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Prices, markups, and exchange rates

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Abstract

AUsing highly disaggregated data for Colombian manufacturing firms during a large depreciation episode, we decompose firm-product prices into marginal cost and markup components to document new stylized facts about how exchange rate changes impact domestic prices. First, by weakening the intensity of import competition, a depreciation increases markups and, therefore, prices. Second, a depreciation raises marginal costs, but the resulting price increases are more modest because firms use their market power to partially offset the cost increases by reducing markups. These empirical patterns can be predicted by trade models featuring subconvex demand systems. They are important for understanding how exchange rate fluctuations affect domestic prices and, in turn, inflation.

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Non-Technical Summary

When a country's currency loses value, imported inputs and competing foreign goods become more expensive. How much these changes affect the price of domestically produced goods is a key question for central banks and policymakers. Exchange rate changes can affect domestic prices in two ways. Costs, by changing the prices firms pay for imported inputs and markups (margins), by affecting the degree of import competition in the domestic market. As both marginal costs and markups are typically unobserved in the data, this paper estimates these for Colombian manufacturing firms during a large currency shock. This allows us to investigate the channels through which changes in exchange rates affect domestic prices.

Between 2014 and 2015, as oil prices fell, the Colombian peso lost about a third of its value against the US dollar. Because Colombia pays for most of its imports in dollars, this sharply raised the peso cost of imported materials and of competing imports. We use data from the Colombian statistical agency (DANE) for manufacturing plants with ten or more employees between 2009 and 2019. Crucially, the data reports the physical quantities of every product firms make and every input they use. This allows us to estimate the production cost and the markup of each product manufactured by each firm, and to split prices into cost and markup components.

We find that a depreciation affects markups through two opposing channels. The first is cost. A weaker peso makes imported inputs more expensive, raising production costs, but firms do not pass through the full increase in costs to customers: they absorb part of it by accepting lower markups. After the 2014–2015 depreciation, production costs rose by about 9%, prices by about 6.5%, and markups fell by about 2.7%. The second is competition. A weaker peso makes competing imports more expensive, easing foreign competition on the domestic market. Comparing firms with the same production costs, we find that this allowed domestic producers to raise markups by roughly 2 to 3%. The effect also holds for firms that only sell in Colombia (i.e., firms that do not export), confirming that it reflects weaker import competition.

The balance between the two channels differs across firms and products. Importers faced the largest cost increases and the greatest squeeze on margins. Firms with high markups before the shock, as well as larger firms, absorbed much of their cost increase into their margins, while firms with low markups gained most from weaker competition. At the same time, larger firms also benefited more from reduced competition. Across products, goods closer to the input stage of production faced the largest cost increases. By contrast, the competition channel was strongest for consumer goods, where domestic and imported varieties are close substitutes.

These responses matter for inflation. The depreciation raised inflation for domestically produced manufacturing goods by about 1.9 percentage points in 2016 and 0.8 percentage points in 2017. As these goods make up roughly a quarter of the consumer basket, this accounts for around 6% of Colombia's consumer price inflation over those two years. The effect came almost entirely through higher costs: the depreciation changed the level of markups but did not persistently change the growth of markups over time.

The findings carry clear policy lessons. For central banks, how a currency depreciation feeds into inflation depends on firms' reliance on imported inputs and on the competition they face, not on a single average pass-through rate. For trade and competition policy, import competition affects domestic prices: when it weakens, firms with market power raise their markups, and consumers bear the cost.

Prices, Markups, and Exchange Rates*

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Abstract

Using highly disaggregated data for Colombian manufacturing firms during a large depreciation episode, we decompose firm-product prices into marginal cost and markup components to document new stylized facts about how exchange rate changes impact domestic prices. First, by weakening the intensity of import competition, a depreciation increases markups and, therefore, prices. Second, a depreciation raises marginal costs, but the resulting price increases are more modest because firms use their market power to partially offset the cost increases by reducing markups. These empirical patterns can be predicted by trade models featuring subconvex demand systems. They are important for understanding how exchange rate fluctuations affect domestic prices and, in turn, inflation.

JEL Classification: F12, F14, L11.

Keywords: Competition; Cost Pass-Through; Exchange Rates; Exporters; Importers; Marginal costs; Markups; Prices; Products.

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1 Introduction

Like trade liberalization (e.g., De Loecker, Goldberg, Khandelwal, and Pavcnik, 2016), exchange rate fluctuations can affect firm-level domestic prices in two ways. On the one hand, a depreciation reduces the degree of import competition in the domestic market and induces firms with market power to *raise* markups and, therefore, prices on the final products they sell.[1] On the other hand, a depreciation increases the prices firms pay for imported inputs and, therefore, raises firms' marginal costs and prices.[2] But if the pass-through of cost changes into prices is incomplete, markups mechanically *fall*, constraining the magnitude of the price increase. Understanding how exchange rate changes impact both markups and marginal costs is therefore crucial to evaluate their effects on domestic prices and, in turn, on inflation.

While a vast literature studies the effects of exchange rate changes on prices, evidence for markups and marginal costs is much scarcer because both are unobserved. Using highly disaggregated firm-level data for Colombia during a large depreciation episode, our paper fills this gap. Our contribution is fourfold. First, we derive markups at the firm-product-year level by estimating production functions using data on the physical quantities of output produced and quantity-based measures of inputs consumed. Our estimates are therefore immune to the input and output price biases that typically arise in revenue-based production function estimations. Marginal costs can then be recovered by dividing prices by estimated markups. Second, we estimate the effects of exchange rate fluctuations on prices, marginal costs, and markups, and disentangle the effects that arise in response to changes in the competitive environment and changes in the costs of imported inputs. Third, we explore heterogeneity across firms and products and find that the effects of exchange rate changes are stronger for firms more exposed to foreign markets. Fourth, we extend the theoretical framework of Mrázová and Neary (2017) to rationalize the patterns we find in the data.

Focusing on the Colombian economy is particularly well suited for our purposes. First, the Colombian peso is freely floating against other major currencies, and between 2014 and 2015, it depreciated by 31.5% in log terms against the US dollar. Given that Colombia predominantly invoices its imports in US dollars, it is likely to experience a large pass-through of US dollar exchange rate changes into its import prices in domestic currency (Gopinath, 2016; Gopinath, Boz, Casas, Díez, Gourinchas, and Plagborg-Møller, 2020).

Second, we were granted access to a highly disaggregated manufacturing survey data set collected by the Colombian statistical agency (DANE), which contains information on the values and physical quantities of all outputs produced and inputs used by each establishment between 2009 and 2019. For each firm, we aggregate the data across establishments, and we estimate quantity-based production functions that allow us to recover markups—and in turn marginal costs—for each product manufactured by each firm over time.

[1] When competition decreases, firms use market power to sell goods at higher prices. Market power, therefore, redistributes resources from consumers to firms and decreases welfare.

[2] According to Goldberg and Campa (2010), imported inputs account for between 10% and 48% of the prices of tradable goods across OECD countries.

Our main results can be summarized as follows. First, we document that exchange rate depreciations are associated with a sizable increase in firms' marginal costs and a more moderate increase in prices. As a result, average markups decline. This pattern is consistent with incomplete pass-through of imported input cost shocks into prices and suggests that firms absorb part of the increase in costs by lowering markups.[3] Our results indicate that the 31.5% depreciation of the peso against the US dollar between 2014 and 2015 resulted in an average 6.48% increase in prices. This increase was driven by a 9.2% increase in marginal costs and a 2.71% fall in markups. Quantitatively, marginal costs respond more strongly than markups, implying that the cost channel dominates the aggregate response of domestic prices.

Second, conditioning on marginal costs reveals a distinct and economically meaningful competition channel. When we control flexibly for marginal costs, markups increase following a depreciation. This finding is consistent with a reduction in import competition in the domestic market that relaxes the residual demand faced by domestic firms, allowing them to raise markups for a given level of costs. Evidence for this competition channel remains robust to excluding exporting firms from the sample, which are likely to increase markups conditional on marginal costs because they invoice exports in US dollars. Overall, we find that the fall in import competition driven by the 31.5% depreciation of the peso against the US dollar increased markups, and therefore prices, by roughly 2.3–3.2%. The contrast between unconditional and conditional estimates highlights that exchange rate movements simultaneously operate through cost and competition channels, with opposite implications for markups.

Third, heterogeneity across firms and products sharpens this two-channel interpretation. Importers experience the largest increases in marginal costs and the greatest markup compression, whereas exporters exhibit stronger price and conditional-markup responses, although US dollar invoicing may contribute to the latter. Importantly, conditional markups also rise among non-exporters, providing direct evidence that a depreciation weakens import competition. Pre-shock markups separate the two mechanisms particularly clearly: firms entering the episode with high markups experience much larger cost increases and substantial markup compression, whereas the positive conditional-markup response is concentrated among firms with low initial markups. Firm size strengthens both forces, as larger firms experience greater cost-driven markup compression but also a stronger positive response of markups conditional on costs. Product-level results reinforce these patterns: intermediate goods display larger cost responses and greater markup compression. Similarly, at the sector-level, markup compression is also more pronounced in upstream sectors. Together, these findings show that the markup response depends on both exposure to exchange-rate-induced cost shocks and the strength of the competition channel.

Fourth, we derive the implications of our results for the dynamics of the CPI inflation rate. We estimate local projections and find that the 31.5% depreciation of the peso from 2014 to 2015 raised firm-level manufacturing inflation in 2016 and 2017 by 1.94 and 0.83 percentage points, respectively. As back-of-the-envelope calculations show that our firm-level

[3] If markups are constant, cost changes fully transmit into prices and pass-through is complete.

prices represent around a quarter of the CPI, these estimates translate into a 0.47 and 0.20 percentage points growth in the CPI in 2016 and 2017. As the actual CPI inflation rate stood at 7.2% in 2016 and at 4.2% in 2017, our estimates therefore explain around 6% of the CPI inflation rate over 2016 and 2017. Moreover, we establish that the inflationary effect of the depreciation among manufacturing firms was predominantly driven by a growth in marginal costs as the depreciation did not persistently affect the growth of markups over time.

Finally, to motivate our findings, we develop a firm-level framework that identifies when exchange rate depreciations compress or expand markups. Building on the demand-manifold approach (Mrázová and Neary, 2017), we show that markup responses depend on the curvature of demand relative to the CES benchmark. In the empirically relevant subconvex region—where most standard demand systems lie—increases in marginal costs lead to markup compression, while reductions in import competition raise markups. The net effect is therefore ambiguous ex ante and depends on the relative strength of cost exposure and competitive pressure, a tension that is borne out in the data.

As markups are unobserved, several approaches have been developed to estimate markups. The "demand" approach estimates a demand system and requires very detailed market-level data on prices, quantities sold, and characteristics of the products and consumers. Due to its demanding data and modeling requirements, this approach is typically used to estimate markups for specific industries only. Instead, the "production" approach estimates production function parameters that identify markups from the first-order condition of cost minimization of a variable input, and it does not require any assumptions about demand or market structure.[4] This approach allows markups to be estimated for all firms and sectors and has therefore become widely used in the recent literature.

The production approach was developed with industry-level data (Hall, 1988), and it has been extended to recover markups at the firm (De Loecker and Warzynski, 2012) and product levels (De Loecker et al., 2016). Markups are defined as prices over marginal costs and are given by the elasticity of output relative to a variable input free of adjustment costs and that input's share in total revenue. Intuitively, the output elasticity of a variable factor of production is equal to its expenditure share in total revenue when price equals marginal cost. When revenue from sales is larger than the payments to the input that yields that marginal revenue, the markup is greater than one.

We apply the methodology of De Loecker et al. (2016) to estimate production markups for multi-product firms. As firms do not report how inputs are allocated across products, we follow these authors and assume that the production function for single- and multi-product

[4]The two approaches are not directly comparable. The demand approach produces markups at the final consumption level, while the production approach delivers markups at the production stage, which includes exports. Norris Keiller, Obermeier, Teichgräeber, and Van Reenen (2024) show that production markups are a revenue-weighted average of demand markups across markets and products. For the UK car industry, they show that demand markups have fallen over time, while production markups have risen due to a surge in the markups that firms gain on exports. For the US brewing industry, De Loecker and Scott (2024) instead find that the two approaches yield similar markup estimates.

firms that produce the same good is the same. We estimate industry-level translog production functions that generate output elasticities which vary over time and across firms, and we rely on materials as the flexible input.

Some papers argue that the production approach suffers from measurement issues and leads to implausible markup estimates (Basu, 2019; Fernald, Gandhi, Ruzic, and Traina, 2025; Syverson, 2024). The first issue relates to the use of nominal, as opposed to physical quantity data, in estimating production functions (De Loecker and Goldberg, 2014; De Ridder, Grassi, and Morzenti, 2025). We do not face this problem as our data set for Colombian firms provides the physical quantities of all outputs produced, and allows us to derive quantity-based measures of all inputs (labor, materials, and capital).[5] Second, Raval (2023) shows that the production approach delivers very different markup distributions depending on the choice of the flexible input.[6] To address this issue we show that our results remain robust to using labor as opposed to materials in our estimations. Finally, to estimate the product-level input expenditure shares, De Loecker et al. (2016) assume that the production function of a product manufactured by single- and multi-product firms is the same. As this assumption is debatable, we demonstrate that our results continue to hold when estimating markups for a subset of industries following the methodology of Blum, Claro, Horstmann, and Rivers (2024), which does not rely on estimating product-level input expenditure shares but instead uses sales value proportions.

Related Literature Our paper is related to several strands of the literature. The first is the literature on incomplete exchange rate pass-through showing that the prices of internationally traded goods only react modestly to changes in exchange rates. One explanation for incomplete pass-through is the pricing-to-market behavior of exporters who differentially adjust markups across destinations in response to exchange rate fluctuations (Krugman, 1987).[7] But as markups are unobserved, much of the existing evidence on pricing-to-market is indirect. For instance, Fitzgerald and Haller (2014) identify the variation in markups by comparing prices across markets under the assumption that the marginal cost within a plant and product is constant across destinations. Amiti, Itskhoki, and Konings (2014) rely on imported inputs and on destination-specific market shares as sufficient statistics for marginal costs and markups, and show that firms with high import shares and high market shares have low pass-through.[8] While these papers focus on the prices of traded goods and indirectly identify the variation in markups and marginal costs, we estimate markups for domestically produced goods and

[5] De Roux, Eslava, Franco, and Verhoogen (2024) argue that quality and variety choices may bias quantity-based production function estimates. They propose an approach to address these issues, but their estimates are not statistically different from the ones obtained using other methods.

[6] Raval (2023) attributes this finding to non-neutral productivity differences across firms. Jaumandreu and Lopez (2024) show that accounting for labor-augmenting productivity instead of Hicks-neutral productivity produces smaller markup estimates. Instead, De Loecker, Eeckhout, and Unger (2020) find that using materials or employment as the variable input yields very similar estimates of markup trends.

[7] Other explanations include short-run nominal rigidities combined with pricing in the currency of the destination market (Gopinath, Itskhoki, and Rigobon, 2010) or in a dominant currency (Gopinath, Boz, Casas, Díez, Gourinchas, and Plagborg-Møller, 2020), and the presence of local distribution costs in the importing economy (Corsetti and Dedola, 2005). For a review, see Burstein and Gopinath (2014).

[8] Pricing-to-market is heterogeneous. For instance, it increases with firm-level productivity (Berman, Martin, and Mayer, 2012) and with product-level quality (Chen and Juvenal, 2016).

recover marginal costs by dividing prices by estimated markups.

Within the pass-through literature, our paper also relates to research that explores the response of consumer price inflation to exchange rate changes. Due to the presence of non-tradables, pass-through into consumer prices is lower than into import prices (Burstein et al., 2005; Goldberg and Campa, 2010; Gopinath, 2016). But according to the "Domestic Currency Paradigm," pass-through into import and consumer prices is higher for countries that predominantly adopt US dollar invoicing for imports (Gopinath, 2016; Gopinath et al., 2020). Similarly to these papers, we evaluate the effects of exchange rate shocks on consumer price inflation, but we further decompose these effects into the contributions driven by changes in markups and changes in marginal costs.

To the best of our knowledge, only two papers explain production markups by changes in exchange rates. Caselli, Chatterjee, and Woodland (2017) estimate markups for multi-product firms but their focus is on export markups which they identify by assuming that inputs are allocated across destinations in proportion to sales. They find that the depreciation of the Mexican peso in December 1994 increased export markups, export prices, and marginal costs. Steiner (2024) estimates firm-level markups and finds that the appreciation of the Swiss franc against the euro in January 2015 reduced the markups of large firms invoicing exports in foreign currency. We differ from these papers by distinguishing between the competitive and incomplete cost pass-through effects of exchange rate changes on domestic markups and by investigating their heterogeneity across firms and products.

Our paper also contributes to the vast literature investigating the effects of trade on markups. The earlier literature focuses on the effects of trade openness (Chen, Imbs, and Scott, 2009) or of the reduction in output tariffs (Levinsohn, 1993) on markups, finding evidence of pro-competitive effects.[9] Closest to our work is De Loecker et al. (2016) who show that output tariff declines have pro-competitive effects while reductions in input tariffs increase markups due to the incomplete pass-through of cost changes into prices.[10] These findings are confirmed by several papers, including Bas and Paunov (2021), Curzi, Garrone, and Olper (2021), and Brandt, Van Biesebroeck, Wang, and Zhang (2017).[11] In contrast to these papers, we examine the impact of a symmetric shock driven by the depreciation of the Colombian peso. Also, while these papers need to account for the potential reverse causality between trade liberalization and firm-level performance, we arguably do not face this issue as changes in exchange rates can plausibly be assumed to be exogenous to Colombia's firm-product markups, prices, and marginal costs.

[9] Amiti, Itskhoki, and Konings (2019) provide evidence of strategic complementarities in price setting as firms adjust markups in response to competitors prices. Also see Auer, Burstein, and Lein (2021).

[10] De Loecker, Goldberg, Khandelwal, and Pavcnik (2016) explain the incomplete pass-through of cost changes into prices by a demand elasticity rising in price. As trade liberalization lowers marginal costs and therefore prices, the demand elasticity falls and markups rise. Trade models delivering a demand elasticity rising in price include Melitz and Ottaviano (2008) with linear demand and monopolistic competition and Atkeson and Burstein (2008) with CES preferences and Cournot competition.

[11] Also, Kharroubi, Spigt, Igan, Takahashi, and Zakrajsek (2023) show that firms do not fully pass on reductions in marginal costs driven by lower oil prices, resulting in higher markups.

Finally, our paper belongs to the literature studying the effects of large devaluations in developing countries. Alessandria, Kaboski, and Midrigan (2010) investigate how the dynamics of imports and prices are impacted by importers' inventory holdings. Gopinath and Neiman (2014) emphasize the role of the extensive margin in explaining the evolution of trade and productivity. Burstein, Eichenbaum, and Rebelo (2005) show that the fall in real exchange rates results from a slow adjustment in the prices of non-tradable goods and services. Cravino and Levchenko (2017) document that the cost of living rises to a larger extent for low-income than for high-income households. Our analysis supplements this literature by focusing on the response of firm-product markups, marginal costs, and prices.

The remainder of the paper is organized as follows. Section 2 describes the data, while Section 3 details the methodology we implement to measure prices, markups, and marginal costs. The empirical results are discussed in Section 4, while Section 5 includes robustness exercises. Section 6 presents the theoretical framework. Finally, Section 7 concludes.

2 Data

We use data from the *Encuesta Anual Manufacturera* (Annual Manufacturing Survey, or EAM), collected by the Colombian statistical agency (DANE). The EAM is a census of manufacturing plants with 10 or more employees. The survey reports information at the establishment-product-year level, which we aggregate at the firm-product-year level.[12] Products are defined at the 8-digit CPC Rev.1 level, but to ensure we have sufficient coverage for the estimations, we aggregate products at the 4-digit level. Each firm-product at the CPC level is mapped to its corresponding 4-digit ISIC code, and industries are defined at the 2-digit ISIC level. As the peso depreciated by 31.5% against the US dollar between 2014 and 2015, our sample focuses on the period between 2009 and 2019.

The survey reports the quantities and values of output produced and sold—which may differ due to inventory accumulation. For each product, the physical quantities of output are recorded in specific units. We rely on produced quantities at the firm-product-year level to estimate production functions and markups, while sales are used to compute market shares and unit values. The data further identifies whether production corresponds to a firm's own products, third-party products, other products, or industrial services. We only retain production associated with firms' own products.

