars



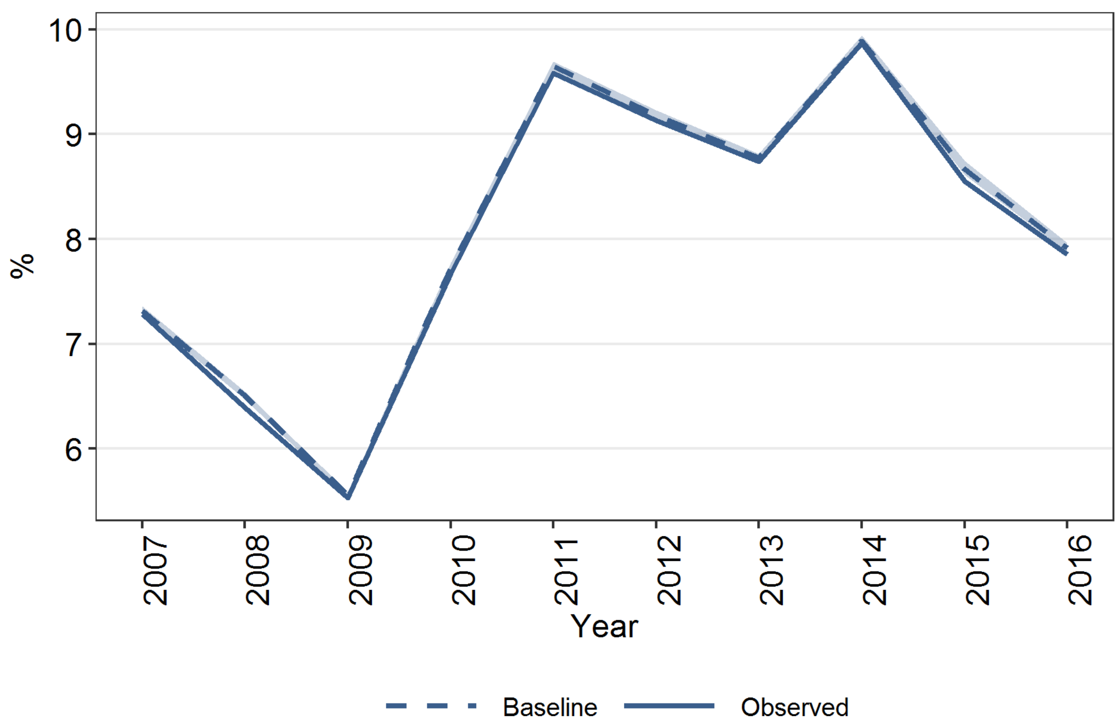
Note: The solid line is the observed average price weighted by the number of cars. The dashed line results from averaging the weighted average prices obtained from the prices and quantities predicted by our model under 50 random draws of unobserved marginal costs. We use the 5th and 95th percentile of the simulated average prices to construct the shaded 95% confidence interval.

Figure 5: Average markup



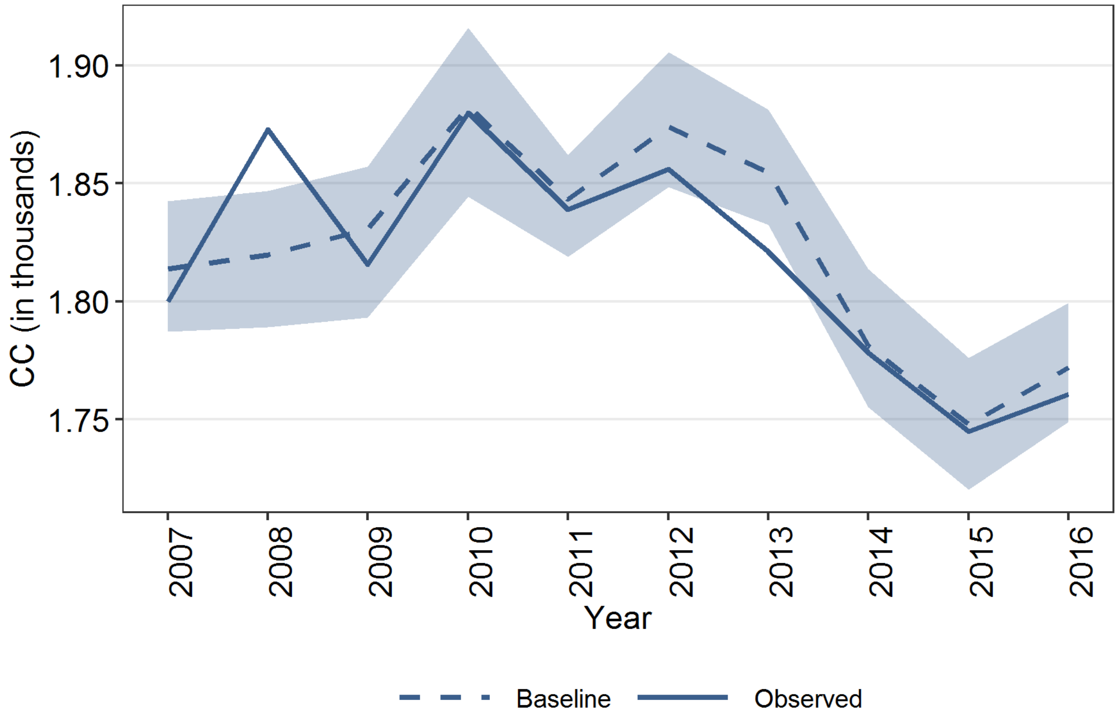
Note: The solid line is the weighted average markup recovered from our estimation. The dashed line results from averaging the weighted average markups obtained from the prices, quantities, and marginal costs implied by our model under 50 random draws of unobserved marginal costs. We use the 5th and 95th percentile of the simulated average markups to construct the shaded 95% confidence interval.