The data set also reports the quantities and values of all materials purchased or consumed. We rely on materials consumed because they better reflect the inputs actually used in production. But as the physical quantities of different material inputs are recorded in different units, it is not possible to aggregate them at the firm level. To address this issue, we follow Garcia-Marin and Voigtländer (2019) and construct a firm-specific material price deflator, using the unit prices of each material input reported by the EAM at the 8-digit CPC Rev.1 level. This

[12] Many variables, such as labor or capital, are only reported at the firm level and not at the establishment level.

allows us to deflate firm-level material expenditures, which are obtained by aggregating the values of all materials consumed at the firm level. The deflated material expenditures at the firm-year level are then used as our quantity-based measure of material inputs. Details on the construction of the firm-level material price index are provided in the Appendix (Section A.1). Labor input is measured as the number of production workers at the firm-year level, computed as total employment minus administrative workers. Capital is measured using the end-of-year book value of fixed assets reported at the firm level, which accounts for depreciation, and is deflated by the industry-level Producer Price Index (PPI).

The survey also reports foreign sales at the firm-product-year level and input-level shares of imported materials. For our purposes, both are aggregated at the firm-year level, allowing us to construct indicators for exporting and importing firms. Foreign sales are only available in nominal terms (i.e., we do not observe the physical quantities of exports).

We restrict the analysis to manufacturing industries and exclude extractive activities such as *Manufacture of coke, refined petroleum products and nuclear fuel* (ISIC 23). We also exclude *Manufacture of tobacco products* (ISIC 16) because of its low firm coverage, which prevents us from obtaining reliable estimates of industry-level production functions. In addition, we merge some manufacturing sectors together as the number products within those sectors is small.[13]

We complement our survey data with data from external sources. The PPI is obtained from DANE; the nominal US dollar-Colombian peso exchange rate is sourced from the IMF International Financial Statistics; the annual price of oil is the average across Brent, WTI, and Dubai as reported by the World Bank's Commodity Price Data (Pink Sheet); and the interest rate is the annual average policy rate from the Colombian Central Bank.[14]

Table 1 reports summary statistics over the period 2009–2019 for the universe of firms belonging to the industries in our sample. All statistics are averages across years except the Total row. Column (1) shows each industry's share of total output, measured using quantities produced. Columns (2) and (3) report the average number of firms and of 4-digit products per industry in each year. Firms may belong to more than one industry since each product maps to a specific industry and firms can produce multiple products. Column (4) reports the average number of single-product firms over time, which are the firms we rely on to estimate production functions. These firms map directly into a single industry, and their average annual number of 4-digit products per industry is reported in column (5). The sample we use to estimate markups includes 9,626 firms (of which 5,036 are single product) and 799 4-digit CPC

[13] We combine ISIC 20 (*Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials*) with ISIC 21 (*Manufacture of paper and paper products*); ISIC 27 (*Manufacture of basic metals*) with ISIC 28 (*Manufacture of fabricated metal products, except machinery and equipment*); ISIC 30 (*Manufacture of office, accounting and computing machinery*) with ISIC 31 (*Manufacture of electrical machinery and apparatus n.e.c.*); ISIC 32 (*Manufacture of radio, television and communication equipment and apparatus*) with ISIC 33 (*Manufacture of medical, precision and optical instruments, watches and clocks*); and ISIC 34 (*Manufacture of motor vehicles, trailers and semi-trailers*) with ISIC 35 (*Manufacture of other transport equipment*).

[14] We use the PPI on aggregate demand, which includes capital goods consumed and produced, final goods consumed and produced, construction materials, and exports.

Table 1: Summary Statistics: Output Shares, Firms and Products

ISIC	Industry		All firms		Single-product firms	
		Output (%)	# firms	# products	# firms	# products
		(1)	(2)	(3)	(4)	(5)
15	Food and Beverages	39.3	1,488	93	534	49
17	Textile Products	2.9	415	58	118	31
18	Clothing and Garments	3.9	798	12	390	8
19	Hides, Shoes, Bags	1.0	399	20	209	14
20-21	Wood, Paper, and Cardboard	2.3	451	33	98	17
22	Printing and Recording	3.5	457	25	112	15
24	Chemical Products	14.9	745	94	200	45
25	Plastic and Rubber	5.5	867	55	314	32
26	Non-metallic Minerals	6.6	414	59	199	31
27-28	Metallurgic Basic and Metal Products	9.3	938	60	325	44
29	Machinery and other Equipment	1.9	478	58	164	28
30-31	Office and Information Products	2.0	220	30	84	20
32-33	Radio and Telecommunication Equipment	0.4	133	28	44	13
34-35	Vehicles and Transportation Equipment	4.5	194	17	81	12
36	Furniture and other Manufacturing	2.0	767	41	177	27
	Total	100	12,966	799	5,082	475

Notes: The data covers the period 2009–2019. Column (1) reports the share of output. Columns (2)–(5) report average per year of the number of firms and products for all firms and for single-product firms. At the bottom, the total reports a count over the entire period.

products between 2009 and 2019.[15]

Since 1999, the Colombian peso has been freely floating. As it is a commodity currency, fluctuations in its value are strongly (and negatively) correlated with fluctuations in commodity prices. In robustness checks, we provide evidence that our results remain unaffected once we control for the oil price. Figure B1 in the Appendix displays the relation between the (log) exchange rate of the Colombian peso against the US dollar and the (log) oil price over the 2009–2019 period which we analyze. The figure also clearly illustrates the large depreciation of the peso starting in 2014.

3 Measuring Prices, Markups, and Marginal Costs

This section describes how we measure firm-product-year markups, unit values, and marginal costs. We also present summary statistics for estimated markups.

Firm-product-year markups are obtained by estimating production functions. It is well established that estimating production functions with data on the nominal values of outputs and inputs delivers biased estimates (e.g., De Loecker and Goldberg, 2014; De Loecker et al., 2016). The bias arises because the residual of the production function, which intends to capture productivity, also includes the prices of outputs and inputs, and these prices are in turn correlated with markups and marginal costs (the biases are referred to as the "output price" and "input price" bias, respectively). Deflating the values of outputs and inputs with industry- or firm-level price indices does not fix the problem because, in that case, the residual

[15] At the 8-digit product level, the number of firms is 10,212, with 3,889 being single product and a total count of 3,685 different products.

is contaminated by the price deflators.

As De Loecker et al. (2016) observe the physical quantities of each product manufactured by each firm, their estimations are immune to the output price bias. But as they only observe input expenditures, they apply an input price correction in their estimations. We apply the methodology of De Loecker et al. (2016) to estimate firm-product-year markups, but since we are able to rely on quantity-based measures of outputs and of labor and material inputs, we apply their input price correction for capital inputs only.

As in De Loecker et al. (2016) and De Loecker and Warzynski (2012), markup estimation follows from the firm's cost-minimization problem and yields the following expression:

$$\mu_{fj,t} = \frac{\partial Q_{fj,t}(\cdot)}{\partial X_{fj,t}} \frac{X_{fj,t}}{Q_{fj,t}} \frac{P_{fj,t}Q_{fj,t}}{W^X_{fj,t}X_{fj,t}} = \theta_{fj,t}\, \alpha^{-1}_{fj,t}, \tag{1}$$

where $\mu_{fj,t} \equiv P_{fj,t}/\lambda_{fj,t}$ is the markup of product j (a 4-digit CPC Rev.1 product code with a unique physical unit) manufactured by firm f in period t, obtained from the first-order condition of the Lagrangian with $\lambda_{fj,t}$ denoting marginal cost at a given level of output. $Q_{fj,t}$ denotes physical output of firm f in product j and in period t.

The term $\theta_{fj,t}$ denotes the output elasticity with respect to a variable input $X_{fj,t}$, and $\alpha_{fj,t}$ is the share of expenditure on input $X_{fj,t}$ allocated to product j ($W^X_{fj,t}$ denotes the unit price of input $X_{fj,t}$) in the total value of sales of product j, i.e., $P_{fj,t}Q_{fj,t}$.[16]

Estimating markups, therefore, requires recovering both components: the output elasticity and the product-level input expenditure shares (as input expenditures are reported at the firm level only). To obtain the output elasticities $\theta_{fj,t}$, we estimate industry-specific translog production functions using produced quantities as the dependent variable. The translog specification allows for interactions across inputs and implies that output elasticities vary with input use. We implement the control-function approach of De Loecker et al. (2016) to address simultaneity between input choices and unobserved productivity, and their input price correction for capital inputs.

As our measures of material, labor, and capital inputs are measured in different units, we normalize each input by subtracting the firm's industry-year average. This normalization affects the interpretation of estimated factor elasticities and returns to scale, particularly under the translog specification, where interaction terms combine inputs measured in different units. The Appendix (Section A.2) provides full details on (i) the production function setup, (ii) the translog specification, and (iii) the estimation procedure.

[16] The markup estimation assumes that input prices do not depend on input quantities (see Assumption 6 in Appendix A.2), and therefore ignores that firms may have monopsony power in input markets (Morlacco, 2020). As shown by De Loecker et al. (2016), not accounting for markdowns may lead to underestimate the level of markups. But as we are interested in how exchange rate movements affect *changes* in markups over time, our estimates will only be biased if the input price elasticity changed after the depreciation of the Colombian peso. In addition, we do not find evidence that post-shock markups of larger firms, which are more likely to have monopsony power, are differentially affected by changes in exchange rates. Monopsony power is therefore unlikely to be a major concern in our estimations.

The product-level input expenditure shares $\alpha_{fj,t}$ represent each firm f's share of expenditure on the variable input allocated to product j in the total sales value of product j. These shares cannot be calculated directly because multi-product firms do not report the inputs they use to manufacture each product (i.e., the inputs are reported at the firm level only). To recover the product-level input allocation shares, we follow De Loecker et al. (2016) and assume that multi-product firms use the same technology as single-product firms that manufacture the same product. We therefore rely on the sample of single-product firms to estimate production functions and we assign their estimates to the multi-product firms manufacturing the same product. See the Appendix (Section A.2) for details. As only considering single-product firms to estimate production functions generates a selection bias, we apply a sample selection procedure.

In estimating equation (1), we treat materials as the flexible (variable) input. As a robustness check, we replicate the estimations using labor as the variable input. We also re-estimate markups using nominal input values, in which case we refer to expenditure markups. In that case, we use material expenditures, the total wage bill of permanent production workers, and the book value of fixed assets as a measure of capital expenditures. We deflate all three input expenditures with industry-level PPIs, where each firm is assigned to the industry of the firm's highest-selling product, and we apply the input price correction of De Loecker et al. (2016). The Appendix (Section A.3) provides full details on the markup estimation from the production function estimates.

We construct a nominal unit value as $\mathrm{P}_{fj,t} \equiv \text{Value of sales}_{fj,t}/\text{Quantity sold}_{fj,t}$.[17] Once we have estimated markups, marginal costs at the firm-product-year level are recovered using the accounting identity implied by the pricing rule, i.e., $\widehat{\mathrm{mc}}_{fj,t} \equiv \mathrm{P}_{fj,t}/\hat{\mu}_{fj,t}$. This construction ensures that, by definition, $\ln \mathrm{P}_{fj,t} = \ln \widehat{\mathrm{mc}}_{fj,t} + \ln \hat{\mu}_{fj,t}$, which provides a transparent decomposition of price responses into marginal cost and markup components in the empirical analysis of Section 4.

The estimation of equation (1) delivers firm-product markups at the production stage, which therefore include exports (Norris Keiller, Obermeier, Teichgräeber, and Van Reenen, 2024). To obtain markups for the goods sold on the domestic market only, we would need to estimate production functions using the physical quantities of output net of exports. As the data set only reports the nominal values—and not the physical quantities—of exports, we instead re-estimate markups excluding exporters from our sample and show that our main results continue to hold.

Summary Statistics Table 2 summarizes the mean and median values of estimated markups over the 2010–2019 period.[18] Additional descriptive statistics are presented in Appendix D (output elasticities and returns to scale). Average markups vary substantially across sectors, with a manufacturing-wide mean of 2.98 and a median of 1.29, indicating a right-skewed

[17] The data set reports actual prices but at the establishment level. The average prices across establishments are highly correlated with the firm-level unit prices we rely on.

[18] When estimating markups we lose one year of data so markups are only obtained for the 2010–2019 period.

Table 2: Markups by Industry: Mean and Median Values

ISIC	Industry	Mean	Median
15	Food and Beverages	1.81	1.26
17	Textile Products	2.15	1.12
18	Clothes and Garments	2.77	2.02
19	Hides, Shoes, Bags	1.65	1.26
20-21	Wood, Paper, and Cardboard	2.76	1.10
22	Printing and Recording	2.43	1.15
24	Chemical Products	5.43	1.50
25	Plastic and Rubber	2.12	1.24
26	Non-metallic Minerals	3.82	1.21
27-28	Metallurgic Basic and Metal Products	5.29	1.53
29	Machinery and other Equipment	1.86	1.01
30-31	Office and Information Products	2.69	1.17
32-33	Radio and Telecommunication Equipment	5.04	1.36
34-35	Vehicles and Transportation Equipment	2.89	1.26
36	Furniture and other Manufacturing	1.99	1.20
	Average across Industries	2.98	1.29

Notes: This table reports the mean and median of $\hat{\mu}_{fj,t}$ by sector for 2010–2019. The table excludes outliers in the top and bottom 3% of the distribution of markups.

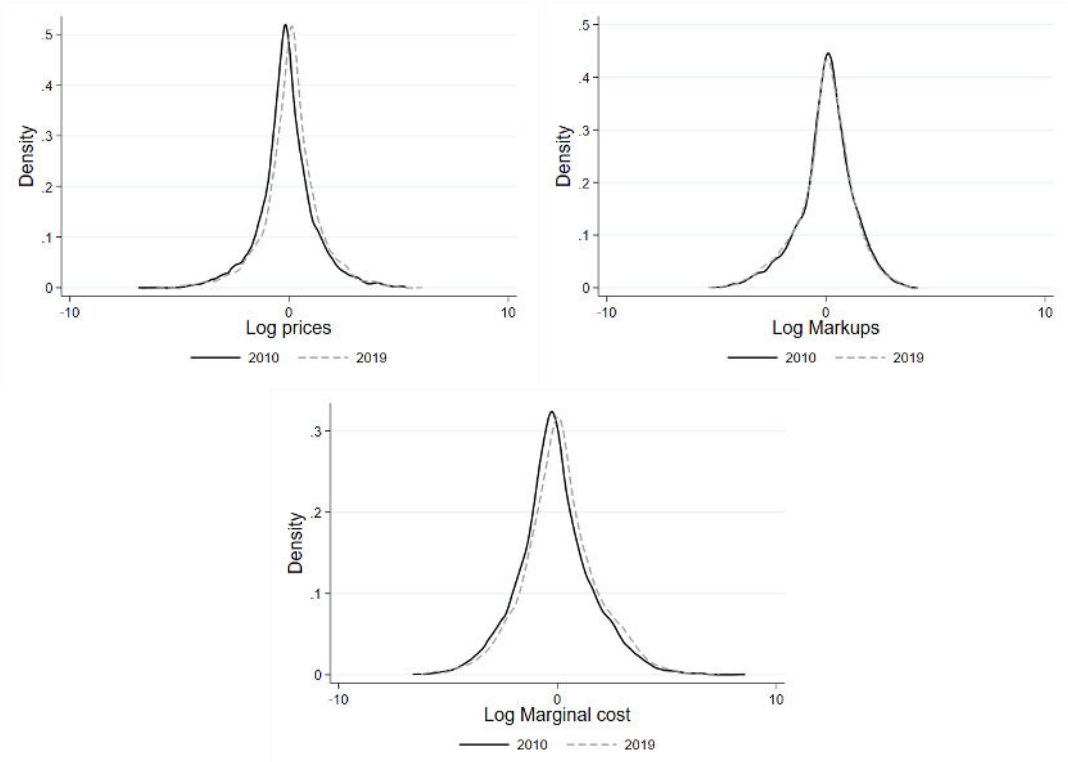
distribution within industries. This skewness is evident in most sectors, where mean markups exceed medians, reflecting the presence of a subset of high-markup firm-product observations alongside a large mass of lower-markup producers.

Markup levels are generally higher in more differentiated industries such as "Chemical products" and "Radio and Telecommunication Equipment," while sectors such as "Textile products" and "Wood, Paper and Cardboard" exhibit lower median markups. Overall, both the level and dispersion of markups are comparable to those documented in the literature using production-based approaches (De Loecker et al., 2016). Importantly, our empirical analysis exploits within firm-product variation over time rather than cross-industry differences in levels, so these descriptive patterns primarily serve to benchmark the magnitude of markups rather than to drive identification.

Figure 1 summarizes the distributions of prices, markups, and marginal costs, comparing a balanced panel of firm-product observations in 2010 and 2019. For each year, variables are residualized with respect to product fixed effects, so the distributions reflect within-product variation rather than differences across products. The distribution of markups remains comparatively similar across the two years, while the distributions of prices and marginal costs shift to the right. Overall, the shapes and magnitudes of the distributions are comparable to those documented in the production-based markup literature.

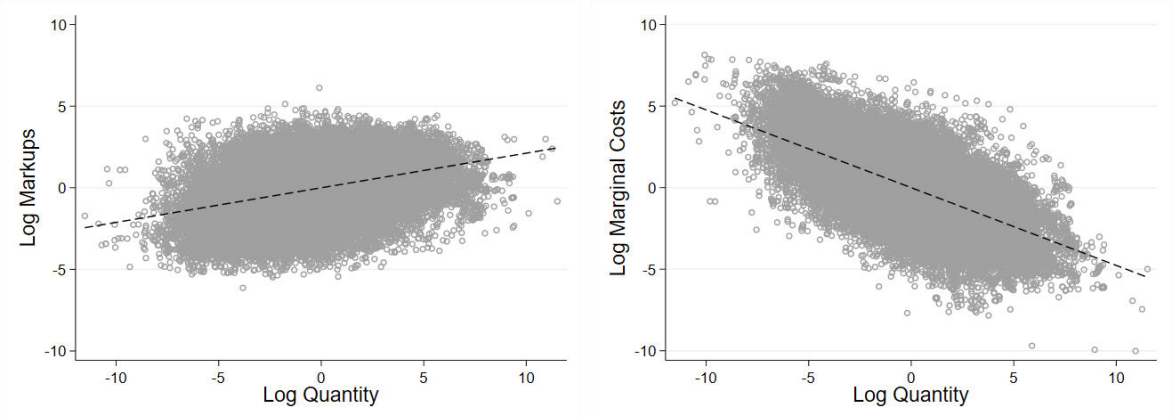
Figure 2 relates estimated markups and marginal costs to production quantities to assess whether they exhibit economically meaningful patterns. Marginal costs are strongly decreasing in quantities, consistent with increasing returns or scale economies at the firm-product level. At the same time, markups are positively correlated with quantities, indicating that larger producers charge higher markups. These relationships are obtained after demeaning all variables

Figure 1: Distribution of Prices, Markups, and Marginal Costs



Notes: The figure plots the distributions of (log) prices, (log) markups and (log) marginal costs for a balanced panel of firms and products in 2010 and 2019. For both years, we regress each variable on product fixed effects and plot the residuals. The figure excludes outliers in the top and bottom 3% of the distribution of each variable.

Figure 2: Markups, Marginal Costs, and Quantities



Notes: The left figure plots the correlation between (log) markups and (log) quantities demeaned by product. The right figure plots the correlation between (log) marginal costs and (log) quantities demeaned by product. The figure excludes outliers in the top and bottom 3% of the distribution of each variable.

by product and therefore reflect within-product variation rather than cross-product differences. The two figures mirror the patterns documented by De Loecker et al. (2016) and are consistent with variable markups: firms with lower marginal costs expand output and capture part of these cost advantages through higher markups.

4 Empirical Analysis

To quantify the response of prices, marginal costs, and markups to exchange rate fluctuations, we first estimate:

$$\ln x_{fj,t} = \theta \ln e_t + \delta_{fj} + \varepsilon_{fj,t}, \tag{2}$$

where $x_{fj,t}$ is either $\mathrm{P}_{fj,t}$, $\hat{\mu}_{fj,t}$, or $\widehat{\mathrm{mc}}_{fj,t}$. The regressor e_t is the nominal exchange rate (Colombian pesos per US dollar) and an increase indicates a depreciation of the peso.[19] The firm-product fixed effects δ_{fj} absorb time-invariant heterogeneity in product quality, technology, firm size, and average pricing levels. They also imply that we estimate the effects of exchange rate changes over time on prices, marginal costs, and markups for a given firm producing a given product.

Because the exchange rate only varies over time, time fixed effects cannot be included in our regressions. This issue is common in exchange rate pass-through applications, and related work on Colombia and on firm-level markups also estimates specifications without time fixed effects when the regressor of interest is time-varying only (e.g., Caselli et al., 2017; Gopinath et al., 2020). In robustness checks, we control for observable macroeconomic factors that move over time (e.g., oil prices, interest rates) to assess the sensitivity of θ to economy-wide confounders. In addition, we are able to control for year fixed effects when we investigate heterogeneity across firms and products. Robust standard errors are clustered at the firm and year levels.

Because $\widehat{\mathrm{mc}}_{fj,t} = \mathrm{P}_{fj,t}/\hat{\mu}_{fj,t}$, equation (2) implies an additive decomposition: the exchange rate elasticity of prices equals the sum of the elasticities of marginal costs and markups. Accordingly, the estimated coefficients on marginal costs and markups should sum to the estimated price coefficient.

As a depreciation of domestic currency increases the costs of imported inputs, we expect the exchange rate to have a positive effect on marginal costs, which should, in turn, increase domestic prices. If the pass-through of cost changes into prices is incomplete, the depreciation should compress markups. The estimated coefficient θ is therefore expected to be positive when explaining marginal costs and prices but negative when regressing markups.

A depreciation can affect prices and markups not only through marginal costs but also through changes in the intensity of import competition. To isolate the component of markup adjustment that is not mediated by marginal costs, we then estimate:

$$\ln \hat{\mu}_{fj,t} = \eta \ln e_t + f(\ln \widehat{\mathrm{mc}}_{fj,t}; \gamma) + \delta_{fj} + \epsilon_{fj,t}, \tag{3}$$

where $f(\ln \widehat{\mathrm{mc}}_{fj,t}; \gamma)$ is a flexible control for marginal costs. In practice, we implement $f(\cdot)$ as a second-order polynomial on $\widehat{\mathrm{mc}}_{fj,t}$. We instrument each polynomial term with its one-period lag to mitigate concerns that contemporaneous measurement error in $\widehat{\mathrm{mc}}_{fj,t}$ mechanically

[19] As Colombian firms predominantly invoice trade transactions in US dollars, we use the US dollar bilateral exchange rate (Gopinath et al., 2020).

contaminates the estimated relationship between $\hat{\mu}_{fj,t}$ and e_t.[20]

The coefficient η represents the effect of exchange rate movements on markups *conditional on marginal costs*. It therefore captures how exchange rate fluctuations affect markups by changing the degree of import competition in the domestic market. As a depreciation reduces import competition, the residual demand faced by firms shifts outward, and markups may rise for a given level of costs. We therefore expect $\eta > 0$.

4.1 Baseline Results

Pass-Through Before presenting the results of estimating equation (2), we first provide evidence that the pass-through of cost changes into prices is incomplete, supporting the notion that markups are variable. We estimate a similar specification to equation (2) but we regress (log) prices on (log) marginal costs (we also control for year fixed effects and robust standard errors are clustered at the firm level only). As (log) prices decompose exactly into (log) marginal costs and (log) markups, any change in marginal costs that is not fully transmitted into prices necessarily results in a change in markups. All estimation samples exclude outliers in the top and bottom 3% of the distributions of unit prices, markups, and marginal costs.

As shown in column (1) of Table 3, the estimated coefficient on marginal costs is positive, which indicates that higher costs raise prices. It is, however, equal to 0.366, which is significantly below one, suggesting that the pass-through of cost changes into prices is incomplete. But as marginal costs are estimated and not observed, measurement error could potentially induce a downward bias in the estimated coefficient, leading to the erroneous conclusion that cost pass-through is incomplete (De Loecker et al., 2016). To address this issue, we instrument marginal costs with their own lag. As shown in column (2), the instrumented marginal cost estimate remains below one (at a value of 0.445), reinforcing the conclusion that cost pass-through is incomplete.

Columns (3)–(5) of Table 3 reports the baseline estimates of equation (2) for (log) prices, (log) marginal costs, and (log) markups at the firm-product-year level. The exchange rate coefficient in column (3) implies that a 10% depreciation is associated with a 2% increase in unit prices.

Table 3 also shows that marginal costs respond strongly: the coefficient in column (4) implies that a 10% depreciation raises marginal costs by 3%. As the increase in marginal costs is larger than the corresponding increase in prices (i.e., cost pass-through is incomplete), markups fall: the coefficient in column (5) implies that a 10% depreciation reduces markups by 0.86%. Overall, as the peso depreciated by 31.5% against the US dollar between July 2014 and March 2015, our estimates suggest that prices increased by around 6.48%, and this increase was driven by a 9.2% increase in marginal costs and a 2.71% fall in markups. Taken together, these results indicate that the depreciation is transmitted primarily through the marginal cost

[20] Because $\widehat{\text{mc}}_{fj,t}$ is constructed from $\text{P}_{fj,t}$ and $\hat{\mu}_{fj,t}$, the contemporaneous association between $\hat{\mu}_{fj,t}$ and $\widehat{\text{mc}}_{fj,t}$ may reflect both economic adjustment and measurement error. The IV strategy addresses this concern by using predetermined variation in $\widehat{\text{mc}}_{fj,t}$.

Table 3: Cost and Exchange Rate Pass-Through

	Log(price) (1)	Log(price) (2)	Log(price) (3)	Log(marginal cost) (4)	Log(markup) (5)
Log(marginal cost)	0.366***	0.445***			
	(0.010)	(0.017)			
Log(exchange rate)			0.206***	0.292***	−0.086***
			(0.032)	(0.035)	(0.019)
Observations	94,886	94,886	94,886	94,886	94,886
Firm-product FE	yes	yes	yes	yes	yes
Year FE	yes	yes	no	no	no
Estimation	OLS	2SLS	OLS	OLS	OLS
Overall effect of depreciation			6.48***	9.20***	−2.71***
			(1.007)	(1.109)	(0.597)

Notes: The dependent variable is indicated in the column headers. Columns (1)–(2) include firm-product and year fixed effects. Columns (3)–(5) include firm-product fixed effects only. The (log) nominal exchange rate is defined as Colombian pesos per US dollar. Column (2) instruments log marginal cost with its lag and the log exchange rate. The regressions use markups and marginal costs estimated over 2010–2019, along with reported unit prices for the same period. Because 2010 is omitted in the lagged specifications in other estimations, we also exclude this year from the non-lagged specifications to maintain a consistent sample across specifications. The final row uses the average 31.5% depreciation of the peso against the US dollar between July 2014 and March 2015 to compute the mean and standard error of the impact of the depreciation. That is, for each column the mean impact is equal to 31.5%×100 times the coefficient on the exchange rate. Standard errors are clustered at the firm level for columns (1)–(2) and two-way at the firm and year levels for columns (3)–(5). To recover the standard error of the total effect we used the delta method s.e $= 31.5\% \times 100\ |\text{s.e}(\hat{\theta})|$. *** indicates significance at the one percent level.

channel and that firms absorb part of the cost increase through lower markups.

The decomposition is mechanically consistent with how we recover marginal costs. Since $\widehat{\text{mc}}_{fj,t} = \text{P}_{fj,t}/\hat{\mu}_{fj,t}$, we have the identity $\ln \text{P}_{fj,t} = \ln \widehat{\text{mc}}_{fj,t} + \ln \hat{\mu}_{fj,t}$. Accordingly, the estimated exchange rate elasticity of prices in column (3) equals (up to rounding) the sum of the elasticities for marginal costs and markups in columns (4) and (5). This additivity clarifies that the increase in unit prices reflects a combination of higher marginal costs and lower markups.

Competition Effects A depreciation can also reduce import competition in the domestic market and therefore raise firms' desired markups. To quantify this mechanism, Table 4 reports estimates of equation (3), which conditions flexibly on marginal costs through $f(\widehat{\text{mc}}_{fj,t}; \gamma)$. Intuitively, this specification asks whether, for a given level of marginal costs, firms set higher markups when the exchange rate depreciates.

Across specifications, the estimated coefficient on the exchange rate is positive and precisely estimated. In column (1), controlling linearly for $\widehat{\text{mc}}_{fj,t}$, a 10% depreciation is associated with a 1.0% increase in markups. The estimate remains positive when $\widehat{\text{mc}}_{fj,t}$ is instrumented with its lag (column 2), when $f(\cdot)$ is specified as a second-order polynomial (column 3), and when the polynomial terms are instrumented by lagged polynomials (column 4). The stability of the estimates across OLS and IV specifications suggests that the positive relationship between markups and the exchange rate conditional on marginal costs is not driven solely by

Table 4: Competition Effects of Exchange Rate Shocks

Log(markup)	(1)	(2)	(3)	(4)
Log(exchange rate)	0.099***	0.076**	0.102***	0.081**
	(0.024)	(0.025)	(0.024)	(0.025)
Log(marginal cost)	−0.634***	−0.554***	−0.809***	−0.978***
	(0.012)	(0.024)	(0.035)	(0.065)
Log(marginal cost)^2			0.008***	0.020***
			(0.002)	(0.003)
Observations	94,886	94,886	94,886	94,886
Firm-product FE	yes	yes	yes	yes
Estimation	OLS	2SLS	OLS	2SLS
Overall effect of depreciation	3.11***	2.39**	3.21***	2.56**
	(0.756)	(0.787)	(0.756)	(0.787)

Notes: Column (1) controls for marginal costs, column (2) instruments marginal costs with a one period lag, column (3) controls for a second-order polynomial of marginal costs and column (4) instruments marginal costs and a second-order polynomial with a second-order polynomial of lagged marginal costs. The (log) nominal exchange rate is defined as Colombian pesos per US dollar. The regressions use markups estimated over 2010–2019, but the estimations exclude 2010 which is omitted when instrumenting marginal costs and the polynomial term with their lags. The final row uses the average 31.5% depreciation of the peso against the US dollar between July 2014 and March 2015 to compute the mean and standard error of the impact of the depreciation. That is, for each column the mean impact is equal to 31.5% $\times$100 times the coefficient on the exchange rate. Standard errors are clustered two-way at the firm and year levels. To recover the standard error of the total effect we used the delta method s.e $= 31.5\% \times 100\ |\text{s.e}(\hat{\theta})|$. ***, **, and * indicate significance at the one, five, and ten percent levels, respectively.

contemporaneous measurement error or transitory shocks to marginal costs. Overall, these estimates indicate that the fall in import competition driven by the 31.5% depreciation of the peso against the US dollar increased markups by roughly 2.3–3.2%.

Comparing Tables 3 and 4 is informative. Unconditionally, markups fall with a depreciation (Table 3, column 5), consistent with incomplete cost pass-through and a movement along the demand curve. Conditional on marginal costs, markups rise (Table 4), consistent with a weakening of import competition and a shift in the demand curve. These patterns indicate that both channels are present in the data. Quantitatively, the positive conditional response of markups partially offsets the negative response implied by the cost channel, but the net effect remains negative.

Quantification of Cost and Competition Channels The estimates reported in columns (3)–(5) of Table 3 decompose the price pass-through of exchange rate changes into marginal cost and markup pass-through. Those pass-through elasticities can be expressed as $d\ln \text{P}/d\ln e = d\ln \widehat{\text{mc}}/d\ln e + d\ln \hat{\mu}/d\ln e$ and are obtained by totally differentiating $\ln \text{P} = \ln \widehat{\text{mc}} + \ln \hat{\mu}$ with respect to the exchange rate (indices are omitted for simplicity).

Given that markups also depend on costs, the pass-through elasticity for markups $d\ln \hat{\mu}/d\ln e$ (reported in column 5 of Table 3) combines the direct (competition) effect of a change in the exchange rate on markups with the indirect effect that arises when markups respond to a change in costs. Markup pass-through can therefore be decomposed into its cost and

competition channels according to:

$$\frac{d\ln\hat{\mu}}{d\ln e} = \underbrace{\frac{d\ln\widehat{\text{mc}}}{d\ln e}\left(\frac{\partial\ln\hat{\mu}}{\partial\ln\widehat{\text{mc}}}\right)}_{\text{cost channel}} + \underbrace{\frac{\partial\ln\hat{\mu}}{\partial\ln e}}_{\text{competition channel}}. \tag{4}$$

All the objects in equation (4) are observed as $d\ln\widehat{\text{mc}}/d\ln e = 0.292$ (column 4 of Table 3), $\partial\ln\hat{\mu}/\partial\ln\widehat{\text{mc}} = -0.634$, and $\partial\ln\hat{\mu}/\partial\ln e = 0.099$ (column 1 of Table 4). On the one hand, the competition channel shows that a 10% depreciation raises markups by 0.99%. On the other hand, the cost channel (which is equal to $0.292(-0.634) = -0.185$) indicates that a 10% depreciation raises costs by 2.92% which in turn triggers a 1.85% fall in markups. Overall, markup pass-through is equal to $-0.185 + 0.099 = -0.086$, which is the same as the pass-through estimate reported in column (5) of Table 3.

Likewise, we can decompose price pass-through (reported in column 3 of Table 3) into its cost and competition channels. Letting markups depend on costs, price pass-through can be written as:

$$\frac{d\ln P}{d\ln e} = \underbrace{\frac{d\ln\widehat{\text{mc}}}{d\ln e}\left(1 + \frac{\partial\ln\hat{\mu}}{\partial\ln\widehat{\text{mc}}}\right)}_{\text{cost channel}} + \underbrace{\frac{\partial\ln\hat{\mu}}{\partial\ln e}}_{\text{competition channel}}, \tag{5}$$

where the cost channel combines the direct effect of a change in the exchange rate on costs ($d\ln\widehat{\text{mc}}/d\ln e$) with the indirect effect of a change in costs on markups ($\partial\ln\hat{\mu}/\partial\ln\widehat{\text{mc}}$). The cost channel (equal to $0.292(1 - 0.634) = 0.107$) indicates that a 10% depreciation increases costs by 2.92%, but more than half of the effect of the cost increase (63.4%) is offset by a fall in markups such that firm-level prices rise by 1.07% only. As the competition effect is equal to 0.099, price pass-through can be retrieved as $0.107 + 0.099 = 0.206$, which matches the estimate reported in column (3) of Table 3.

4.2 Firm-Level Heterogeneity

We next assess heterogeneity along three dimensions that are directly relevant for exchange rate transmission. First, we study heterogeneity in firms' exposure to imported inputs and their participation in export markets. Second, we investigate the heterogeneous results according to pre-shock markups. Finally, we assess how the effects vary depending on firm's size.

Importers, Exporters, and Domestic Firms Table 5 estimates a pooled version of equation (2) in which the exchange rate is interacted with firms' pre-depreciation import and export status. The table distinguishes firms that only import intermediate inputs, firms that only export, and firms that both export and import (the three groups are mutually exclusive). The coefficient on the exchange rate should therefore be interpreted as the effect for domestic firms (i.e., those that do not export or import).

Columns (1)–(4) include firm-product fixed effects. Columns (5)–(8) also include year fixed effects. In these latter specifications, the year fixed effects absorb the common exchange-rate movement and all other aggregate year shocks, so the coefficients identify differential responses

Table 5: Pass-Through: Heterogeneity Importers and Exporters

	Log(price)	Log(cost)	Log(markup)		Log(price)	Log(cost)	Log(markup)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log(ER)	0.167***	0.250***	−0.083***	0.059***				
	(0.023)	(0.031)	(0.022)	(0.018)				
Log(ER)× Importer only	0.081*	0.153**	−0.072	0.015	0.078	0.150**	−0.072	0.014
	(0.047)	(0.070)	(0.053)	(0.036)	(0.047)	(0.070)	(0.053)	(0.036)
Log(ER)× Exporter only	0.094**	0.028	0.066	0.083**	0.090*	0.024	0.067	0.081**
	(0.048)	(0.060)	(0.048)	(0.038)	(0.048)	(0.060)	(0.048)	(0.038)
Log(ER)× Importer	0.081**	0.095*	−0.014	0.047*	0.074**	0.088	−0.014	0.043
& Exporter	(0.035)	(0.055)	(0.044)	(0.028)	(0.035)	(0.055)	(0.044)	(0.028)
Importer only	0.248***	0.403***	−0.155***	0.074**	0.078	0.150**	−0.072	0.014
	(0.041)	(0.062)	(0.049)	(0.033)	(0.047)	(0.070)	(0.053)	(0.036)
Exporter only	0.261***	0.277***	−0.017	0.142***	0.090*	0.024	0.067	0.081**
	(0.042)	(0.052)	(0.042)	(0.034)	(0.048)	(0.060)	(0.048)	(0.038)
Importer	0.328***	0.498***	−0.169**	0.121***	0.152**	0.238**	−0.086	0.057
	(0.054)	(0.083)	(0.066)	(0.043)	(0.068)	(0.099)	(0.076)	(0.051)
Exporter	0.341***	0.372***	−0.031	0.188***	0.164**	0.111	0.053	0.124**
	(0.055)	(0.075)	(0.061)	(0.044)	(0.068)	(0.093)	(0.072)	(0.052)
Importer & Exporter	0.422***	0.525***	−0.103	0.204***	0.242**	0.261**	−0.019	0.138*
	(0.079)	(0.112)	(0.087)	(0.062)	(0.095)	(0.132)	(0.100)	(0.072)
Observations	94,040	94,040	94,040	94,040	94,040	94,040	94,040	94,040
Firm-product FE	✓	✓	✓	✓	✓	✓	✓	✓
Year FE					✓	✓	✓	✓
Marginal cost control				✓				✓

Notes: The dependent variable is indicated in the column headers. Columns (4) and (8) include a second-order polynomial in log marginal costs. The (log) nominal exchange rate is defined as Colombian pesos per US dollar. Standard errors are clustered at the firm and year level in columns (1)–(4), and at the firm level in columns (5)–(8).

across firms with different pre-existing exposure to international markets. Overall, once the year fixed effects are included, the coefficients on interaction terms remain similar to those in columns (1)–(4). These results are reassuring, as they provide evidence that our results omitting the year fixed effects are not confounded by the omission of time-varying factors.

Four findings stand out. First, in columns (1)–(3), firms with no direct pre-shock import or export activity display the same baseline pattern as the full sample: a depreciation raises marginal costs and prices but reduces markups. The finding that exchange rates matter for the marginal costs of non importers could result from these firms purchasing imported inputs from other firms in the domestic market.

Second, firms with greater exposure to international markets display stronger price responses to exchange rate movements. The price increase is higher for all firms exposed to international markets (column 1), with increases in prices similar to those of importers and exporters at 0.328 and 0.341, respectively. Column 5 shows that the price differential between foreign-exposed and non-foreign-exposed firms is driven by exporters (including importers that export), ranging from 0.090 to 0.164.

Third, marginal costs respond more strongly for firms exposed to imported inputs. In the specification without year fixed effects, the marginal-cost elasticity is 0.403 for importer-only firms, compared with 0.277 for exporter-only firms. For firms that both export and import, the

implied marginal-cost elasticity is 0.525. This pattern is consistent with the imported-input cost channel. The year-fixed-effects estimates point in the same direction: the differential marginal-cost response is positive and statistically significant for importer-only firms, while the corresponding response for exporter-only firms is small and not statistically significant. Thus, the cost response to depreciation is concentrated among firms with import exposure. For firms importing materials before the depreciation, there is a substitution between the purchases of imports and domestic goods, and in general, purchases of imported materials decreased significantly (see Table B1).

Fourth, markup responses reflect the relative strength of the price and cost responses. For importer-only firms, marginal costs rise more than prices, leading to a decline in markups. The implied markup elasticity for this group is -0.155 in the specification without year fixed effects. In contrast, for exporter-only firms, it nearly matches the marginal-cost response, and the implied markup response is close to zero. For firms that both export and import, both prices and marginal costs respond strongly, and the implied markup response is negative but less precisely estimated. Overall, the evidence indicates that import exposure is most closely associated with the cost channel, while export exposure is associated with stronger price adjustment.

Table 5 columns (4) and (8) report estimates from the corresponding competition-channel specification, which controls flexibly for marginal costs using a second-order polynomial. In column (4), the positive coefficient on the exchange rate indicates that a depreciation raises markups among domestic firms, conditional on marginal costs. The implied elasticity is similar for importer-only firms, at 0.074, but larger for exporter-only firms, at 0.142. Once year fixed effects absorb the common exchange-rate movement, only the exporter-only differential relative to domestic firms is positive and statistically significant; the differentials for importer-only firms and for firms that import are not statistically significant. Thus, the stronger conditional markup response is associated primarily with export exposure rather than import exposure. Because our production markups for exporters combine domestic and export sales, however, this larger response may reflect both weaker import competition and US-dollar invoicing of exports.

Why are exporters raising markups to a larger extent in response to a depreciation, conditional on marginal costs? We believe that the answer lies in the currency of invoicing used by Colombian exporters. As documented by Gopinath et al. (2020), Colombia relies heavily on US dollar invoicing for both exports and imports.[21] If Colombian exporters set export prices that are sticky in US dollars, pass-through in US dollar prices is zero. As a result, following a depreciation, exporters do not become more competitive in export markets and there is no increase in exports. Instead, exporters earn larger profits (in pesos) as markups

[21] Using firm-level transaction data for bilateral exports and imports, Gopinath et al. (2020) observe that 98% of Colombian exports are invoiced in US dollars. For imports, the currency of invoicing is not available. But in pass-through regressions for import prices, they find that controlling for the US dollar exchange rate knocks down the coefficient on the bilateral exchange rate, suggesting that Colombian firms largely invoice imports in US dollars as well.