Figure 6: Proportion of consumers buying new cars



Note: The solid line shows the observed share of households buying cars. The dashed line averages the proportion of car buyers for 50 random draws of unobserved marginal costs. We construct the shaded 95% confidence intervals using the 5th and 95th percentile shares of the 50 simulations.

Figure 7: Average engine displacement



Note: The solid line is the observed weighted average engine displacement. The dashed line averages 50 simulated weighted average displacements obtained from randomly drawing unobserved marginal costs. We construct the shaded 95% confidence intervals using the 5th and 95th percentile simulated weighted average engine displacement.

compare the evolution of the average engine displacement under the baseline scenario and the observed average engine size. In figure 7, we compare the average displacement of cars bought each year in the data and as predicted by the estimated model. The 95% confidence intervals generated by our baseline specification contain the observed average displacement of observed purchases for all years except 2008, when our model underestimates it, and 2013 where our model slightly overestimates it. This highlights the ability of the model to replicate the behavior of both consumers and firms under changing market conditions, specially after the exchange rate depreciation in 2014-2015. Firms, on the one hand, introduced less powerful models in response to the increase in their trading costs (exchange rate). Consumers, on the other hand, substituted more powerful–and more expensive–cars for newly available cheaper cars with smaller engines.

In the model, car prices reflect the decisions of both consumers and firms. In order to illustrate the ability of the estimated model to replicate observed prices and the decisions of consumers, we compute two different average prices. First, we compute average prices as before, weighted by the contemporary market shares of each car model. Second, we construct a fixed basket using the market shares observed in 2013. We use our model to simulate the equilibrium pricing decisions of firms and the purchase decisions of consumers, and calculate weighted average prices under the two alternative sets of weights.

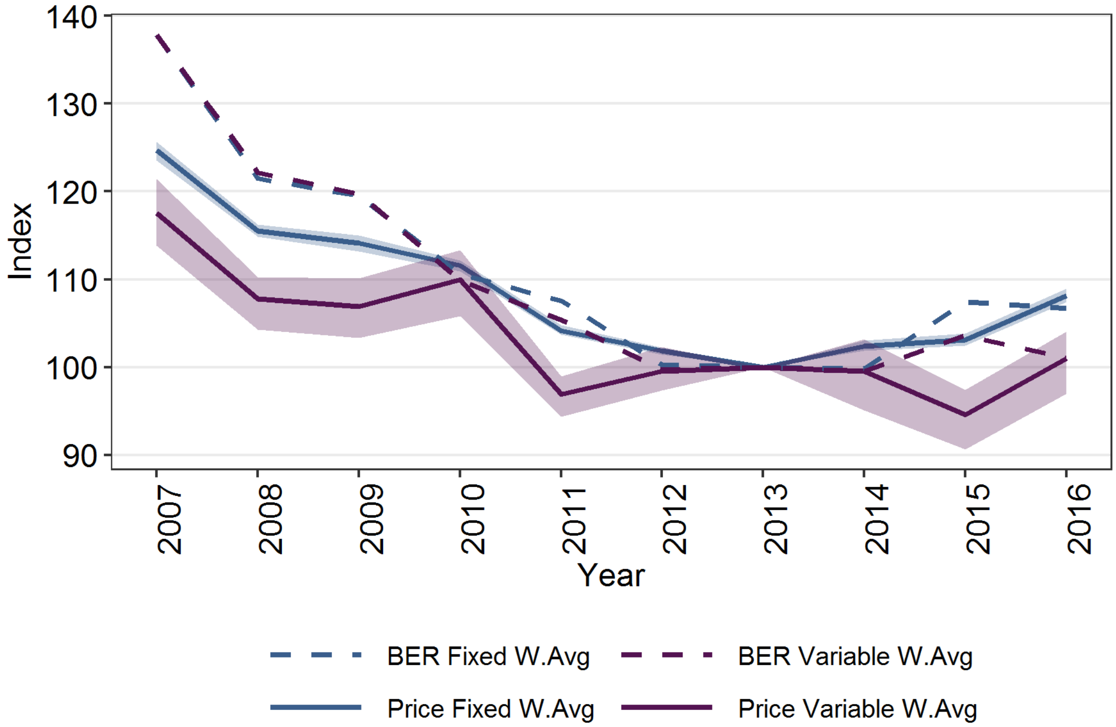
To construct the price index with the shares of the 2013 models as weights, we need to fix the set of attainable cars across years. Because models change over time, we define pseudo models by combining makes and engine displacements that we can follow across different years. Effectively we define six categories of engine displacement: less than 1600 cc, between 1600 cc and 2000 cc, between 2000 cc and 2500 cc, between 2500 cc and 3000 cc, between 3000 and 3500 cc, and over 3500 cc. Within each displacement category and brand, we calculate the mean of the prices and compute the total sales of the "model" as defined by the displacement-brand pair.

In figure 8, we show the two bilateral exchange rate averages and the two average prices. As before, we have a weighted average that uses contemporary market shares as weights, and we add an average price that uses the 2013 market shares as weights every year. The solid blue line corresponds to the price index calculated using the shares of cars sold in 2013 as weights. In contrast, the solid purple line shows the average price of cars weighted by the contemporary time-changing shares. The graph illustrates the fact that, as prices change, consumers substitute towards less expensive alternatives. After 2013, the price index computed using 2013 shares increases while the average price of purchased cars falls and returns to its 2013 level by 2016.