Table 6: Non-Exporters vs. Exporters

Log(markup)	(1)	(2)
Log(exchange rate)	0.054*	0.210***
	(0.028)	(0.037)
Log(marginal cost)	−0.798***	−0.902***
	(0.082)	(0.169)
Log(marginal cost)^2	0.014***	0.008
	(0.004)	(0.008)
Markups estimated for	Non exporters	Exporters only
Observations	66,509	21,502
Firm-product FE	yes	yes
Estimation	2SLS	2SLS
Overall effect of depreciation	1.701*	6.615***
	(0.882)	(1.16)

Notes: Regressions instrument marginal costs and a second-order polynomial with a second-order polynomial of lagged marginal costs. The (log) nominal exchange rate is defined as Colombian pesos per US dollar. The regressions use markups estimated over 2010–2019, but the estimations exclude 2010 which is omitted when instrumenting marginal costs and the polynomial term with their lags. The final row uses the average 31.5% depreciation of the peso against the US dollar between July 2014 and March 2015 to compute the mean and standard error of the impact of the depreciation. That is, for each column the mean impact is equal to 31.5% $\times$100 times the coefficient on the exchange rate. Standard errors are clustered two-way at the firm and year levels. To recover the standard error of the total effect we used the delta method s.e $= 31.5\% \times 100$ |s.e$(\hat{\theta})$|. ***, **, and * indicate significance at the one, five, and ten percent levels, respectively.

increase conditional on marginal costs. In other words, following a depreciation, exporters may raise markups on domestic sales because of a weakening of the intensity of import competition on the domestic market, and they may earn higher markups on exports because they invoice in US dollars.

As noted earlier, we estimate firm-product markups at the production stage. For exporting firms, these estimates therefore combine markups on domestic sales and on exports. To separately recover the markups on domestic sales and on exports, we would need to observe the physical quantities of exports, which are not available (exports are reported in nominal terms only). We are therefore unable to disentangle whether, in response to a depreciation, exporters raise markups because of a weakening of import competition and/or because they invoice exports in US dollars.

To ensure that the estimates we report in Table 4 identify a competition effect, we re-estimate markups on the sample of non-exporting firms, and we use these markups as the dependent variable in equation (3). These markups are only charged on domestic sales and are therefore immune to the invoicing currency of exports. We also re-estimate markups using the sample of exporting firms only. In that case, the response of markups to a depreciation conditional on marginal costs (in equation 3) combines the effects of a weakening of import competition and of US dollar invoicing on exports.

The results are reported in Table 6. Column (1) shows that following a depreciation, markups among non-exporting firms increase, conditional on marginal costs. Because these

Table 7: Pass-Through: Heterogeneity by Pre-Shock Markups

	Log(price) (1)	Log(cost) (2)	Log(markup) (3)	Log(markup) (4)	Log(price) (5)	Log(cost) (6)	Log(markup) (7)	Log(markup) (8)
Log(ER)	0.234***	0.139***	0.095**	0.185***				
	(0.036)	(0.040)	(0.031)	(0.029)				
Log(ER)× High	−0.055*	0.299***	−0.355***	−0.163***	−0.056*	0.299***	−0.355***	−0.164***
	(0.030)	(0.050)	(0.043)	(0.025)	(0.031)	(0.043)	(0.033)	(0.024)
Total elasticity								
High markup	0.179***	0.439***	−0.260***	0.021				
	(0.034)	(0.046)	(0.027)	(0.026)				
Observations	93,318	93,318	93,318	93,318	93,318	93,318	93,318	93,318
Firm-product FE	✓	✓	✓	✓	✓	✓	✓	✓
Year FE					✓	✓	✓	✓
Marginal cost control				✓				✓

Notes: The dependent variable is indicated in the column headers. Columns (4) and (8) include a second-order polynomial in log marginal costs. The log nominal exchange rate is defined as Colombian pesos per US dollar. Pre-shock markup is the firm's average firm-year log markup before 2014. High-pre-shock-markup firms are those at or above the pooled median, equal to 0.191. Low-pre-shock-markup firms are the omitted group. Standard errors are clustered at the firm and year level in columns (1)–(4), and at the firm level in columns (5)–(8). In columns (5)–(8), year fixed effects absorb the common exchange-rate effect; the entries in the high-pre-shock-markup row therefore report high-minus-low differentials rather than total elasticities. ***, **, and * indicate significance at the one, five, and ten percent levels, respectively.

firms' markups reflect domestic sales only and are unaffected by the invoicing currency of exports, this result provides direct evidence that firms raise markups in response to weaker import competition in the domestic market. The estimated coefficient is 0.054. Column (2) reports a substantially larger point estimate of 0.210 for exporting firms. For these firms, however, the increase in markups may reflect both weaker import competition in the domestic market and higher peso-denominated markups on exports arising from US dollar invoicing.

Pre-Shock Markups We next examine whether exchange-rate transmission depends on firms' markup levels before the depreciation episode. For each firm, we measure the pre-shock markup as the average of its firm-year log markup over the years before 2014. We then interact the exchange rate with an indicator for firms whose pre-shock markup is at or above the median. Columns (1)–(4) of Table 7 include firm-product fixed effects, while columns (5)–(8) additionally include year fixed effects. In the latter specifications, the year fixed effects absorb the common exchange-rate movement, so the interaction coefficient identifies the differential response of high- relative to low-pre-shock-markup firms.

The results in Table 7 reveal a sharp difference in exchange-rate transmission across firms with different initial markups. In the specification without year fixed effects, the price elasticity is 0.234 for low-pre-shock-markup firms and 0.179 for high-pre-shock-markup firms. The difference in price responses is therefore relatively modest. The decomposition into marginal costs and markups, however, differs substantially across the two groups. The marginal-cost elasticity is 0.139 for low-pre-shock-markup firms but 0.439 for high-pre-shock-markup firms, yielding a high-minus-low difference of 0.299. By contrast, the markup elasticity is positive for low-pre-shock-markup firms, at 0.095, but strongly negative for high-pre-shock-markup firms, at −0.260. The corresponding high-minus-low difference is −0.355.

The year-fixed-effects estimates deliver essentially the same relative pattern. Once common aggregate shocks are absorbed, high-pre-shock-markup firms exhibit a marginal-cost response that is 0.299 larger and a markup response that is 0.355 more negative than the response of low-pre-shock-markup firms. These estimates indicate that the average decline in markups masks pronounced heterogeneity. Firms entering the depreciation episode with relatively low markups raise markups as the peso depreciates, whereas firms entering with relatively high markups experience substantial markup compression. The latter pattern is driven by a much stronger increase in marginal costs that is only partially reflected in prices.

Table 7 columns (4) and (8) report the corresponding competition-channel estimates. As in the other competition specifications, we condition flexibly on marginal costs using a second-order polynomial. The results show that the positive conditional markup response is concentrated among firms with low pre-shock markups. Without year fixed effects, the conditional markup elasticity is 0.185 for low-pre-shock-markup firms. The interaction for high-pre-shock-markup firms is −0.163, implying an elasticity of 0.021 for that group, which is close to zero. The year-fixed-effects specification yields a nearly identical high-minus-low differential of −0.164. Taken together, the unconditional and conditional estimates suggest that the competition channel is relatively more important for firms with low initial markups, while the cost channel dominates for firms with high initial markups.

Our results contrast with Kharroubi et al. (2023), who find for the US that high-markup firms dampen the pass-through of disinflationary oil shocks but respond to inflationary oil shocks in the same way as low-markup firms. In our setting, high-markup firms absorb a large share of an inflationary cost shock. One explanation is the nature of the shock: the 2014–2015 depreciation was large and persistent and directly raised the cost of imported inputs, whereas oil supply shocks are typically more transitory.

Firm Size We also examine whether exchange-rate transmission varies with firm size measured before the depreciation episode. This exercise is motivated by the literature on heterogeneous variable markups. In the spirit of Berman et al. (2012), larger or better-performing firms may have more scope to adjust markups in response to exchange-rate shocks. We therefore interact the exchange rate with pre-shock firm size, measured as mean real firm sales before 2014.

The results in Table 8 show that exchange-rate responses vary systematically with pre-shock firm size. Larger firms experience stronger marginal-cost and price responses, but the additional increase in costs is only partially reflected in prices. In the specification without year fixed effects, moving from the 25th to the 75th percentile of pre-shock size raises the marginal-cost elasticity from 0.227 to 0.338, while the price elasticity rises from 0.166 to 0.235. The gap between the two responses therefore widens from 0.061 to 0.103, implying greater markup compression among larger firms: the reduced-form markup elasticity declines from −0.060 to −0.103. The year-fixed-effects specifications yield nearly identical size differentials, indicating that this pattern is robust to absorbing common annual shocks. This is consistent with models of variable markups in which cost pass-through declines with market power. In Atkeson and

Table 8: Pass-Through: Heterogeneity by Pre-Shock Firm Size

	Log(price) (1)	Log(cost) (2)	Log(markup) (3)	Log(markup) (4)	Log(price) (5)	Log(cost) (6)	Log(markup) (7)	Log(markup) (8)
Log(ER)	0.203***	0.287***	−0.084***	0.101***				
	(0.016)	(0.022)	(0.017)	(0.013)				
Log(ER)× Log(size)	0.027***	0.044***	−0.017*	0.013**	0.025***	0.042***	−0.017*	0.012**
	(0.007)	(0.011)	(0.009)	(0.006)	(0.007)	(0.011)	(0.009)	(0.006)
25^{th} percentile	0.166***	0.227***	−0.060***	0.083***	−0.034***	−0.057***	0.023*	−0.016**
	(0.022)	(0.030)	(0.022)	(0.017)	(0.010)	(0.016)	(0.013)	(0.008)
75^{th} percentile	0.235***	0.338***	−0.103***	0.117***	0.029***	0.049***	−0.020*	0.014**
	(0.015)	(0.023)	(0.019)	(0.013)	(0.008)	(0.013)	(0.011)	(0.007)
Observations	90,754	90,754	90,754	90,754	90,754	90,754	90,754	90,754
Firm-product FE	✓	✓	✓	✓	✓	✓	✓	✓
Year FE					✓	✓	✓	✓
Marginal cost control				✓				✓

Notes: The dependent variable is indicated in the column headers. Columns (4) and (8) include a second-order polynomial in log marginal costs. The log nominal exchange rate is defined as Colombian pesos per US dollar. Standard errors are clustered at the firm and year level in columns (1)–(4), and at the firm level in columns (5)–(8). Pre-shock firm size is the log of mean real firm sales before 2014 and is demeaned using the regression-sample mean. In columns (5)–(8), year fixed effects absorb the common exchange-rate effect, so the percentile rows report differentials relative to mean pre-shock firm size.

Burstein (2008), markups increase with market share, so that firms with small shares pass cost changes through almost fully, whereas larger firms absorb a greater fraction of cost increases in their markups. More generally, cost pass-through is incomplete when the demand elasticity rises with price (De Loecker et al., 2016).

Table 8 columns (4) and (8) report the competition channel. Once we control for marginal costs, the markup response to a depreciation is positive and increases with pre-shock firm size. The implied conditional markup elasticity rises from 0.083 at the 25th percentile to 0.117 at the 75th percentile, and the year-fixed-effects specification shows the same ranking. Both size patterns mirror Amiti et al. (2019), who find that small firms pass cost shocks through fully and do not respond to competitors' prices, whereas large firms exhibit incomplete cost pass-through and raise their prices when competitors do. Our results suggest that a depreciation raises the peso prices of competing imports, and larger firms respond to this by raising their markups more. Thus, firm-size heterogeneity reinforces the two-channel interpretation: depreciations raise costs especially for larger firms, but larger firms also benefit more from weaker import competition.

4.3 Product and Sector Heterogeneity

We examine heterogeneous responses by product final use (BEC classification). Under the BEC classification (Table C1 in the Appendix), price responses are similar for intermediate and consumption goods, but the marginal-cost elasticity is 0.098 higher for intermediate goods (significant at 10%), and markup compression is correspondingly larger (−0.090). This is consistent with intermediate goods relying more heavily on imported inputs, the channel that Goldberg and Campa (2010) identify as the main driver of the sensitivity of domestic prices to exchange rates, and with the evidence that import-intensive firms face larger exchange-rate-

driven cost changes (Amiti et al., 2014).

Capital goods, the omitted category, show the lowest and statistically insignificant price response (0.147) despite a sizable cost increase (0.302), as their markups absorb a large part of it (−0.155). This is in line with evidence that pass-through is lower for differentiated manufactures, where firms have more scope to adjust markups, than for commodities (Campa and Goldberg, 2005). Conditional on marginal costs, consumption goods show the largest markup increase (0.098), although the difference with intermediate goods is not significant. This is consistent with import competition being most relevant for final consumption goods, where domestic and imported varieties compete directly, as in Flaaen, Hortaçsu, and Tintelnot (2020), who find that domestic producers raised prices when tariffs weakened import competition in the US washing machine market.

Finally, we construct a sector-level upstreamness measure following Antràs et al. (2012). Table C2 shows that more upstream sectors raise prices by less (0.204 at the 75th percentile of upstreamness vs 0.248 at the 25th). This lower pass-through is consistent with Georgiadis et al. (2019), who find that participation in global value chains, while increasing firms' cost exposure to exchange rates, lowers exchange rate pass-through to import prices. In our data, however, the mechanism operates through markups rather than costs: the marginal-cost response does not vary significantly with upstreamness (0.318 vs 0.338), whereas markup compression is stronger in more upstream sectors (−0.133 vs −0.069). Conditional on marginal costs, the markup increase is also smaller upstream (0.073 vs 0.118), suggesting that the competition channel weakens with distance from final demand. One interpretation is that upstream producers sell to other firms, which are more price-sensitive and can switch between domestic and imported suppliers, limiting the scope to raise markups when import competition weakens.

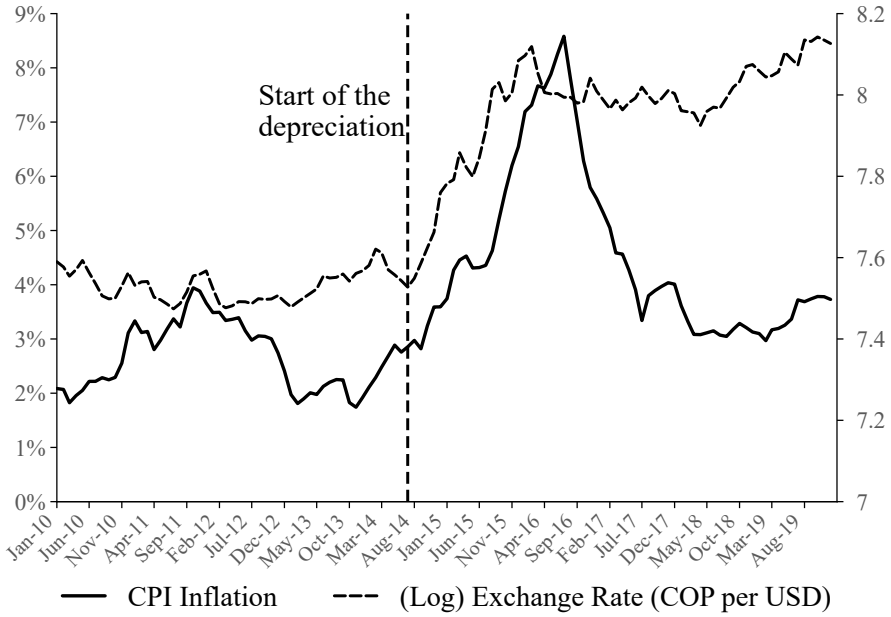
4.4 Consumer Prices

As our analysis studies the prices of domestically produced goods, it obviously has implications for consumer prices. Besides domestic goods, the consumer price bundle also includes imported final goods and non-tradable goods (mainly services). While the prices of domestic and imported final goods are sensitive to exchange rate changes, the prices of non-tradable goods are less responsive and their inclusion therefore limits the pass-through of exchange rate changes into consumer prices (Burstein et al., 2005; Goldberg and Campa, 2010; Gopinath, 2016). In addition, distribution costs also dampen the price pass-through of imported goods into consumer prices (Corsetti and Dedola, 2005; Goldberg and Campa, 2010). As a result, pass-through into consumer prices is expectedly lower than the pass-through into domestic goods prices that we study in this paper.[22]

Figure 3 plots the year-on-year monthly consumer price inflation rate against the (log) exchange rate (pesos per US dollar) between January 2010 and December 2019. It is clear that the inflation rate rose sharply after the peso started to depreciate in July 2014. Inflation stood

[22]The prices of imported final goods are in turn more sensitive to exchange rate changes than the prices of domestic goods and can be expected to have a higher pass-through.

Figure 3: Depreciation and Inflation



Notes: The figure plots the year-on-year consumer price inflation rate (left axis) and (log) exchange rate (Colombian pesos per US dollar, right axis). Sources: CPI from DANE National Statistics and nominal exchange rate from the International Financial Statistics of the International Monetary Fund.

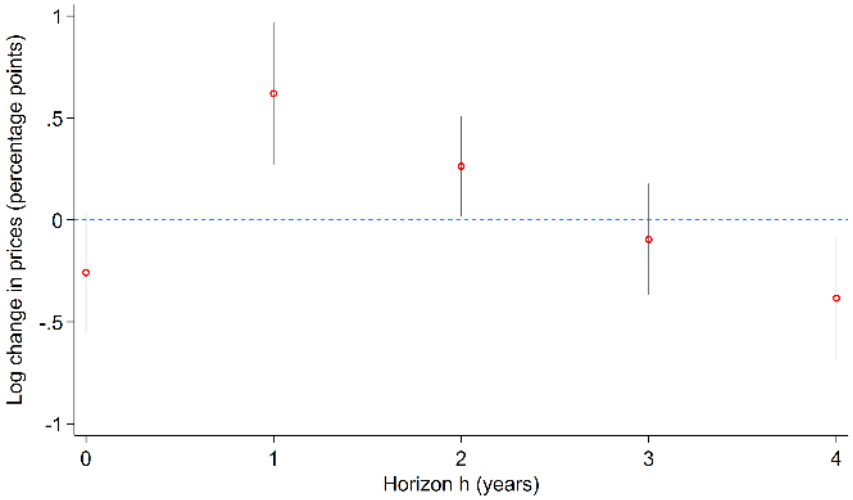
at 2.8% in July 2014, and it subsequently accelerated to reach a peak of 8.6% in July 2016 before easing to around 3% in early 2018. This rapid response of inflation to the depreciation can most likely be explained by the predominance of the US dollar as an invoicing currency for Colombian imports (Gopinath, 2016; Gopinath et al., 2020).

To derive the implications of our results for consumer prices, ideally we would need to match the prices in our data set with the microdata underlying the construction of the Colombian CPI. These data, however, do not distinguish between imported and domestic goods. We therefore derive an estimate of the share of the CPI that can be explained by our results. We then estimate local projections of the effects of a change in the exchange rate on the growth of prices, marginal costs, and markups, and calculate back-of-the-envelope estimates of the implications of our findings for the CPI inflation rate.

In a first step, based on the weights assigned to each product category in the CPI (available from DANE), we calculate that the share of tradable goods in the CPI is 31.33%. In order to further distinguish between domestically produced and imported final goods, we rely on the OECD's input-output table for Colombia in 2013 (i.e., the year before the depreciation). We follow Gopinath (2016) and calculate the share of imported final goods in total household consumption for manufacturing industries which is 22.67%.[23] The fraction of domestically produced (manufacturing) goods in the CPI is therefore approximately $(1 - 0.2267) \times 0.3133 = 24.23\%$. In other words, we assume that the estimates we derive from our data can explain

[23]In order to evaluate the effects of exchange rate changes on consumer price inflation, Gopinath (2016) estimates country-level import pass-through elasticities with respect to trade-weighted exchange rates and multiplies these estimates with each country's imported share of consumer goods expenditure.

Figure 4: Dynamic Response of Prices to Exchange Rate Depreciation



Notes: The figure shows local projection estimates for the (log) change in prices are obtained by estimating equation (6) and are multiplied by 10. 90% confidence intervals are reported as error bars.

around a quarter of the variation in the CPI.

In a second step, for each horizon $h = 0, 1, ..., 4$ years, we estimate local projections of the form (Jordà, 2005):

$$\Delta \ln x_{fj,t+h} = \beta_h^x \Delta \ln e_t + \delta_{fj} + \nu_{fj,t}^x, \tag{6}$$

where $\Delta \ln x_{fj,t+h} = \ln x_{fj,t+h} - \ln x_{fj,t+h-1}$ and $x_{fj,t}$ is either $\mathrm{P}_{fj,t}$, $\widehat{\mathrm{mc}}_{fj,t}$, or $\hat{\mu}_{fj,t}$. The estimated coefficient β_h^x measures the response of $\Delta \ln x_{fj,t+h}$ at horizon h to a change in the exchange rate at time t. As before, we include firm-product fixed effects, and robust standard errors are clustered by firm and year.[24]

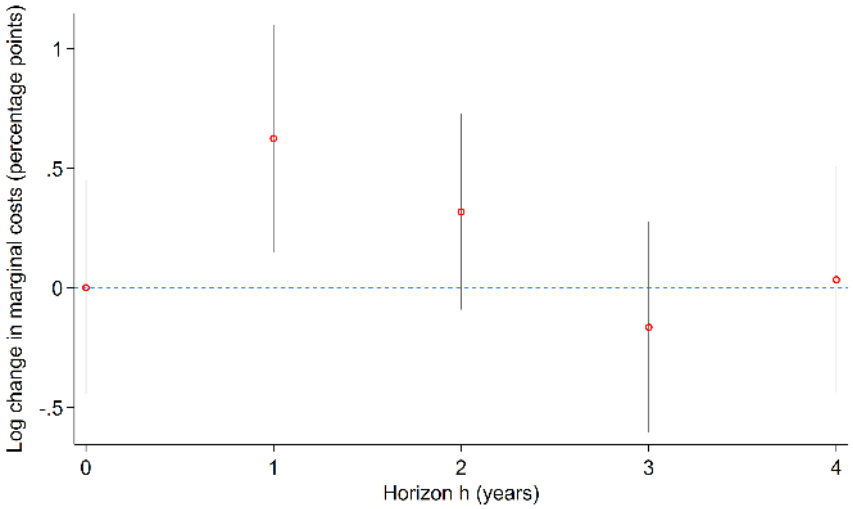
The dynamic effects of an exchange rate depreciation at time t on the growth of firm-level prices at each horizon h are graphically depicted in Figure 4 (together with 90% confidence intervals). The contemporaneous effect is not significant. But after one and two years, a 10% depreciation raises firm-level inflation by 0.62 and 0.26 percentage points, respectively. Since our firm-level prices represent around a quarter of the CPI, these estimates translate into a 0.15 and 0.06 percentage points growth in the CPI one and two years after the depreciation.[25]

How do these results compare to estimates reported in the literature? Across OECD countries, Goldberg and Campa (2010) report an average exchange rate pass-through elasticity of CPI inflation of 0.17 over four quarters. Gopinath (2016) documents that a one percent depreciation of the US dollar raises US cumulative CPI inflation over two years by 0.07 percentage points. For countries like Mexico and Turkey that predominantly invoice imports in a foreign currency (i.e., the US dollar), she finds larger effects of 0.16 and 0.20 percentage

[24] Even if we allow for the possibility of a structural break, the exchange rate is non stationary, while prices are stationary in levels. But both the exchange rate and prices are first-difference stationary.

[25] We measure the response of CPI inflation to a change in the prices of domestically produced goods *all else equal*, that is, holding fixed any endogenous response of monetary policy to inflation (Gopinath, 2016).

Figure 5: Dynamic Response of Marginal Costs to Exchange Rate Depreciation



Notes: The figure shows local projection estimates for the (log) change in marginal costs are obtained by estimating equation (6) and are multiplied by 10. 90% confidence intervals are reported as error bars.

points, respectively. As expected, these pass-through elasticities into CPI inflation are low. They are, however, larger than our estimates because they also account for the pass-through of exchange rate changes into the prices of imported final goods, while our elasticities only measure the pass-through into the prices of domestically produced goods.

On an annual basis, the peso exchange rate depreciated by 31.5% from 2014 to 2015. Therefore, our estimates imply that this depreciation raised firm-level manufacturing inflation in 2016 and 2017 by 1.94 and 0.83 percentage points, respectively, which in turn increased CPI inflation by 0.47 and 0.20 percentage points in the same two years. In comparison, the actual CPI inflation rate stood at 7.2% in 2016 and at 4.2% in 2017.[26] Our estimates therefore explain around 6% of the CPI inflation rate over 2016 and 2017 (i.e., 0.47 percentage points of the 7.2% CPI inflation rate in 2016 and 0.20 percentage points of the 4.2% CPI inflation rate in 2017).

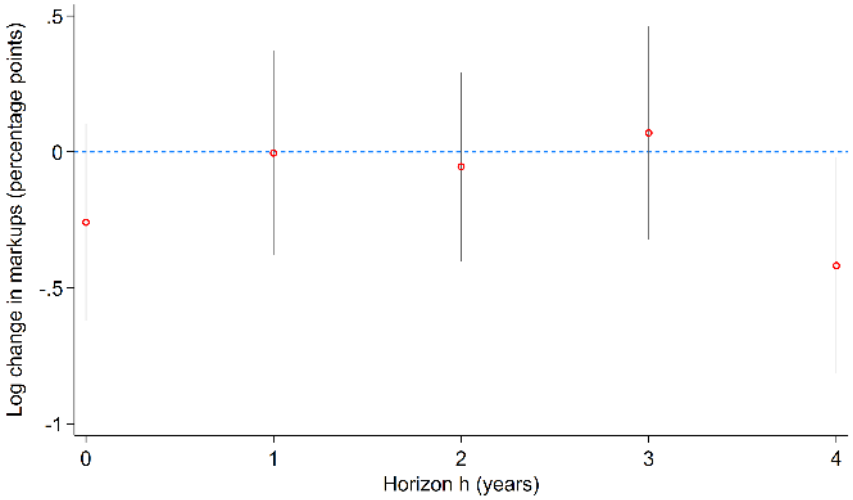
As was the case in Table 3, the response of price inflation decomposes exactly into marginal cost and markup components as $\Delta \ln P_{fj,t} = \Delta \ln \widehat{mc}_{fj,t} + \Delta \ln \hat{\mu}_{fj,t}$. Figures 5 and 6 display the local projection estimates for marginal cost and markup growth. A 10% depreciation induces marginal costs to grow by 0.62 percentage points after one year, which is of the same order of magnitude as the corresponding effect on firm-level price inflation (Figure 4). Instead, the effects of exchange rate movements on markup growth are muted at any horizon.[27] In other words, while a depreciation affects the *level* of markups (Table 3), it does not persistently affect the *growth* of markups over time. The inflationary effect of the depreciation is therefore predominantly driven by the growth in marginal costs.

We then ask whether the growth in markups is affected by a change in the intensity of

[26] As our estimates are obtained using annual frequency data, we cannot directly compare them to the monthly CPI inflation rate depicted in Figure 3.

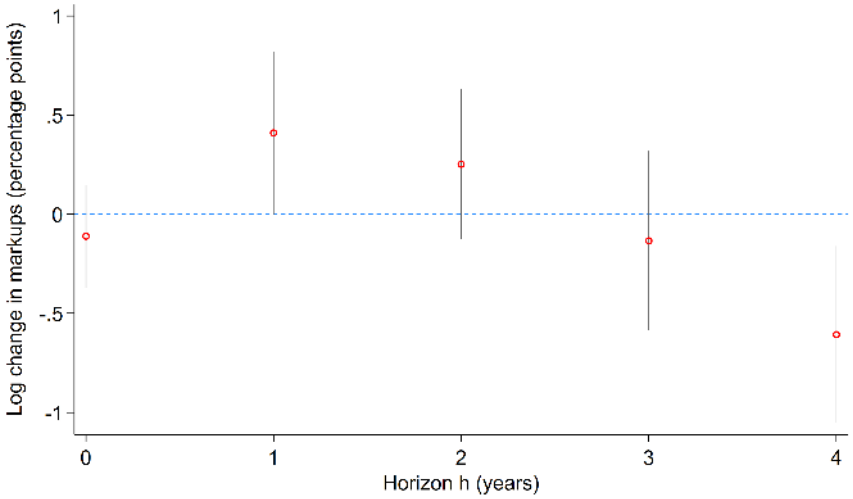
[27] The effect is slightly negative after 4 years but is only significant at the 10% level.

Figure 6: Dynamic Response of Markups to Exchange Rate Depreciation



Notes: The figure shows local projection estimates for the (log) change in markups are obtained by estimating equation (6) and are multiplied by 10. 90% confidence intervals are reported as error bars.

Figure 7: Conditional Markup Response



Notes: The figure shows local projection estimates for the (log) change in markups (conditional estimates) are obtained by estimating equation (6) with the (log) change in marginal costs and its second order polynomial included as additional controls (both are instrumented with their lags) and are multiplied by 10. 90% confidence intervals are reported as error bars.

import competition in the domestic market. We estimate equation (6) for markups, and further control for the growth of marginal costs between $t+h$ and $t+h-1$ and its second-order polynomial (both instrumented with their own lags). Figure 7 shows that the weakening of import competition driven by a depreciation has no significant impact on markup growth. This result corroborates our previous finding showing that exchange rate movements only impact markup levels, not their growth over time.

While changes in exchange rates affect firm-level prices by altering the levels of marginal costs and markups (Tables 3 and 4), the results of this section establish that the inflationary

impact of exchange rate depreciations only operates via the marginal cost channel as changes in markups are not persistent over time. Our estimates of the effects of the 2014 depreciation on firm-level manufacturing inflation, which are entirely driven by a growth in costs, can explain around 6% of the CPI inflation rate experienced by Colombia between 2016 and 2017. These results can be related to Goldberg and Campa (2010) who find that the main channel driving the sensitivity of CPI inflation to changes in exchange rates operates through the costs of imported inputs.

5 Robustness

In this section, we summarize the main takeaways of the sensitivity analysis. To preserve space, the results are presented in Appendix D.

First, we replicate the markup estimations using labor as the variable input. The results are reported in Section D.1, including Tables D2– D4 and figure D1. The correlation between material markups (benchmark) and labor markups is high at 0.68. In turn, the pass-through results are similar in both magnitude and statistical significance. The pass-through is slightly higher when using labor markups. The competition effects are also similar to the benchmark results. These findings are reassuring as Raval (2023) argues that the distribution of production-based markups can be very sensitive to the choice of the flexible input.

Second, we estimate markups using expenditure variables. For this specification, we use the same expenditure variables employed in the production function as inputs. Firm-level inputs are deflated using PPI deflators at the firm-industry level, where industry corresponds to the firm's main product by sales. In addition to correcting for selection bias, we also address input price bias in the estimation of production functions, following De Loecker et al. (2016), and we re-estimate input shares using input allocations with input-specific prices. The results are reported in Section D.2, in Tables D5-D7 and figure D2. The correlation between quantity and expenditure-based markups is 0.90. The pass-through and competition results remain similar to the benchmark.

We estimate pass-through using long differences, dividing the sample into pre- and post-periods around the pronounced depreciation in 2015. The pre-shock period covers 2013–2014 and the post-shock period covers 2017–2018, using 2011–2012 and 2015–2016 as lagged periods, respectively. Section D.3 reports the results, which remain robust.

Finally, to address the issue that time fixed effects cannot be included in our regressions, we also re-estimate our benchmark specifications including time-varying macroeconomic controls—oil shocks and interest rates. The results are reported in Section D.4 and remain robust.

Our benchmark pass-through results use markups estimated with the De Loecker et al. (2016) methodology (DGKP).[28] To assess whether these results are driven by the choice of estimation method rather than by economic behavior, we re-estimate markups following

[28] For details on the estimation see Appendix D.5.

Blum et al. (2024) (BCHR) and compare the two across specifications. The BCHR markup is recovered as $\mu_{fj,t} = \ln \xi_I - \ln s_{f,t}$ with a Cobb–Douglas, time-invariant output elasticity ξ_I. In levels, this makes the two measures difficult to compare: the constant ξ_I enters as a firm-product-specific level shift, and any error in the estimated elasticity, or any relative-price trend in the nominal share, contaminates the level of the BCHR markup but not the DGKP one. In first differences, however, the time-invariant elasticity drops out entirely and allows for a comparison.

Table D13 shows a markup compression of -0.056 and increase of 0.071 in cost, leading to a null effect for the price. The BCHR estimates are more precise, which follows from its finer (3-digit) production-function aggregation while DGKP estimates use 2-digit level on product-unit markups with more observations that can add to the noise. We treat the BCHR results as a robustness check rather than as our main specification as the BCHR procedure imposes stricter data requirements (mostly for sectors with heterogeneous units). In our data it recovers markups for only about 32% of manufacturing sales, whereas the DGKP method covers markups for a larger sample.

6 Theoretical Framework

Although CES preferences are very convenient analytically, they are very restrictive in terms of theoretical and empirical predictions. In particular, when combined with monopolistic competition, CES preferences predict that all firms have the same constant markup, which is inconsistent with empirical evidence.[29]

We depart from CES preferences by relying on the approach of Mrázová and Neary (2017, 2020). This framework allows us to characterize the effects of exchange rate movements on firm-level domestic prices, markups, and marginal costs without having to specify the functional form of the demand system. We extend their model by showing that the effects of exchange rate movements can operate through two different channels. The first is an *imported-input cost channel* whereby a depreciation raises marginal costs for firms that rely on imported intermediate inputs. The second is an *import-competition channel*, which implies that a depreciation raises the relative price of foreign varieties and may, therefore, relax the residual demand faced by domestic producers.

6.1 Environment

A monopolistically competitive domestic firm f in sector j sells in the home market at time t. Let $q \equiv q_{fj,t}$ denote output, and $p \equiv p_{fj,t}$ be the domestic price. For simplicity, we assume that firms produce a single good.

[29] Examples of models with monopolistic competition and CES demand that predict constant markups include, for instance, Krugman (1980) and Melitz (2003).

The firm faces inverse demand:

$$p \;=\; P(q), \qquad P_q(q) \;<\; 0, \tag{7}$$

and we only assume that the price is a strictly decreasing function of firm output, i.e., $P_q = \partial P/\partial q < 0$. The firm chooses output q to maximize variable profits:

$$\pi(q) = (P(q) \;- c)q, \tag{8}$$

where c is the marginal cost of the firm.

The first-order condition (FOC) is:

$$P(q) + P_q(q)\, q \;=\; c, \tag{9}$$

and shows that marginal revenue is equal to marginal cost. Defining the (local) price elasticity of demand as:

$$\varepsilon(q) \;\equiv\; -\frac{P(q)}{q\, P_q(q)}, \tag{10}$$

the optimal price is therefore a markup μ over marginal cost:

$$p \;=\; P(q) \;=\; c\,\frac{\varepsilon(q)}{\varepsilon(q)-1} \;=\; c\mu(q). \tag{11}$$

The first-order condition requires $\varepsilon > 1$, ensuring that the optimal markup is finite. Since ε varies with the operating point, markups are variable.

Let the marginal revenue be $MR(q) \equiv P(q) + P_q(q)\, q$. Differentiating yields:

$$MR'(q) = 2P_q(q) + qP_{qq}(q) = P_q(q)\big(2 - \rho(q)\big), \tag{12}$$

where ρ is the convexity of inverse demand, which is defined as:

$$\rho(q) \;\equiv\; -\frac{q\, P_{qq}(q)}{P_q(q)}, \tag{13}$$

and its sign is determined by P_{qq}.

The second-order condition (SOC) shows that, at the optimum, marginal revenue is decreasing in output:

$$MR'(q) \;<\; 0, \tag{14}$$

which implies:

$$2 - \rho(q) \;>\; 0 \qquad \Longleftrightarrow \qquad \rho(q) < 2. \tag{15}$$

Mrázová and Neary (2017, 2020) define the "manifold" as the curve that relates the elasticity to the convexity of demand in the (ε, ρ) space (see Figure 8 below). As shown above, a profit-maximizing monopolistically competitive firm must operate at a point on its demand

curve where $\varepsilon > 1$ and $\rho < 2$ (so profits are locally concave in output). This admissible region in the (ε, ρ) space can be further split into two sub-regions that imply different comparative statics depending on how the elasticity of demand varies with firm output. The two regions are separated by the locus of CES demands ($\rho = 1 + 1/\varepsilon$), along which the elasticity does not vary with output such that all firms face the same markup.

Mrázová and Neary (2017, 2020) classify demand curves relative to the CES locus. A *subconvex* demand (i.e., less convex than CES such that $\rho < 1 + 1/\varepsilon$) implies that ε declines with output. Larger firms therefore face less elastic demand and charge higher markups, consistent with the size-markup patterns documented in the literature and in our data (see Figure 2). Under *superconvex* demand ($\rho > 1 + 1/\varepsilon$), these predictions are reversed.[30]

6.2 Exchange Rate Changes

This subsection characterizes how changes in exchange rates affect prices, markups, and marginal costs through the cost and import competition channels.

6.2.1 Cost Pass-Through

We first determine how exchange rate movements transmit into prices, marginal costs, and markups through the *cost channel*. We extend the model presented in the previous section by assuming that marginal costs vary with exchange rates.

Let us first characterize cost pass-through. As shown by Mrázová and Neary (2020), totally differentiating the FOC with respect to a marginal cost change, the *proportional pass-through from marginal cost to price*, κ, is defined as:

$$\frac{d\ln p}{d\ln c} = \frac{\varepsilon - 1}{\varepsilon(2-\rho)} = \kappa(\varepsilon, \rho), \tag{16}$$

which is a *pure demand object* pinned down by the local manifold statistics (ε, ρ). This is also the object that corresponds to what we can measure, since we recover realized marginal costs $\widehat{\text{mc}}_{fj,t}$ in the data. Under the admissibility conditions $\varepsilon > 1$ and $\rho < 2$, it can be seen that $\kappa > 0$.

The markup response to a change in marginal cost is:

$$\frac{d\ln \mu}{d\ln c} = \frac{\varepsilon - 1}{\varepsilon(2-\rho)} - 1 = \frac{\varepsilon\rho - \varepsilon - 1}{\varepsilon(2-\rho)} = \kappa - 1. \tag{17}$$

If the pass-through of cost changes into prices is incomplete, as we observe in our data, an increase in marginal costs compresses markups as the induced price response is weaker than the induced marginal cost response, i.e., $d\ln\mu = d\ln p - d\ln c < 0$. Under the admissibility condition $\rho < 2$, the sign of the markup response is governed entirely by the demand-side

[30] The elasticity of demand varies with firm output according to $\varepsilon_q = (\varepsilon/q)(\rho - (\varepsilon+1)/\varepsilon)$. For CES demand, $\rho = (\varepsilon+1)/\varepsilon$ such that $\varepsilon_q = 0$. For subconvex demand, $\rho < (\varepsilon+1)/\varepsilon$ such that $\varepsilon_q < 0$. For superconvex demand, $\rho > (\varepsilon+1)/\varepsilon$ such that $\varepsilon_q > 0$. See Mrázová and Neary (2020).

numerator. Specifically:

$$\frac{d\ln\mu}{d\ln c} < 0 \quad \Longleftrightarrow \quad \varepsilon\rho - \varepsilon - 1 < 0 \quad \Longleftrightarrow \quad \rho < 1 + \frac{1}{\varepsilon}.$$

Therefore, the pass-through of cost increases into prices is incomplete (i.e., cost increases compress markups) only if demand is *subconvex*. This implies that the operating point lies to the left of the CES demand manifold.

Let us now introduce exchange rates. We assume that the firm uses both domestic and imported variable inputs, where the latter are paid in foreign currency. Defining $e \equiv e_t$ as the nominal exchange rate (domestic currency per USD, so an increase is a depreciation), the firm's marginal cost $c(e)$ varies with e through imported input prices. The exchange rate elasticity of marginal costs is:

$$\frac{d\ln c}{d\ln e} = \alpha. \tag{18}$$

where $\alpha = \partial \ln c(e)/\partial \ln e > 0$. For an imported-input-exposed firm, a depreciation ($d\ln e > 0$) shifts marginal costs up.

To map this into prices, we use equation (16) and obtain:

$$\frac{d\ln p}{d\ln e} = \kappa \frac{d\ln c}{d\ln e} = \kappa\,\alpha. \tag{19}$$

Because $\ln\mu = \ln p - \ln c$, the markup elasticity is:

$$\frac{d\ln\mu}{d\ln e} = (\kappa - 1)\frac{d\ln c}{d\ln e} = (\kappa - 1)\alpha. \tag{20}$$

Equations (18)-(20) illustrate that an exchange rate depreciation raises marginal costs and prices but compresses markups (due to the incomplete pass-through of cost changes into prices) only if demand is *subconvex*, i.e., if $\rho < 1 + 1/\varepsilon$ which is equivalent to $\kappa < 1$. These predictions are consistent with the empirical results reported in Table 3.