The plot also highlights the extent of incomplete pass-through. Even though the fixed basket price index rises, it does so only slightly compared to the increase in the exchange rate. Take 2015 for example. The blue dashed line shows that in 2015 the exchange rate increased 9% relative to its 2013 level. Instead, the fixed-weights average price of the car, shown by the solid blue line, increases only about 3%. On the other hand, the average price of purchased cars decreases by about 5%.

Our model captures well the decisions of consumers and sellers of new cars. Moreover, it precisely predicts the interaction between the agents of the market every year and captures many important features governing their behavior. Since all prices and quantities are endogenous, disentangling the components of the pass-through requires computing equilibria under alternative assumptions and compare them with the baseline simulation, which we do in the following section.

Figure 8: Exchange rates and price of cars



Note: Solid lines depict price indices with 2013 as the base year. The blue line corresponds to a fixed-weight price using the 2013 shares as weights. The purple line is a variable-weight price index that uses contemporary shares as weights. The shaded areas show the corresponding 95% confidence intervals. The dashed line is an index for the COP/USD exchange rate and has 2013 as the base year.

5.3 Simulation of counterfactual equilibria

An exchange rate shock, like the one that affected Colombia around 2013-2014, has the potential to impact several aspects that determine the equilibrium of the automobile market. The most important of such aspects are the costs faced by the firms. Dealers face two types of costs when selling cars. There are traded costs, that is, costs that are affected by the exchange rate, and non-traded costs, that is, outlays that are done in domestic currency that are naturally not exposed to exchange rate shocks. We have emphasized how important traded costs are for this particular industry. However, that doesn't mean non-traded costs aren't a big component of the total cost of selling a car. For instance, (8) have found the distribution costs of consumer goods to be 40% and 60% on average for the US and Argentina respectively.

The most salient traded cost is the cost of manufacturing cars. As stated before, most automobiles in Colombia are imported and even the automobiles assembled domestically rely heavily on imported parts, so shocks to the exchange rate have a first order impact on the costs of producing and selling cars. It is worth noting that this impact not only affects directly the costs of the cars imported from countries whose currencies are affected by the exchange rate shock, but also the relative costs of cars manufactured in countries whose exchange rates remain unchanged. For instance, a shock that increases the COP/USD exchange rate will make Chevrolet imports from Argentina, Brazil or Mexico, where Chevrolet has manufacturing plants, cheaper in comparison to imports from the US. A second order effect, induced directly by the cost shock, is how much of it is transferred to consumers. For instance, a manufacturer selling a model that has no close substitutes might be able, all other things constant, to transfer most of the cost shock to consumers, but they can't do the same with models that have numerous close substitutes.

Another way in which a COP/USD exchange rate shocks can affect the equilibrium of the Colombian automobile market is via consumer substitution. Once sellers have responded optimally to the initial shock by deciding where to import from, and strategically to their rivals by adjusting prices, consumers may respond by substituting away from models whose prices have increased. As we showed before, when comparing the average price of cars under a fixed basket and the average price of all the cars available, this kind of substitution plays an important role in keeping the average price low.

Finally, the exchange rate shock affects the disposable income of potential buyers either because it affects the amount of pesos they receive in the form of remittances or because it has a general equilibrium effect on aggregate income. In both cases consumers will optimally look for cars that better match their budget constraints, which might affect the pass-through of exchange rate to local prices.

We want to study the effect of each one of these causes of the incomplete pass-through that is usually documented. In order to do so, we simulate the purchasing behavior of car buyers and the strategic pricing behavior of car manufacturers under different scenarios to assess the relative importance of each one of these impacts on the response of local prices to exchange rate shocks.

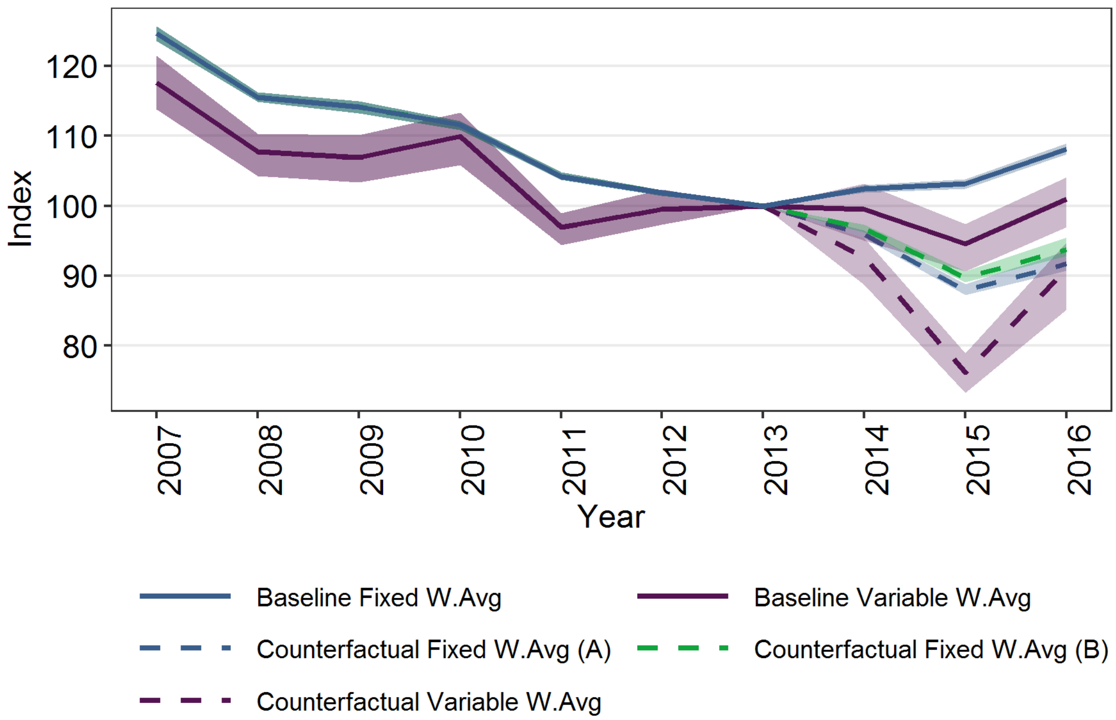
5.3.1 Exchange rate counterfactual

As mentioned before, when Colombian dealers sell cars, they face traded and non-traded costs. In a first counterfactual, we want to isolate the direct effect of traded costs. To do so we want to freeze the traded cost component of each car after the 2013-2014 depreciation. Since we have regressed the estimated marginal costs on car characteristics, including dummies for country of origin and year, we have estimates for the component of the marginal cost that corresponds to traded costs.

In practice, we take (12), and for each model we set the value of $\gamma_{jt}^{country}$ for $t \in \{2014, 2015, 216\}$ equal to their corresponding $\gamma_{j2013}^{country}$. We then use the counterfactual marginal costs to re-optimize the system described by (13) and obtain the prices that the firms would charge in a state of the world without depreciation. The optimized prices can be used to compute the counterfactual demand for each model. Notice that we are assuming that the time-varying country of origin-specific effect is not affected by any other factor different than the bilateral real exchange rate. Moreover, in this computation we assume that all other factors vary as in the data, including the menu of available cars and household income.

Figure 9 compares the average prices (normalized to be 100 in 2013) under this scenario with the average prices under the baseline scenario, in which we allow the traded costs to vary every year. To assess the effect of traded costs on the average price under each scenario, we compute weighted average prices using contemporaneous market shares and the 2013 market shares as weights, alternatively, as we did in the previous section. Regardless of the weights used to compute the average prices, fixing the traded component of the cost of selling cars at its 2013 level, implies a cheaper average car than under the baseline scenario in which the exchange rate is allowed to vary. In other words, our model predicts that non-traded production costs fell between 2013 and 2015, but prices increased slightly due to the change in the exchange rate.

Figure 9: Effect of exchange rate shock on prices of new cars



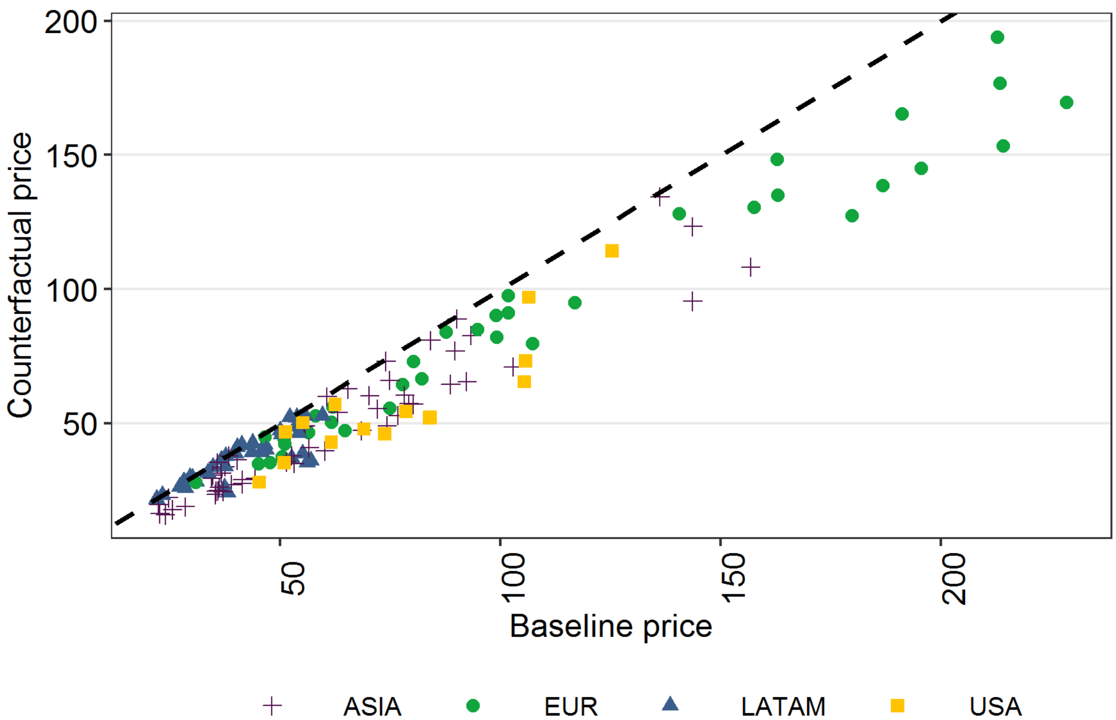
Note: Solid lines show baseline price indices for prices simulated by our model. The blue lines are fixed-weight price indices that use 2013 shares as weights. The purple lines use contemporary shares as weights. The dashed lines show the price indices under the simulated scenario in which the traded costs are held constant at their 2013 values (A). Similarly, we simulate this scenario with constant markups at their 2013 values (B). The shaded areas show 95% confidence intervals.