De Loecker et al. (2016) argue that the incomplete pass-through of cost changes into prices is driven by an elasticity of demand that is increasing in price.[31] An increase in marginal costs (resulting, for instance, from an exchange rate depreciation), which raises prices, therefore leads to an increase in the demand elasticity and a decrease in markups. In other words, marginal costs are negatively correlated with markups and the pass-through of marginal cost changes into prices is incomplete. Differentiating the demand elasticity with respect to price yields:

$$\frac{d\ln\varepsilon}{d\ln p} = 1 + \varepsilon(1-\rho). \tag{21}$$

The demand elasticity is increasing in price if $1+\varepsilon(1-\rho) > 0$ which is equivalent to $\rho < 1+1/\varepsilon$, i.e., demand is *subconvex*. The condition under which cost pass-through is incomplete in our framework is therefore equivalent to the one provided by De Loecker et al. (2016).

[31] This property is also known as "Marshall's Second Law of Demand."

6.2.2 Competition

The cost channel analysis holds demand conditions fixed. We now hold costs fixed and let exchange rate movements affect the residual demand faced by domestic firms by shifting the intensity of import competition. We capture this import competition channel with a scalar shifter.

Let $\Lambda_{j,t} > 0$ denote an index of the competitive environment in sector j, normalized so that higher Λ corresponds to weaker import competition.[32] We model Λ as a multiplicative shifter of inverse demand:

$$p \;=\; P(q, \Lambda) = \Lambda\, \widetilde{P}(q). \tag{22}$$

Because Λ scales inverse demand, it does not affect the elasticity or the local demand curvature at a given q:

$$\varepsilon(q, \Lambda) = -\frac{P}{qP_q} = -\frac{\widetilde{P}}{q\widetilde{P}_q}, \qquad \rho(q, \Lambda) = -\frac{qP_{qq}}{P_q} = -\frac{q\widetilde{P}_{qq}}{\widetilde{P}_q}.$$

Nevertheless, changes in Λ shift the firm's marginal revenue schedule and move the optimum along the demand curve (and along the same demand manifold). When demand is non-CES, the induced change in q alters the elasticity faced by the firm and hence its markup.

Holding marginal costs fixed ($dc = 0$), totally differentiating the FOC with respect to Λ yields the output response:

$$\frac{d\ln q}{d\ln \Lambda} = \frac{\varepsilon - 1}{2 - \rho} > 0. \tag{23}$$

The price response is therefore:

$$\frac{d\ln p}{d\ln \Lambda} = \frac{1 + 1/\varepsilon - \rho}{2 - \rho} = 1 - \kappa, \tag{24}$$

where $\kappa \equiv d\ln p / d\ln c$ is given by (16).

With marginal costs fixed, $d\ln \mu = d\ln p$, so:

$$\frac{d\ln \mu}{d\ln \Lambda} \;=\; \frac{1 + 1/\varepsilon - \rho}{(2 - \rho)} = 1 - \kappa. \tag{25}$$

Since admissibility requires $\rho < 2$, the denominator is positive and the sign of equations (24) and (25) is pinned down by $1 + 1/\varepsilon - \rho$. A weakening of competition ($d\ln \Lambda > 0$) raises prices and markups *only if* demand is subconvex, $\rho < 1 + 1/\varepsilon$ (equivalently $\kappa < 1$).

Intuitively, a weakening of competition ($d\ln \Lambda > 0$), by shifting out the residual demand curve faced by the firm, increases output (equation 23). When demand is subconvex, higher

[32] This shifter has a standard microfoundation under additively separable preferences. Consumer first order conditions imply inverse demand of the form $p(q) = u'(q)/\lambda$, where λ is the marginal utility of income. In our case, $p = P(q; \Lambda) = \Lambda \widetilde{P}(q)$ with $\Lambda \equiv 1/\lambda$. Hence, Λ is the inverse of the marginal utility of income in the formulation of Mrázová and Neary (2020) and Mayer, Melitz, and Ottaviano (2014).

output reduces the demand elasticity which raises markups and therefore prices (equations 24 and 25).

Let us now consider exchange rates. Assuming that a depreciation reduces import competition (raising Λ), define $\beta = \partial \ln \Lambda / \partial \ln e$ and hence:

$$\frac{d \ln \Lambda}{d \ln e} = \beta, \tag{26}$$

where $\beta > 0$.[33] It therefore follows that:

$$\frac{d \ln p}{d \ln e} = \frac{d \ln \mu}{d \ln e} = \beta(1 - \kappa), \tag{27}$$

such that a depreciation raises prices and markups through the competition channel (holding costs constant) only if demand is *subconvex*. These predictions are consistent with the estimates reported in Table 4.

6.2.3 Cost Pass-Through and Competition

To capture the two mechanisms simultaneously, we allow the exchange rate to affect (i) marginal costs and (ii) the toughness of competition. Recall that we summarize the exchange rate exposure of these two objects by the following elasticities:

$$\frac{d \ln c}{d \ln e} = \alpha, \qquad \frac{d \ln \Lambda}{d \ln e} = \beta, \tag{28}$$

where $\alpha > 0$ captures that a depreciation raises marginal costs, and $\beta > 0$ indicates that a depreciation reduces import competition (raising Λ).

The total effect of exchange rate movements on prices can be written compactly as:

$$\frac{d \ln p}{d \ln e} = \underbrace{\kappa \, \alpha}_{\text{cost channel}} + \underbrace{(1 - \kappa) \, \beta}_{\text{competition channel}}, \tag{29}$$

and shows that when demand is subconvex ($\rho < 1 + 1/\varepsilon$ so that $0 < \kappa < 1$), a depreciation raises prices through both the cost and competition channels. The total effect on markups is:

$$\frac{d \ln \mu}{d \ln e} = \underbrace{(\kappa - 1)\alpha}_{\text{cost channel}} + \underbrace{(1 - \kappa)\beta}_{\text{competition channel}} = (1 - \kappa) \, (\beta - \alpha). \tag{30}$$

Hence, when demand is subconvex ($\rho < 1 + 1/\varepsilon$ so that $0 < \kappa < 1$), a depreciation raises markups through the competition channel and compresses them through the cost channel. The net effect depends on whether β exceeds or falls short of α.[34]

[33] The reduced-form elasticity β is microfounded with a free entry condition (Mrázová and Neary, 2020; Mayer et al., 2014).

[34] Equations (29) and (30) yield the same cost and competition channels as in Section 4. Given that $\kappa = 0.366$ (column 1 of Table 3) and $\alpha = 0.292$ (column 4 of Table 3), the cost channel is equal to $\kappa\alpha = 0.366(0.292) = 0.107$ for prices and $(\kappa - 1)\alpha = (0.366 - 1)0.292 = -0.185$ for markups. We do not observe the value of β in the data,

6.3 Mapping Back to the Demand Manifold

Let μ and κ denote the empirically estimated markup and marginal cost pass-through: $\mu \equiv p/c$, and $\kappa \equiv d\ln p/d\ln c$. Because the competition shifter enters multiplicatively, $p = \Lambda\,\widetilde{P}(q)$ in (22), the local demand statistics (ε, ρ) are invariant to Λ and can be recovered from (μ, κ) at the operating point.

Using the manifold formula for marginal cost pass-through:

$$\kappa = \frac{\varepsilon - 1}{\varepsilon(2-\rho)} = \frac{1 - \frac{1}{\varepsilon}}{2-\rho},$$

we invert for curvature as:

$$\rho = 2 - \frac{1 - \frac{1}{\varepsilon}}{\kappa} = 2 - \frac{1}{\mu\,\kappa}. \tag{31}$$

Equation (31) implies that holding $\kappa = \bar{\kappa}$ fixed traces an iso-κ locus in the (ε, ρ) space:

$$\rho(\varepsilon; \bar{\kappa}) = 2 - \frac{1 - \frac{1}{\varepsilon}}{\bar{\kappa}} = 2 - \frac{\varepsilon - 1}{\varepsilon\,\bar{\kappa}}. \tag{32}$$

Figure 8 maps the admissible region and the representative constant-proportional-pass-through (CPPT) contours. The admissible set is bounded below by $\varepsilon > 1$ and by the second-order condition $\rho < 2$. Within the admissible region, the CES locus ($\kappa = 1$) separates subconvex demand ($\kappa < 1$) from superconvex demand ($\kappa > 1$).[35] Our empirical results for both the cost and competition channels are consistent with a demand manifold that lies to the left of the CES locus in the subconvex space.

6.4 Implications

The framework yields three implications that guide the empirical analysis. First, in the benchmark case where the competitive environment is held fixed ($\beta = 0$), exchange rate movements affect prices only through firms' exposure to imported inputs. As shown in equation (19), price pass-through is proportional to the marginal cost pass-through parameter κ, while markups respond according to equation (20). Markup compression arises precisely when demand is subconvex, that is, when $\rho < 1 + 1/\varepsilon$ or, equivalently, $0 < \kappa < 1$.

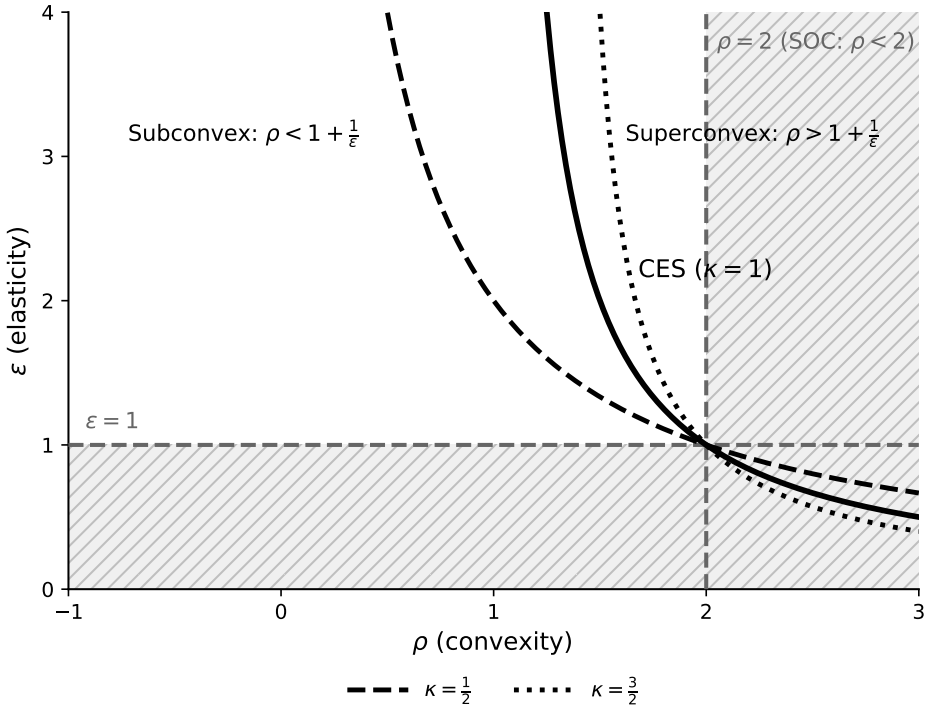
Second, holding marginal costs fixed ($\alpha = 0$), a depreciation that reduces import competition ($\beta > 0$) operates exclusively through the competition channel. In this case, equation (27) implies that markups increase whenever $\kappa < 1$, with prices responding with the same magnitude through the same mechanism.

Finally, when both channels operate simultaneously, the net price and markup responses reflect the relative strength of cost exposure and competitive effects, as summarized in equations (29) and (30). Even in the empirically relevant subconvex region, the sign of the markup

but for both prices and markups the competition channel is equal to $(1-\kappa)\beta = 0.099$ (column 1 of Table 4).

[35] Two familiar benchmark families are nested as special cases: $\bar{\kappa} = 1$ yields the CES relation $\rho = 1 + 1/\varepsilon$, and $\bar{\kappa} = 1/2$ yields $\rho = 2/\varepsilon$ (the LES manifold).

Figure 8: Demand Manifold with Admissible Region



Notes: The shaded region violates the FOC and SOC. The CES locus separates subconvex ($\kappa < 1$) from superconvex ($\kappa > 1$) demand. Dashed/dotted curves are iso-κ contours from (32).

response is, therefore, ambiguous and depends on whether β exceeds or falls short of α. This ambiguity motivates estimating both the reduced-form response of markups to exchange rate movements and the response conditional on marginal costs as we do in the empirical section.

Appendix E.1 maps standard demand systems into the (ε, ρ) space and summarizes their implied pass-through and markup responses.[36]

7 Conclusion

This paper studies how exchange rate movements transmit into domestic prices when firms have market power and are exposed to international markets through imported inputs and import competition. Using highly disaggregated data for Colombian manufacturing firms, we estimate firm-product markups from quantity-based production functions and recover marginal costs from prices and markups. This decomposition allows us to quantify how a large depreciation episode affects (i) marginal costs through the imported-input channel and (ii) prices and markups through changes in competitive conditions and in the costs of imported inputs.

Our results show that a depreciation activates two opposing forces on markups. A 10% depreciation raises marginal costs by about 3% but prices by only 2%, so average markups fall by about 1%: firms absorb part of the cost increase because cost pass-through is incomplete.

[36] Familiar specifications such as linear, CARA, LES, and translog demands map to the subconvex region, while CES is the knife-edge boundary case $\rho = 1 + 1/\varepsilon$.

At the same time, conditional on marginal costs (instrumented to address measurement error), markups rise by about 0.8–1%, consistent with a depreciation weakening import competition in the domestic market and allowing firms to raise markups for a given level of costs. Exchange rate movements therefore operate simultaneously through a cost channel and a competition channel with opposite effects on markups.

The relative strength of the two channels varies substantially across firms and products. Importers experience the largest cost increases and markup compression, whereas exporters show stronger price and conditional-markup responses, partly reflecting US dollar invoicing of exports. Conditional markups also rise among non-exporters, whose markups reflect domestic sales only, providing direct evidence of the competition channel. The cost channel dominates for firms with high pre-shock markups, while the competition channel is concentrated among firms with low initial markups; larger firms display both stronger markup compression and a stronger conditional-markup response. Across products, intermediate and reference-priced goods exhibit larger cost increases and greater markup compression than consumption and differentiated goods, while organized-exchange goods pass more of their cost increases into prices and show the strongest conditional-markup response, consistent with their prices tracking world US dollar prices. Overall, exchange rate transmission depends jointly on firms' exposure to cost shocks and on the competitive environment in which their products are sold.

The firm-level responses have meaningful implications for inflation. We estimate that the 31.5% depreciation of the peso between 2014 and 2015 raised manufacturing price inflation by 1.94 percentage points in 2016 and 0.83 percentage points in 2017. Given the estimated weight of domestically produced manufacturing goods in the consumer basket, these effects translate into increases in CPI inflation of approximately 0.47 and 0.20 percentage points, respectively, explaining around 6% of Colombian CPI inflation over these two years. The dynamic decomposition shows that this inflationary effect was driven predominantly by marginal-cost growth. Exchange rate movements alter the level of markups, but do not generate persistent changes in markup growth. The competition channel is therefore important for the level and cross-sectional incidence of prices and markups, while the medium-run inflation response operates primarily through costs.

To interpret our findings, we develop a firm-level framework based on the demand-manifold approach. The framework clarifies when exchange rate driven cost shocks generate markup compression and when exchange rate driven changes in competition generate markup expansion. In the empirically relevant subconvex region of the demand manifold—which encompasses many standard demand systems—the incomplete pass-through of marginal cost increases leads to markup compression along a given demand curve, while a weakening of import competition raises markups through a shift in demand. With both channels present, the net markup response is ambiguous ex ante and depends on the relative strength of a firm's cost exposure to the exchange rate versus the exchange rate sensitivity of competitive conditions. This theoretical characterization provides a mapping between the reduced-form and conditional empirical specifications and offers a disciplined way to think about the heterogeneous responses

across firms.

Our results have implications for how large depreciations translate into domestic inflation and for how exchange rate shocks are redistributed among firms and consumers. When imported inputs are important, depreciations can generate sizable marginal cost increases that feed into prices even if firms compress markups. At the same time, for firms and products where import competition is central, depreciations can relax competitive pressure and increase markups conditional on costs, amplifying price pressures in those segments. These findings suggest that assessing the inflationary consequences of exchange rate movements requires accounting for both the input-cost structure of firms and the competitive environment in which they operate, rather than treating pass-through as a single reduced-form elasticity.

Our work could be extended in several ways. First, integrating the firm-level decomposition into a general equilibrium environment could clarify how cost and competition channels aggregate to sectoral and economy-wide inflation dynamics. Second, allowing for richer dynamics—including adjustment costs, inventory behavior, or input substitution—could further shed light on how quickly marginal costs and markups respond to exchange rate movements during large depreciations. Finally, applying the same decomposition to other countries and episodes would help assess external validity and the extent to which differences in import dependence, market structure, and trade integration shape the relative importance of cost and competition channels.

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A Markup Estimation

A.1 Firm-Level Material Price Deflator

Although we observe the physical quantities of each material input consumed by each firm, these quantities cannot be aggregated at the firm level because different materials are reported in different units. To address the input price bias, we therefore follow Garcia-Marin and Voigtländer (2019) (GMV hereafter) and construct a *firm-specific* input price deflator that we use to deflate firm-level material expenditures. The deflator is constructed using the unit prices the EAM provides for each material input m with a unique physical unit at the 8-digit CPC level.

Compared to GMV, we introduce several adjustments to suit our empirical setting. First, we conduct the analysis at the firm rather than at the establishment level. Second, because we aggregate at the level of firms, the initialization of the price index differs from GMV: instead of relying on deviations across establishments in the first observed period, for each material we rely on deviations relative to the industry average.

We begin by aggregating, across establishments, the expenditures and the unit prices of materials consumed at the firm-material-year level. For each firm f and year t, we define the firm-level average material price change as:

$$\Delta P^M_{f,t} = \sum_{m \in M_f} \bar{\alpha}_{fm} \, \Delta \ln p_{fm,t},$$

where $\bar{\alpha}_{fm}$ is the mean expenditure share of material m in firm f's total material expenditures, $p_{fm,t}$ denotes the unit price of material m, and $\Delta \ln p_{fm,t} = \ln p_{fm,t} - \ln p_{fm,t-1}$ is the log change in the material price. The sequence of firm-level material prices is then recovered recursively as:

$$P^M_{f,t} = P^M_{f,t-1} + \Delta P^M_{f,t}.$$

To initialize the index, for each firm f's first observed period, we compute the average price of material m across all firms that use the same input within the same industry, and we use the (log) deviation between the firm's material price and this industry average as the initial value for $\Delta \ln p_{fm,t}$. This allows us to recover the full sequence of firm-level material prices through the recursion described above.

Once the firm-level material price deflator is obtained (in logs), we take the exponential to convert it back into levels and we use the latter to deflate firm-level material expenditures. The deflated material expenditures are then used, together with the number of production workers (labor in quantities) and capital (measured in book values and treated as quantities), to estimate quantity-based production functions.

A.2 Production Function Estimation

Our methodology closely follows De Loecker et al. (2016). Interested readers should refer to their paper for more details.

Consider the following production function:

$$Q_{fj,t} = F_{j,t}(V_{fj,t}, K_{fj,t})\ \Omega_{f,t},$$

where $Q_{fj,t}$ denotes physical output of firm f in product j and in period t. $V_{fj,t}$ is a vector of variable inputs, consisting of materials and labor, and $K_{fj,t}$ is a vector of fixed inputs facing adjustment costs. We denote by $X_{fj,t} = \{V_{fj,t}, K_{fj,t}\}$ the full set of inputs used in production. Firm-level productivity is given by $\Omega_{f,t}$. Firms may produce a discrete number $J_{f,t}$ of products.

The production technology satisfies *Assumptions* 1–6 in De Loecker et al. (2016):

Assumption 1 (Product-specific technology). The production function $F_{j,t}$ is product specific. This assumption implies that single-product firms and multi-product firms that manufacture the same product have the same production technology.

Assumption 2 (Regularity). $F_{j,t}(\cdot)$ is continuous and twice differentiable with respect to at least one element of the variable input vector $V_{fj,t}$. This element is a variable, freely adjustable input in the production function.

Assumption 3 (Productivity). Hicks-neutral productivity $\Omega_{f,t}$ is firm-specific and enters the production function in a log-additive manner. This assumption implies that multi-product firms have the same productivity in manufacturing all of their products (the assumption is redundant in the case of single-product firms).

Assumption 4 (Input allocation across products). Expenditures on all variable and fixed inputs are attributable to products:

$$W^X_{fj,t} X_{fj,t} = \varrho_{fj,t} \sum_j (W^X_{fj,t} X_{fj,t}),$$

where $X_{fj,t}$ and $W^X_{fj,t}$ denote the physical quantity and unit price of an input X used by firm f to manufacture product j. In the data, we only observe input expenditures at the firm level $\sum_j (W^X_{fj,t} X_{fj,t})$. The parameter $\varrho_{fj,t}$, which is not observed and needs to be estimated, denotes the share of expenditures on input X that firm f uses to manufacture product j with the restriction that $\sum_j \varrho_{fj,t} = 1$. We maintain the assumption that $\varrho_{fj,t}$ is constant across inputs, consistent with Assumption 3.