Specifically, in 2015 the fixed-weights average price of a car increases 3% relative to 2013, while its counterfactual counterpart decreases by about 13%. If we instead use contemporaneous market shares reflecting the changing consumption patterns, the price of the average car falls both under the baseline and the counterfactual scenario, respectively 10% and 22%. The difference between the baseline and the counterfactual is a measure of the pass-through of the exchange rate depreciation, which was around 33%.

We use figure 10 to gain insights into the differential effects that exchange rate shocks have on the price of cars from different origins. On the vertical axis we have the price of cars purchased when the traded costs are kept constant in their 2013 levels, and on the horizontal axis we measure the baseline price of cars when the traded costs are allowed to vary after 2013. Each dot corresponds to a brand-displacement pair. Notice that the vertical distance from each dot to the diagonal is a measure of the product-specific pass-through.

As shown, the prices of cars imported from Latin American countries, with which the

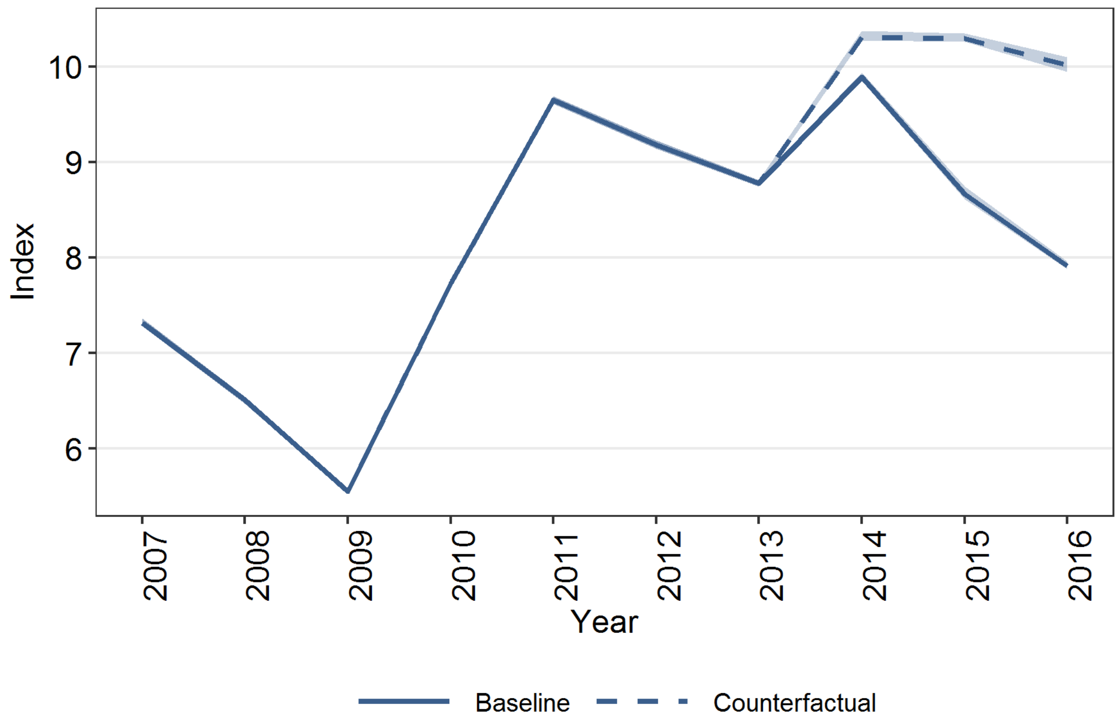
Figure 10: Effect of exchange rate shock on prices by origin



Note: Each dot represents a brand-size category. Size corresponds to a discretization of the engine displacement space into small, medium, and big. The horizontal axis measures the baseline prices for cars sold after the 2013 exchange rate shock. The vertical axis measures counterfactual prices for cars sold after the 2013 exchange rate shock. The car categories are grouped according to their origin: Asia, Europa, Latin America, and the USA.

exchange rate shocks are smaller, are bunched close to the 45 degree line which means, reassuringly, that the counterfactual and baseline prices are very similar. Equivalently, cars originated in Asia are in general cheaper in the counterfactual, which reflects the fact that the depreciation with respect to Asian currencies was smaller. The effect of the exchange rate shocks on the price of cars coming from Europe depends on which segment of cars we analyze. The counterfactual prices of relatively cheap European cars are less affected by the exchange rate shock, while the counterfactual prices of more expensive European cars show a clear deviation downwards with respect to their baseline levels. In other words, high-tiered European cars become cheaper with respect to their low-tiered counterparts. This highlights the fact that substitution happens in several dimensions, and even cars that share origin are affected differently in equilibrium. Finally, the counterfactual prices of cars coming from the US, against whose currency the peso lost more value, exhibit much larger deviations downwards, in proportional terms, than prices of cars originated in other regions.

Figure 11: Effect of exchange rate shock on share of buyers



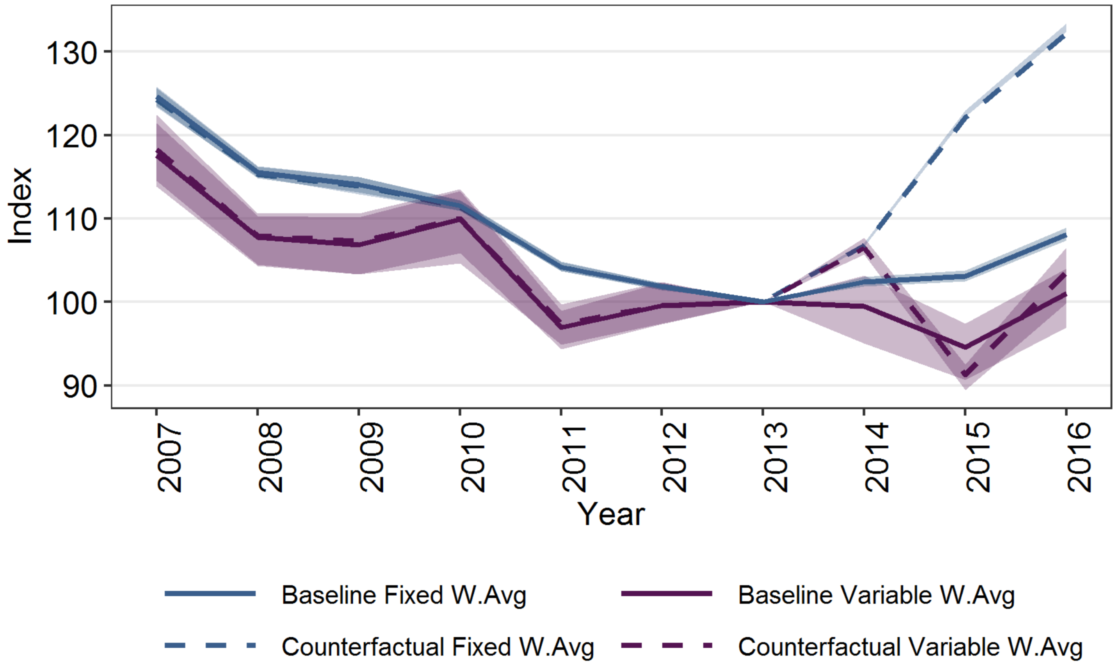
Note: The solid line shows the average proportion of consumers buying a car in our simulations each year. Each simulation finds the equilibrium prices for a random draw of unobserved marginal costs. With the equilibrium prices, we compute the proportion of consumers buying cars. The dashed line shows the proportion of consumers buying cars under the counterfactual scenario. The shaded area corresponds to the 95% confidence interval.

Although the proportion of households buying cars does not directly affect the level of pass-through that we are studying, it does affect it indirectly because more households buying cars puts pressure on the demand, particularly in the segment of more affordable cars, which in turn triggers a consumer response. We show in figure 11 the proportion of households that purchased cars every year under the baseline and counterfactual scenario. If the portion of the costs affected by exchange rates had remained the same after 2013 between 0.5% and 2% more households would have bought a car than in the baseline scenario.

5.3.2 Holding the firms' menus constant

Other strategic decision of the participants in this market that prevents pass-through from being complete is firms reacting to the increase in traded costs by altering their offer of goods. To gauge the extent of the impact that this response has on the equilibrium price of cars, we construct a counterfactual equilibrium in which dealers are forced to sell every year

Figure 12: Effect of holding the firms' menus constant on the prices of new cars



Note: Solid lines show baseline price indices for prices simulated by our model. The blue lines are fixed-weight price indices that use 2013 shares as weights. The purple lines use contemporary shares as weights. The dashed lines show the price indices under the simulated scenario in which the menus are held constant after 2013. The shaded areas show 95% confidence intervals.

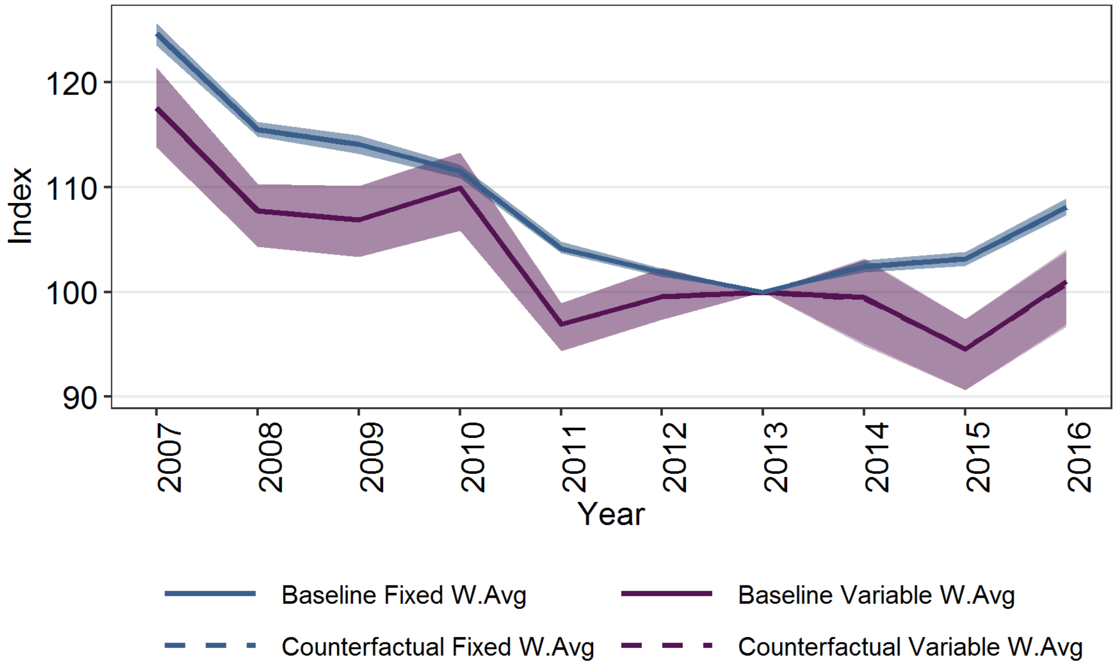
after the depreciation the same set of cars they were selling in 2013.