Assumption 5 (State variables). The firm's state variables are:

$$s_{f,t} = \left\{ J_{f,t}, K_{f,j=1,t}, \ldots, K_{f,j=J_{f,t},t}, \Omega_{f,t}, r_{f,t} \right\},$$

where $J_{f,t}$ is the number of products produced by the firm, $K_{fj,t}$ denotes the capital input associated with product j, $\Omega_{f,t}$ is firm productivity, and $r_{f,t}$ captures other relevant serially

correlated variables affecting firm payoffs, such as export status. Since prices are not used in the estimation, we do not require state variables related to spatial variation in factor prices.

Assumption 6 (Cost minimization). Firms minimize short-run costs taking output quantities and input prices as given.

Estimation To estimate the production function, we take logs of $F(\cdot)$ and we allow for measurement error or for unexpected shocks to output by adding a log-additive error term $\epsilon_{fj,t}$. Due to data constraints, we estimate production function coefficients that remain constant over time and therefore drop the subscript t in the (log) production function f_j:

$$q_{fj,t} = f_j(\tilde{x}_{fj,t}; \beta) + \omega_{f,t} + \epsilon_{fj,t},$$

where $q_{fj,t} = \ln Q_{fj,t}$, $\omega_{f,t} = \ln \Omega_{f,t}$, and $\tilde{x}_{fj,t}$ is the vector of (log) inputs X.

As we do not observe the inputs used by firm f to manufacture product j, i.e., $\tilde{x}_{fj,t}$, we log-linearize Assumption 4:

$$\tilde{x}_{fj,t} = \tilde{\varrho}_{fj,t} + \tilde{x}_{f,t},$$

where $\tilde{x}_{f,t} = \ln X_{f,t}$ and $\tilde{\varrho}_{fj,t} = \ln \varrho_{fj,t}$, and we substitute this expression into the production function:

$$q_{fj,t} = f_j(\tilde{x}_{f,t}; \beta) + A(\tilde{x}_{f,t}, \tilde{\varrho}_{fj,t}; \beta) + \omega_{f,t} + \epsilon_{fj,t},$$

where $A(\cdot)$ is a bias arising from the unobserved input allocations across products $\tilde{\varrho}_{fj,t}$.[37]

To deal with this bias, we estimate the production function for single-product firms only as their input allocations are observed by construction. We restrict the sample to firms producing a single 4-digit product that is observed at least twice in the data, excluding the final period in which a firm appears. Specifically, we estimate an industry-specific translog production function of the form:

$$\begin{aligned} q_{fj,t} = {} & \beta_l \tilde{l}_{f,t} + \beta_m \tilde{m}_{f,t} + \beta_k \tilde{k}_{f,t} + \beta_{ll} \tilde{l}^2_{f,t} + \beta_{mm} \tilde{m}^2_{f,t} + \beta_{kk} \tilde{k}^2_{f,t} + \beta_{mk} \tilde{m}_{f,t} \tilde{k}_{f,t} \\ & + \beta_{lm} \tilde{l}_{f,t} \tilde{m}_{f,t} + \beta_{lk} \tilde{l}_{f,t} \tilde{k}_{f,t} + \beta_{lmk} \tilde{l}_{f,t} \tilde{m}_{f,t} \tilde{k}_{f,t} + \omega_{f,t} + \epsilon_{fj,t}, \end{aligned}$$

where $\tilde{x}_{f,t} = \{\tilde{l}_{f,t}, \tilde{m}_{f,t}, \tilde{k}_{f,t}\}$ which respectively denote (log) labor, material, and capital inputs, and all coefficients are estimated separately by industry. For single-product firms, $\tilde{x}_{f,t} = \tilde{x}_{fj,t}$ and $\exp(\tilde{\varrho}_{fj,t}) = 1$ by construction.

Restricting the sample to single-product firms introduces a potential selection bias, as firms self-select into multi-product status based on productivity. To correct for this bias, we apply a sample selection correction by including the probability that a firm remains single product in the subsequent period. This probability is modeled as a flexible third-order polynomial in production inputs, market shares (firm share of total sales, firm share of product revenue, firm

[37] In the estimations, we use quantity-based measures of $\tilde{x}_{f,t}$. The firm-level material expenditures are deflated by the firm-level material input price deflator $\exp(P^M_{f,t})$ defined in Section A.1. Labor is measured as the number of production workers, and for capital we use the end-of-year book value in fixed assets which accounts for depreciation. All inputs are expressed in (log) deviation from the industry-year average.

share of total revenue, and product share of industry revenue), export status, and year fixed effects.

To recover the product-level input allocations for multi-product firms $\tilde{\varrho}_{fj,t}$, we proceed as follows. First we purge the output quantity data from unanticipated shocks and/or measurement error (i.e., the $\epsilon_{fj,t}$) by computing $\hat{q}_{fj,t}$ as the predicted value of the translog production function using coefficients estimated from the single-product sample, applied to all firms (single and multi product) within the same industry. Using Assumption 4 and the separability of logarithms, the multi-product production function can then be written as:

$$\hat{q}_{fj,t} = f_1(\tilde{x}_{f,t}, w_{fj,t}; \hat{\beta}) + f_2(\tilde{x}_{f,t}, \tilde{\varrho}_{fj,t}, w_{fj,t}; \hat{\beta}) + \omega_{f,t},$$

where $f_1(\cdot)$ only contains terms involving observed firm-level inputs, and $f_2(\cdot)$ collects all terms involving the unobserved input allocation shares. Specifically:

$$\begin{aligned} f_1 = {} & \hat{\beta}_l \tilde{l}_{f,t} + \hat{\beta}_m \tilde{m}_{f,t} + \hat{\beta}_k (\tilde{k}_{f,t} - \hat{w}_{fj,t}) + \hat{\beta}_{ll} \tilde{l}^2_{f,t} + \hat{\beta}_{mm} \tilde{m}^2_{f,t} + \hat{\beta}_{lk} (\tilde{l}_{f,t} \tilde{k}_{f,t} - \hat{w}_{f,t} \tilde{l}_{f,t}) + \\ & \hat{\beta}_{kk} (\tilde{k}^2_{f,t} + \hat{w}^2_{f,t} - 2\tilde{k}_{f,t} \hat{w}_{fj,t}) + \hat{\beta}_{mk} (\tilde{m}_{f,t} \tilde{k}_{f,t} - \hat{w}_{fj,t} \tilde{m}_{f,t}) \\ & + \hat{\beta}_{lm} \tilde{l}_{f,t} \tilde{m}_{f,t} + \hat{\beta}_{lmk} (\tilde{l}_{f,t} \tilde{m}_{f,t} \tilde{k}_{f,t}, -\tilde{m}_{f,t} \tilde{l}_{f,t} \hat{w}_{fj,t}) \end{aligned}$$

and:

$$\begin{aligned} f_2 = {} & \hat{\beta}_l \tilde{\varrho}_{fj,t} + \hat{\beta}_m \tilde{\varrho}_{fj,t} + \hat{\beta}_k \tilde{\varrho}_{fj,t} + \hat{\beta}_{ll} (\tilde{\varrho}^2_{fj,t} + 2\tilde{\varrho}_{fj,t} \tilde{l}_{f,t}) + \hat{\beta}_{mm} \left(\tilde{\varrho}^2_{fj,t} + 2\tilde{\varrho}_{fj,t} \tilde{m}_{f,t} \right) \\ & + \hat{\beta}_{kk} (\tilde{\varrho}^2_{fj,t} + 2\tilde{\varrho}_{fj,t} \tilde{k}_{f,t} - 2\tilde{\varrho}_{fj,t} \hat{w}_{f,j}) + \hat{\beta}_{lk} (\tilde{\varrho}^2_{fj,t} + \tilde{\varrho}_{fj,t} \tilde{l}_{f,t} + \tilde{\varrho}_{fj,t} \tilde{k}_{f,t} - \tilde{\varrho}_{fj,t} \hat{w}_{f,j}) \\ & + \hat{\beta}_{mk} (\tilde{\varrho}^2_{fj,t} + \tilde{\varrho}_{fj,t} \tilde{m}_{f,t} + \tilde{\varrho}_{fj,t} \tilde{k}_{f,t} - \tilde{\varrho}_{fj,t} \hat{w}_{fj,t}) + \hat{\beta}_{lm} (\tilde{\varrho}^2_{fj,t} + \tilde{\varrho}_{fj,t} \tilde{l}_{f,t} + \tilde{\varrho}_{fj,t} \tilde{m}_{f,t}) \\ & + \hat{\beta}_{lmk} \big(\tilde{\varrho}^3_{fj,t} + \tilde{\varrho}^2_{fj,t} (\tilde{l}_{f,t} + \tilde{m}_{f,t} + \tilde{k}_{f,t} - \hat{w}_{fj,t}) - \tilde{\varrho}_{fj,t} (\tilde{l}_{f,t} \tilde{m}_{f,t} + \tilde{l}_{f,t} \tilde{k}_{f,t} + \\ & \tilde{m}_{f,t} \tilde{k}_{f,t} - \tilde{l}_{f,t} \hat{w}_{fj,t} - \varrho \tilde{m}_{f,t} \hat{w}_{fj,t}) \big) \end{aligned}$$

We therefore have:

$$\hat{q}_{fj,t} - f_1(\tilde{x}_{f,t}; \hat{\beta}) = f_2(\tilde{x}_{f,t}, \tilde{\varrho}_{fj,t}; \hat{\beta}) + \omega_{f,t},$$

and as $\hat{q}_{fj,t}$ and $f_1(\tilde{x}_{f,t}; \hat{\beta})$ are observed, we define $\hat{\omega}_{fj,t}$ which can be calculated as:

$$\hat{\omega}_{fj,t} = \hat{q}_{fj,t} - f_1(\tilde{x}_{f,t}, \hat{w}_{fj,t}; \hat{\beta}),$$

such that:

$$\hat{\omega}_{fj,t} = f_2(\tilde{x}_{f,t}, \tilde{\varrho}_{fj,t}, \hat{w}_{fj,t}; \hat{\beta}) + \omega_{f,t},$$

which under a translog specification reduces to:

$$\hat{\omega}_{fj,t} = \hat{a}_{fj,t} \tilde{\varrho}_{fj,t} + \hat{b}_{fj,t} \tilde{\varrho}^2_{fj,t} + \hat{c}_{fj,t} \tilde{\varrho}^3_{fj,t} + \omega_{f,t},$$

where $\hat{a}_{fj,t}$, $\hat{b}_{fj,t}$, and $\hat{c}_{fj,t}$ depend on the estimated coefficients of the production function, and

$\tilde{\varrho}_{fj,t}$ and $\omega_{f,t}$ are unknown.[38] Together with the adding-up constraint $\sum_j \exp(\tilde{\varrho}_{fj,t}) = 1$, for each firm f in each year t we therefore have a system of $J_{f,t}+1$ equations (where $J_{f,t}$ is the number of products produced by firm f in year t) and $J_{f,t}+1$ unknowns (the $\tilde{\varrho}_{fj,t}$'s and $\omega_{f,t}$), and we solve this system numerically to obtain the input allocation shares $\tilde{\varrho}_{fj,t}$ and firm-level productivity $\omega_{f,t}$.

To address the bias induced by unobserved input prices when estimating the production function using capital expenditures rather than input quantities, we construct an input price correction, $\widehat{w}_{fj,t}$, for each product. This correction is based on a control function, $w(p_{f,t}, ms_{f,t}, D)$, specified as a function of output prices $p_{f,t}$, market shares $ms_{f,t}$, and product dummies D. Using the estimated production function coefficients, we recover the capital input price correction as $\widehat{w}_{fj,t} = -\Gamma\, w(p_{f,t}, ms_{f,t}, D)$, where $\Gamma = \widehat{\beta}_k + \widehat{\beta}_m + \widehat{\beta}_l$ denotes the estimated returns to scale.

A.3 Markups for Multi-Product Firms

Combining the firm-product input allocations $\varrho_{fj,t} = \exp(\tilde{\varrho}_{fj,t})$ with the translog production function coefficients $\hat{\beta}$, we obtain the two components of markups using materials as the input $X_{fj,t}$. The firm-product markup is given by:

$$\hat{\mu}_{fj,t} = \hat{\theta}_{fj,t} \frac{P_{fj,t}Q_{fj,t}}{\varrho_{fj,t}\sum_j (W^X_{fj,t}X_{fj,t})} = \hat{\theta}_{fj,t}\alpha^{-1}_{fj,t},$$

where $\varrho_{fj,t}\sum_j (W^X_{fj,t}X_{fj,t})$ recovers firm-product material expenditures from firm-level (nominal) material expenditures $\sum_j (W^X_{fj,t}X_{fj,t})$, $\alpha_{fj,t}$ is the share of firm-product expenditures on material inputs out of nominal sales $P_{fj,t}Q_{fj,t}$, and $\hat{\theta}_{fj,t}$ is the output elasticity with respect to material inputs, obtained from the estimated translog production function as:

$$\hat{\theta}_{fj,t} \equiv \frac{\partial \hat{q}_{fj,t}}{\partial \tilde{m}_{fj,t}} \frac{\tilde{m}_{fj,t}}{\hat{q}_{fj,t}} = \hat{\beta}_m + 2\hat{\beta}_{mm}\tilde{m}_{fj,t} + \hat{\beta}_{mk}\tilde{k}_{fj,t} + \hat{\beta}_{lm}\tilde{l}_{fj,t} + \hat{\beta}_{lmk}\tilde{l}_{fj,t}\tilde{k}_{fj,t}.$$

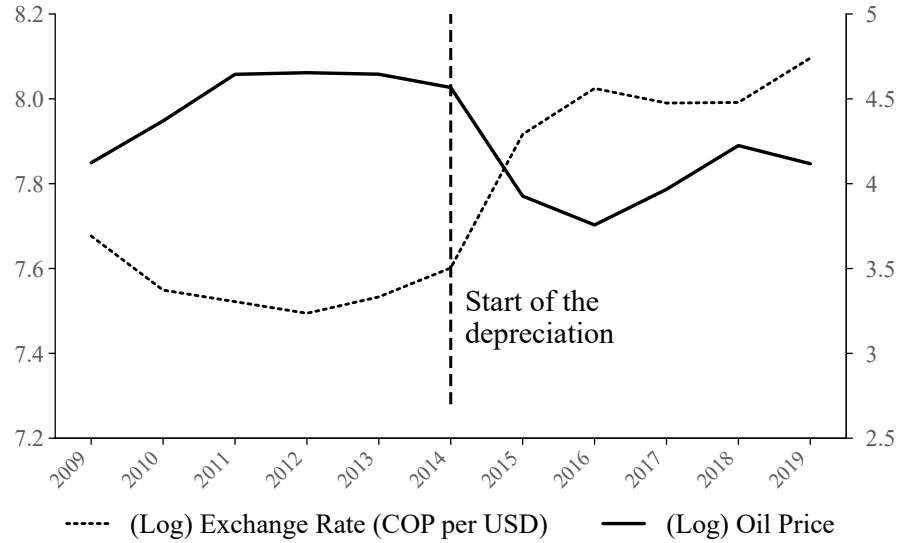
An analogous procedure applies when we estimate markups using labor as the flexible input. In that case, $\alpha_{fj,t}$ is computed as the firm-product share of wage expenditures out of sales, and the output elasticities with respect to labor $\hat{\theta}_{fj,t}$ are obtained by replacing materials with labor (where labor is measured as the number of production workers).

[38] For translog, these terms are defined as:

$$\hat{a}_{fj,t} = \hat{\beta}_l + \hat{\beta}_m + \hat{\beta}_k + 2(\hat{\beta}_{ll}\tilde{l}_{f,t} + \hat{\beta}_{mm}\tilde{m}_{f,t} + \hat{\beta}_{kk}\tilde{k}_{f,t} - \hat{\beta}_{kk}\hat{w}_{f,t}) + \hat{\beta}_{lk}(\tilde{l}_{f,t} + \tilde{k}_{f,t} - \hat{w}_{f,t}) + \hat{\beta}_{mk}(\tilde{m}_{f,t} + \tilde{k}_{f,t} - \hat{w}_{f,t})$$
$$+ \hat{\beta}_{lm}(\tilde{l}_{f,t} + \tilde{m}_{f,t}) + \hat{\beta}_{lmk}(\tilde{l}_{f,t}\tilde{m}_{f,t} + \tilde{l}_{f,t}\tilde{k}_{f,t} + \tilde{m}_{f,t}\tilde{k}_{f,t} - \tilde{l}_{f,t}\hat{w}_{f,t} - \tilde{m}_{f,t}\hat{w}_{f,t}),$$
$$\hat{b}_{fj,t} = \hat{\beta}_{ll} + \hat{\beta}_{mm} + \hat{\beta}_{kk} + \hat{\beta}_{lk} + \hat{\beta}_{mk} + \hat{\beta}_{lm} + \hat{\beta}_{lmk}(\tilde{l}_{f,t} + \tilde{m}_{f,t} + \tilde{k}_{f,t} - \hat{w}_{f,t}),$$
$$\hat{c}_{fj,t} = \hat{\beta}_{lmk}.$$

B Additional Exhibits

Figure B1: Nominal Exchange Rate and the Oil Price



Notes: The figure plots the (log) nominal exchange rate (Colombian pesos per US dollar) against the (log) oil price between 2009 and 2019.

Table B1: Change in purchased materials quantities: Pre-shock importers

	asinh(domestic) (1)	asinh(imported) (2)
asinh(ER)	0.337***	−2.373***
	(0.075)	(0.565)
Observations	19,215	17,114
Firm-product FE	✓	✓

Notes: The dependent variable is *asinh* of domestic and imported inputs in quantities, deflated according to import or domestic prices. The sample isrestricted to firms in the pre-shock period (2009-2014) importer. Standard errors are clustered at the firm level. ***, **, and * indicate significance at the one, five, and ten percent levels, respectively.

C Extensions

Table C1: Pass-Through: Product heterogeneity by End-Use

	log(price)	log(cost)	log(markup)		log(price)	log(cost)	log(markup)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log(ER)	0.147	0.303**	−0.155*	−0.044				
	(0.091)	(0.129)	(0.091)	(0.070)				
Log(ER) × 1{intermediate}	0.053	0.023	0.030	0.103	0.051	0.021	0.030	0.103
	(0.087)	(0.129)	(0.093)	(0.065)	(0.089)	(0.121)	(0.092)	(0.070)
Log(ER) × 1{consumption}	0.043	−0.077	0.120	0.143**	0.043	−0.077	0.120	0.143**
	(0.085)	(0.143)	(0.107)	(0.066)	(0.090)	(0.120)	(0.092)	(0.071)
Total elasticity								
Intermediate	0.199***	0.325***	−0.125***	0.059**				
	(0.032)	(0.045)	(0.031)	(0.026)				
Consumption	0.189***	0.225***	−0.035	0.098***				
	(0.042)	(0.048)	(0.034)	(0.033)				
Capital	0.147	0.303**	−0.155*	−0.044				
	(0.091)	(0.129)	(0.091)	(0.070)				
Differential effect								
Intermediate − consumption					0.008	0.098*	−0.090**	−0.040
					(0.037)	(0.053)	(0.042)	(0.029)
Observations	51,863	51,863	51,863	51,863	51,863	51,863	51,863	51,863
Firm-product FE	✓	✓	✓	✓	✓	✓	✓	✓
Year FE					✓	✓	✓	✓
Marginal cost control				✓				✓

Notes: The dependent variable is indicated in the column headers. Columns (4) and (8) include a second-order polynomial in log marginal costs. The log nominal exchange rate is defined as Colombian pesos per US dollar. End-use categories are fixed at their pre-shock (pre-2014) values; products introduced after 2014 are excluded from the estimation sample. The end-use classification, based on the BEC, indicates whether a product is exclusively a consumption, intermediate, or capital good. Standard errors are clustered at the firm and year level in columns (1)–(4), and at the firm level in columns (5)–(8). ***, **, and * indicate significance at the one, five, and ten percent levels, respectively.