As we can see in figure 12 not allowing the firms to optimally tailor their menus in response to the shock results in higher average prices. Without consumer substitution (blue dashed line) the average price of cars would have increased by more than 30% (almost complete pass-through). In contrast the purple dashed line is the weighted average price computed using the actual shares that reflect the consumers' choice. Taking into account consumer substitution the average price of cars in 2015 is 10% lower than the average price of car just before the depreciation.

5.3.3 Holding the households' income constant

So far we've considered the effect of the exchange rate shock on prices, keeping everything else constant. As we mentioned before, an exchange rate shock might also be correlated with changes of the disposable income of households. To assess the importance of these income

Figure 13: Effect of aggregate income on the prices of new cars



Note: Solid lines show baseline price indices for prices simulated by our model. The blue lines are fixed-weight price indices that use 2013 shares as weights. The purple lines use contemporary shares as weights. The dashed lines show the price indices under the simulated scenario in which the traded costs are held constant at their 2013 values. The shaded areas show 95% confidence intervals.

effects on the equilibrium price of cars, we fix the households' income on their 2013 levels. In the baseline equilibrium, we randomly draw 1,000 individuals from the household survey corresponding to the year we are simulating. This way, the baseline scenario incorporates any aggregate income effects that influence the purchase decisions. In the counterfactual equilibrium, we keep the same 1,000 individuals we draw in 2013 for the rest of the years in our sample period and let all other variables adjust. Since we allow for the country-year fixed effects to vary, we are simulating an equilibrium in which we isolate the income effect component of the exchange rate shock.

We show the result of simulating such counterfactual equilibrium along with the baseline scenario in figure 13. There is a perfect overlap of the baseline and counterfactual average prices (and their corresponding 95% CI). We interpret this as evidence of the income effects associated with the exchange rate shock being negligible.

5.4 Concluding remarks

We have presented an empirical exercise that advances our knowledge about the mechanisms and causes of incomplete exchange rate pass-through, as well as about their relative importance in explaining price stickiness. Incomplete pass-through is the result of consumers and producers reacting to exchange rate shocks in several ways. Firms react to increases in traded costs by changing the origin of their intermediate goods, by altering their offer of products to better match the market conditions and by pricing their goods in reaction to their rivals. Consumers, in turn, respond by substituting between products or opting out of the market entirely.

We focus on the Colombian exchange rate depreciation that took place in 2013-2015 of around 35% (COP/USD). The observed price changes across models increased, while the average price of cars sold even decreased due to the fact that consumers participated less or substituted towards less expensive cars. Our model predicts that production costs fell and average prices increased between 10% and 20% due to the exchange rate shock. We find no evidence that changes in aggregate income induced by the depreciation played a significant role in the market for new cars.

In many settings, the price adjustment costs play an important role in explaining the sluggishness of price adjustment (see (18)). Our approach is agnostic to the role played by price adjustment costs because our time frame is long enough–one year–for these not to be a problem unlike settings where pricing decisions are made in such short time periods that prices might not change due to the cost of repricing exceeding its benefits.

Our work is agnostic to the structure of the upstream part of the market. A potential way to improve our understanding of pass-through is to model the relationships between dealerships and manufacturers. Some dealers might be owner-operated, while others might be vertically integrated. These ownership structures have potential to alter the sensitivity of retail prices to exchange rate shocks. For instance, (22) show that the upstream structure of goods sold by a big US retailer affects the extent of pass-through.

Future research also needs to take into account the firms' decision to alter their menus in response to exchange rate shocks because firms may phase out some products and introduce new ones. Our work implicitly assumes that the menus are exogenous, which is a strong assumption but allows us to assume away dynamic decisions such as entry and exit of products.

References

[1] Amiti, M., Itskhoki, O., and Konings, J. (2014). Importers, exporters, and exchange rate disconnect. *American Economic Review*, 104(7):1942–78.

[2] Amiti, M., Itskhoki, O., and Konings, J. (2019). International shocks, variable markups, and domestic prices. *The Review of Economic Studies*, 86(6):2356–2402.

[3] Atkeson, A. and Burstein, A. (2008). Pricing-to-market, trade costs, and international relative prices. *American Economic Review*, 98(5):1998–2031.

[4] Auer, R., Burstein, A., and Lein, S. M. (2021). Exchange rates and prices: evidence from the 2015 Swiss franc appreciation. *American Economic Review*, 111(2):652–86.

[5] Auer, R. A. and Schoenle, R. S. (2016). Market structure and exchange rate pass-through. *Journal of International Economics*, 98:60–77.

[6] Bergin, P. R. and Feenstra, R. C. (2001). Pricing-to-market, staggered contracts, and real exchange rate persistence. *Journal of international Economics*, 54(2):333–359.

[7] Berry, S., Levinsohn, J., and Pakes, A. (1995). Automobile prices in market equilibrium. *Econometrica: Journal of the Econometric Society*, pages 841–890.

[8] Burstein, A. T., Neves, J. C., and Rebelo, S. (2003). Distribution costs and real exchange rate dynamics during exchange-rate-based stabilizations. *Journal of monetary Economics*, 50(6):1189–1214.

[9] Carranza, J. E. (2010). Product innovation and adoption in market equilibrium: The case of digital cameras. *International Journal of Industrial Organization*, 28(6):604–618.

[10] Carranza, J. E., Casas, C., and González, A. (2020). The colombian peso depreciation of 2014-2015 and the adjustment of trade in the manufacturing sector. *Borradores de Economía; No. 1125.*

[11] Corsetti, G. and Dedola, L. (2005). A macroeconomic model of international price discrimination. *Journal of International Economics*, 67(1):129–155.

[12] De Loecker, J., Goldberg, P. K., Khandelwal, A. K., and Pavcnik, N. (2016). Prices, markups, and trade reform. *Econometrica*, 84(2):445–510.

[13] Dornbusch, R. et al. (1987). Exchange rates and prices. *American Economic Review*, 77(1):93–106.

[14] Engel, C. (1999). Accounting for us real exchange rate changes. *Journal of Political economy*, 107(3):507–538.

[15] Fabra, N. and Reguant, M. (2014). Pass-through of emissions costs in electricity markets. *American Economic Review*, 104(9):2872–99.

[16] Gandhi, A. and Houde, J.-F. (2019). Measuring substitution patterns in differentiated-products industries. *NBER Working paper*, (w26375).

[17] Goldberg, L. S. and Campa, J. M. (2010). The sensitivity of the cpi to exchange rates: Distribution margins, imported inputs, and trade exposure. *The Review of Economics and Statistics*, 92(2):392–407.

[18] Goldberg, P. and Hellerstein, R. (2013). A structural approach to identifying the sources of local currency price stability. *Review of Economic Studies*, 80(1):175–210.

[19] Gopinath, G., Gourinchas, P.-O., Hsieh, C.-T., and Li, N. (2011). International prices, costs, and markup differences. *American Economic Review*, 101(6):2450–86.

[20] Gowrisankaran, G. and Rysman, M. (2012). Dynamics of consumer demand for new durable goods. *Journal of political Economy*, 120(6):1173–1219.

[Hendel and Nevo] Hendel, I. and Nevo, A. A simple model of demand anticipation.

[22] Hong, G. H. and Li, N. (2017). Market structure and cost pass-through in retail. *Review of Economics and Statistics*, 99(1):151–166.

[23] Knetter, M. M. (1989). Price discrimination by us and german exporters. *The American Economic Review*, 79(1):198–210.

[24] Melnikov, O. (2013). Demand for differentiated durable products: The case of the us computer printer market. *Economic Inquiry*, 51(2):1277–1298.

[25] Miller, N. H., Osborne, M., and Sheu, G. (2017). Pass-through in a concentrated industry: empirical evidence and regulatory implications. *RAND Journal of Economics*, 48(1):69–93.

[26] Muehlegger, E. and Sweeney, R. L. (2021). Pass-through of own and rival cost shocks: Evidence from the us fracking boom. *The Review of Economics and Statistics*, pages 1–32.

[27] Nakamura, E. and Zerom, D. (2010). Accounting for incomplete pass-through. *Review of Economic Studies*, 77(3):1192–1230.

[28] Parsley, D. C. and Wei, S.-J. (2001). Explaining the border effect: the role of exchange rate variability, shipping costs, and geography. *Journal of International Economics*, 55(1):87–105.

[29] Sanyal, K. K. and Jones, R. W. (1982). The theory of trade in middle products. *The American Economic Review*, 72(1):16–31.

[30] Schiraldi, P. (2011). Automobile replacement: a dynamic structural approach. *The RAND Journal of Economics*, 42(2):266–291.

A Appendix

Table 3: Number and Type of Car Sold

Year	Total	Imported (%)	Type of Car (%)		Models
			Automobile	Pickup	
2007	192,993	58.90	70.22	14.23	543
2008	170,895	63.85	67.17	15.11	593
2009	148,432	66.54	69.09	14.51	568
2010	212,013	64.92	65.68	17.43	672
2011	267,342	66.78	67.97	18.05	770
2012	255,263	67.97	61.88	16.91	977
2013	245,825	68.88	60.08	9.31	1,008
2014	277,690	64.95	58.27	7.40	1,115
2015	242,536	64.28	60.98	6.16	1,117
2016	224,083	62.55	61.17	6.48	1,018

Table 4: Engine Displacement, Prices and Sales

Year	Engine Displacement		Price (Million COP)				Sales
	S. Avg.	W. Avg.	S. Avg.	W. Avg.	Min.	Max.	(Billion COP)
2007	2.20	1.80	75.80	50.42	17.23	293.85	9,731.30
	(0.83)	(0.66)	(44.22)	(27.07)			
2008	2.24	1.87	69.34	48.89	16.42	298.83	8,355.27
	(0.82)	(0.66)	(40.66)	(25.97)			
2009	2.23	1.81	70.84	45.69	11.90	467.32	6,781.45
	(0.83)	(0.65)	(49.98)	(27.10)			
2010	2.24	1.86	69.71	45.16	13.30	419.04	9,573.82
	(0.86)	(0.65)	(42.41)	(25.03)			
2011	2.15	1.82	64.51	40.99	13.56	343.53	10,957.56
	(0.85)	(0.63)	(40.10)	(24.27)			
2012	2.14	1.84	62.76	40.92	14.08	464.68	10,445.00
	(0.87)	(0.64)	(43.56)	(23.32)			
2013	2.11	1.81	58.27	41.02	14.27	443.21	10,084.53
	(0.82)	(0.60)	(37.92)	(23.99)			
2014	2.37	1.77	75.68	39.73	12.43	514.60	11,032.25
	(1.14)	(0.61)	(65.35)	(24.61)			
2015	2.33	1.74	75.17	39.34	14.29	507.49	9,542.21
	(1.09)	(0.56)	(61.97)	(24.47)			
2016	2.31	1.76	83.21	41.37	13.70	685.91	9,270.72
	(1.05)	(0.56)	(74.16)	(27.56)			

Standard deviation in parenthesis.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