Table C2: Pass-Through: Heterogeneity by Sector by Upstreamness

	log(price)	log(cost)	log(markup)		log(price)	log(cost)	log(markup)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log(ER)	0.337***	0.278***	0.059	0.210***				
	(0.059)	(0.065)	(0.059)	(0.052)				
Log(ER) × log(Upstr.)	−0.189**	0.086	−0.275***	−0.197***	−0.191**	0.084	−0.275***	−0.198***
	(0.081)	(0.121)	(0.102)	(0.066)	(0.077)	(0.116)	(0.089)	(0.059)
25^{th} percentile	0.248***	0.318***	−0.069***	0.118***	−0.089**	0.039	−0.128***	−0.092***
	(0.032)	(0.032)	(0.021)	(0.027)	(0.036)	(0.054)	(0.042)	(0.027)
75^{th} percentile	0.204***	0.338***	−0.133***	0.073***	−0.133**	0.058	−0.191***	−0.137***
	(0.030)	(0.042)	(0.026)	(0.022)	(0.052)	(0.080)	(0.061)	(0.041)
Observations	73,472	73,472	73,472	73,472	73,472	73,472	73,472	73,472
Firm-product FE	✓	✓	✓	✓	✓	✓	✓	✓
Year FE					✓	✓	✓	✓
Marginal cost control				✓				✓

Notes: The dependent variable is indicated in the column headers. Columns (4) and (8) include a second-order polynomial in log marginal costs. The log nominal exchange rate is defined as Colombian pesos per US dollar. Upstreamness is measured at the sector level following Antràs et al. (2012), with higher values indicating sectors farther from final demand. Total elasticities are evaluated at the 25th and 75th percentiles of log(Upstreamness). Standard errors are clustered at the firm and year level in columns (1)–(4), and at the firm level in columns (5)–(8). ***, **, and * indicate significance at the one, five, and ten percent levels, respectively.

D Robustness

Table D1: Mean Output Elasticities and Returns to Scale by Industry

ISIC	Industry	Labor	Materials	Capital	Returns to scale
15	Food and Beverages	0.20	0.73	0.05	0.97
17	Textile Products	0.21	0.64	0.01	0.86
18	Clothes and Garments	0.07	0.79	0.01	0.87
19	Hides, Shoes, Bags	0.29	0.60	0.05	0.94
20-21	Wood, Paper, and Cardboard	0.48	0.47	−0.07	0.87
22	Printing and Recording	0.31	0.57	0.28	1.16
24	Chemical Products	0.62	0.85	−0.10	1.37
25	Plastic and Rubber	0.31	0.58	0.07	0.96
26	Non-metallic Minerals	0.38	0.41	0.03	0.81
27-28	Metallurgic Basic and Metal Products	0.14	0.53	0.11	0.77
29	Machinery and other Equipment	0.22	0.50	0.04	0.76
30-31	Office and Information Products	0.34	0.54	−0.01	0.88
32-33	Radio and Telecommunication Equipment	−0.37	0.54	−0.03	0.13
34-35	Vehicles and Transport Equipment	0.17	0.64	−0.09	0.72
36	Furniture and other Manufacturing	0.36	0.51	0.02	0.89
	Total	0.27	0.63	0.05	0.95

Notes: This table reports the mean output elasticities from the translog production function. Columns (1)–(3) show the mean elasticity of output with respect to labor, materials, and capital. Inputs are measured in physical quantities and demeaned at the industry level. The table excludes outliers in the top and bottom 3% of the distribution of markups.

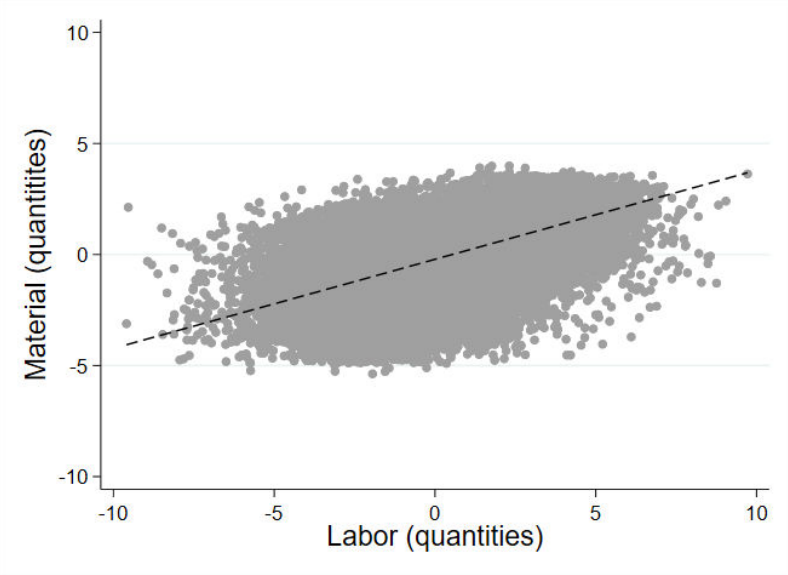
D.1 Labor as Variable Input

Table D2: Markups Mean and Median (Labor Estimations)

ISIC	Industry	Mean	Median
15	Food and Beverages	4.70	2.42
17	Textile Products	4.25	1.30
18	Clothes and Garments	1.57	0.71
19	Hides, Shoes, Bags	2.81	2.12
20-21	Wood, Paper, and Cardboard	20.20	3.44
22	Printing and Recording	3.79	1.89
24	Chemical Products	84.45	14.12
25	Plastic and Rubber	11.16	3.47
26	Non-metallic Minerals	5.67	3.38
27-28	Metallurgic Basic and Metal Products	4.75	1.61
29	Machinery and other Equipment	4.04	1.64
30-31	Office and Information Products	8.65	2.28
32-33	Radio and Telecommunication Equipment	6.09	2.69
34-35	Vehicles and Transportation Equipment	10.28	1.60
36	Furniture and other Manufacturing	5.77	2.09
	Total	12.93	2.25

Notes: This table reports the mean and median of $\hat{\mu}_{fjt}$ by sector for 2010–2019. The table excludes outliers in the top and bottom 3% of the distribution of markups. The final row reports the pooled mean and median across all industries.

Figure D1: Correlation Quantity Markups: Materials vs. Labor Estimations



Notes: The figure shows the correlation between quantity estimated markups for materials and quantity estimated markups for labor. The sample excludes outliers in the top and bottom 3% of the distributions of markups.

Table D3: Pass-Through of Exchange Rate Shocks (Labor Markup)

	Log(price) (1)	Log(marginal cost) (2)	Log(markup) (3)
Log(exchange rate)	0.204***	0.488***	−0.283***
	(0.036)	(0.079)	(0.049)
Observations	86,067	86,067	86,067
Firm-product FE	yes	yes	yes
Estimation	OLS	OLS	OLS

Notes: The dependent variable is indicated in the column headers. The (log) nominal exchange rate is defined as Colombian pesos per US dollar. The regressions use markups and marginal costs estimated over 2010–2019, along with reported unit prices for the same period. Because 2010 is omitted in the lagged specifications in other estimations, we also exclude this year from the non-lagged specifications to maintain a consistent sample across specifications. Standard errors are clustered two-way at the firm and year levels. *** indicates significance at the one percent level.

Table D4: Competitive Effects of Exchange Rate Shocks (Labor Markup)

Log(markup)	(1)	(2)	(3)	(4)
Log(exchange rate)	0.060**	0.023	0.065**	0.031
	(0.021)	(0.021)	(0.021)	(0.021)
Log(marginal cost)	−0.703***	−0.628***	−0.928***	−1.061***
	(0.012)	(0.020)	(0.024)	(0.048)
Log(marginal cost)^2			0.011***	0.022***
			(0.001)	(0.003)
Observations	86,067	86,067	86,067	86,067
Firm-product FE	yes	yes	yes	yes
Estimation	OLS	2SLS	OLS	2SLS

Notes: Column (1) controls for marginal costs, column (2) instruments marginal costs with a one period lag, column (3) controls for a second-order polynomial of marginal costs and column (4) instruments marginal costs and a second-order polynomial with a second-order polynomial of lagged marginal costs. The (log) nominal exchange rate is defined as Colombian pesos per US dollar. The regressions use markups estimated over 2010–2019, but the estimations exclude 2010 which is omitted when instrumenting marginal costs and the polynomial term with their lags. Standard errors are clustered two-way at the firm and year levels and are reported in parentheses. ***, **, and * indicate significance at the one, five, and ten percent levels, respectively.

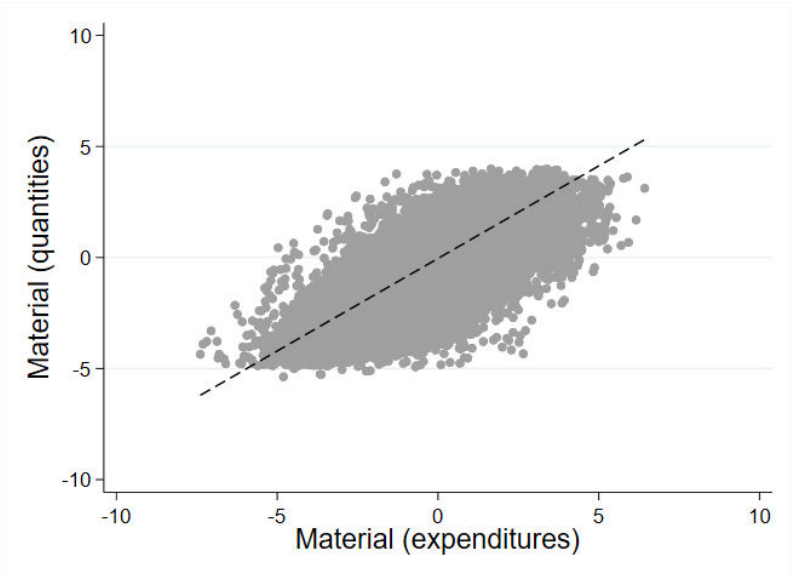
D.2 Expenditure Estimations

Table D5: Markups Mean and Median (Expenditure Estimations)

ISIC	**Industry**	**Mean**	**Median**
15	Food and Beverages	1.76	1.27
17	Textile Products	1.90	1.25
18	Clothes and Garments	2.56	1.96
19	Hides, Shoes, Bags	1.79	1.40
20-21	Wood, Paper, and Cardboard	2.54	1.27
22	Printing and Recording	2.46	1.21
24	Chemical Products	4.71	1.29
25	Plastic and Rubber	2.60	1.48
26	Non-metallic Minerals	3.93	1.27
27-28	Metallurgic Basic and Metal Products	2.79	1.38
29	Machinery and other Equipment	2.24	1.20
30-31	Office and Information Products	2.56	1.34
32-33	Radio and Telecommunication Equipment	11.11	1.86
34-35	Vehicles and Transportation Equipment	3.13	1.38
36	Furniture and other Manufacturing	4.70	1.45
	Total	2.89	1.38

Notes: This table reports the mean and median of $\hat{\mu}_{fjt}$ by sector for 2010–2019. The table excludes outliers in the top and bottom 3% of the distribution of markups. The final row reports the pooled mean and median across all industries.

Figure D2: Correlation Material Markups: Quantity vs. Expenditures



Notes: The figure shows the correlation between quantity estimated markups and expenditure estimated markups for materials. The sample excludes outliers in the top and bottom 3% of the distributions of markups (quantities).

Table D6: Pass-Through of Exchange Rate Shocks (Material Expenditure)

	Log(price)	Log(marginal cost)	Log(markup)
	(1)	(2)	(3)
Log(exchange rate)	0.213***	0.368***	−0.156***
	(0.035)	(0.042)	(0.019)
Observations	97,471	97,471	97,471
Firm-product FE	yes	yes	yes
Estimation	OLS	OLS	OLS

Notes: The dependent variable is indicated in the column headers. The (log) nominal exchange rate is defined as Colombian pesos per US dollar. The regressions use markups and marginal costs estimated over 2010–2019, along with reported unit prices for the same period. Because 2010 is omitted in the lagged specifications in other estimations, we also exclude this year from the non-lagged specifications to maintain a consistent sample across specifications. Standard errors are clustered two-way at the firm and year levels and are reported in parentheses. *** indicates significance at the one percent level.

Table D7: Competitive Effects of Exchange Rate Shocks (Expenditure Estimation)

Log(markup)	(1)	(2)	(3)	(4)
Log(exchange rate)	0.076**	0.047*	0.079**	0.052*
	(0.025)	(0.025)	(0.025)	(0.025)
Log(marginal cost)	−0.630***	−0.549***	−0.912***	−0.987***
	(0.013)	(0.021)	(0.041)	(0.071)
Log(marginal cost)^2			0.013***	0.020***
			(0.002)	(0.003)
Observations	97,471	97,471	97,471	97,471
Firm-product FE	yes	yes	yes	yes
Estimation	OLS	2SLS	OLS	2SLS

Notes: Column (1) controls for marginal costs, column (2) instruments marginal costs with a one period lag, column (3) controls for a second-order polynomial of marginal costs and column (4) instruments marginal costs and a second-order polynomial with a second-order polynomial of lagged marginal costs. The (log) nominal exchange rate is defined as Colombian pesos per US dollar. The regressions use markups estimated over 2010–2019, but the estimations exclude 2010 which is omitted when instrumenting marginal costs and the polynomial term with their lags. Standard errors are clustered two-way at the firm and year levels and are reported in parentheses. ***, **, and * indicate significance at the one, five, and ten percent levels.

D.3 Long Differences

Table D8: Pass-Through of Exchange Rate Shocks
2013–2014 vs 2017–2018

	Log(price)	Log(marginal cost)	Log(markup)
	(1)	(2)	(3)
Log(exchange rate)	0.164***	0.268***	−0.104***
	(0.017)	(0.025)	(0.019)
Observations	31,509	31,509	31,509
Firm-product FE	yes	yes	yes
Estimation	OLS	OLS	OLS

Notes: The dependent variable is indicated in the column headers. The (log) nominal exchange rate is defined as Colombian pesos per US dollar. The regressions use markups and marginal costs estimated over 2010–2019, along with reported unit prices for the same period. Because 2010 is omitted in the lagged specifications in other estimations, we also exclude this year from the non-lagged specifications to maintain a consistent sample across specifications. Standard errors are clustered two-way at the firm and year levels. *** indicates significance at the one percent level.

Table D9: Competitive Effects of Exchange Rate Shocks
2013–2014 vs 2017–2018

Log(markup)	(1)	(2)	(3)	(4)
Log(exchange rate)	0.065***	−0.013	0.066***	0.404
	(0.015)	(0.034)	(0.015)	(4.000)
Log(marginal cost)	−0.629***	−0.338**	−0.752***	−44.270
	(0.014)	(0.112)	(0.048)	(449.132)
Log(marginal cost)^2			0.006**	2.076
			(0.002)	(21.282)
Observations	31,509	31,509	31,509	31,509
Firm-product FE	yes	yes	yes	yes
Estimation	OLS	2SLS	OLS	2SLS

Notes: Column (1) controls for marginal costs, column (2) instruments marginal costs with a one period lag, column (3) controls for a second-order polynomial of marginal costs and column (4) instruments marginal costs and a second-order polynomial with a second-order polynomial of lagged marginal costs. The (log) nominal exchange rate is defined as Colombian pesos per US dollar. Standard errors are clustered two-way at the firm and year levels and are reported in parentheses. ***, **, and * indicate significance at the one, five, and ten percent levels, respectively.

D.4 Additional Controls

Table D10: Pass-Through of Exchange Rate Shocks (Additional Controls)

	Log(price)			Log(marginal cost)			Log(markup)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Log(exchange rate)	0.372***	0.228***	0.406***	0.490***	0.321***	0.523***	−0.118**	−0.093***	−0.118**
	(0.034)	(0.039)	(0.034)	(0.051)	(0.044)	(0.051)	(0.038)	(0.020)	(0.040)
Log(oil price)	0.126***		0.169***	0.150***		0.193***	−0.024		−0.024
	(0.021)		(0.024)	(0.027)		(0.032)	(0.024)		(0.026)
Interest rate		−0.043	0.047*		−0.056	0.047**		0.013	0.000
		(0.028)	(0.023)		(0.039)	(0.019)		(0.017)	(0.015)
Observations	94,886	94,886	94,886	94,886	94,886	94,886	94,886	94,886	94,886
Firm-product FE	yes	yes	yes	yes	yes	yes	yes	yes	yes
Estimation	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS

Notes: The dependent variable is indicated in the column headers. The (log) nominal exchange rate is defined as Colombian pesos per US dollar. The regressions use markups and marginal costs estimated over 2010–2019, along with reported unit prices for the same period. Because 2010 is omitted in the lagged specifications in other estimations, we also exclude this year from the non-lagged specifications to maintain a consistent sample across specifications. Standard errors are clustered two-way at the firm and year levels. ***, **, and * indicate significance at the one, five, and ten percent levels, respectively.

Table D11: Competitive Effects of Exchange Rate Shocks
(Additional Controls)

Log(markup)	(1)	(2)	(3)	(4)
Log(exchange rate)	0.198***	0.164***	0.113***	0.090**
	(0.028)	(0.030)	(0.029)	(0.030)
Log(marginal cost)	−0.810***	−0.981***	−0.809***	−0.978***
	(0.035)	(0.066)	(0.035)	(0.065)
Log(marginal cost)^2	0.008***	0.020***	0.008***	0.020***
	(0.002)	(0.003)	(0.002)	(0.003)
Log(oil price)	0.072***	0.062***		
	(0.018)	(0.018)		
Interest rate			−0.022	−0.017
			(0.017)	(0.016)
Observations	94,886	94,886	94,886	94,886
Firm-product FE	yes	yes	yes	yes
Estimation	OLS	2SLS	OLS	2SLS

Notes: Column (1) controls for marginal costs and the log oil price; column (2) instruments marginal costs and a second-order polynomial of marginal costs with a second-order polynomial of lagged marginal costs and controls for the log oil price; column (3) controls for marginal costs and the interest rate; column (4) instruments marginal costs and a second-order polynomial of marginal costs with a second-order polynomial of lagged marginal costs and controls for the interest rate. The (log) nominal exchange rate is defined as Colombian pesos per US dollar. The regressions use markups estimated over 2010–2019, but the estimations exclude 2010 which is omitted when instrumenting marginal costs and the polynomial term with their lags. Standard errors are clustered two-way at the firm and year levels and are reported in parentheses. ***, **, and * indicate significance at the one, five, and ten percent levels, respectively.

D.5 Alternative markup estimation: BCHR

To estimate markups in our data following the methodology of Blum et al. (2024) (henceforth BCHR), we first aggregate industries from their original 4-digit level to 3 digits, and products from their original 8-digit level (CPC8) to 4 digits (CPC4). We note that each CPC8 product has a unique unit of measurement (mass, liquid volume, bulk volume, length, area, or units), which allows us to aggregate to the CPC4-measurement-unit level. For each CPC8 product we aggregate to CPC4 following BCHR's price aggregator. The aggregator constructs a numeraire price for each CPC8 by taking the average product price across all firms in each year; it then selects, within each CPC4, the CPC8 product with the highest sales across all years as the baseline, and multiplies each CPC8 quantity produced by the ratio of the average numeraire price to the average price of that product, keeping CPC4 products of different measurement units separate.

This procedure yields CPC4 data in which a given product may be associated with more than one unit of measurement. Because the methodology allows only for product fixed effects, a product cannot carry two units of measurement; our preferred specification therefore selects a single unit per product, choosing the unit that accounts for the highest sales. We obtain similar results when we instead select a single unit of measurement within each 3-digit sector,

so that all products in a sector share the same unit; in most sectors this restriction is close to innocuous, as 13 of the 18 estimated sectors already have a single measurement unit. For each 3-digit sector we also exclude tobacco (160) and the oil-extraction sectors (231, 232), as in the main estimations.

Estimation variables. We estimate the shares s_i using reported input expenditures over corrected revenues (corrected using the adjusted prices). As in the baseline estimation, we keep our input variables in quantities: capital is measured as the deflated book value, deflated using an industry-level PPI (IPP); material expenditures are deflated to recover quantities using the price index from Garcia-Marin and Voigtländer (2019); and labor is measured as the total number of workers. All variables are normalized to firm-industry averages. Because we do not observe export quantities, we cannot recover domestic quantities or prices, and we therefore rely on total quantities. We restrict the estimation to sectors with at least 30 observations per product (BCHR use 40 in their main specification but also report a 20-observation selection) and at least 400 observations per sector for the single-product estimation used to recover the production function. Finally, we estimate one set of markups for CPC4 products produced by both single- and multi-product firms, and, in alternative estimations, allow for products that are produced by multi-product firms but not by single-product firms.

We recover markups for 32% of sales value in the universe of firms, covering 18 3-digit sectors and about 99 CPC4 products. In most sectors returns to scale are close to 1, and the mean and median markups lie between 1.7 and 1.8.

Comparison with benchmark methodology. We replicate the BCHR estimation on our sample, recovering the output elasticity from a Cobb–Douglas production function. In this framework the domestic markup is defined as

$$\ln \mu_{fj,t} \;=\; \ln \xi^{M}_{i,t} \;-\; \ln s_{f,t}, \tag{33}$$

where $\xi^{M}_{i,t}$ is the output elasticity of intermediate inputs and $s_{f,t}$ is the (log) nominal materials revenue share. Although the elasticity is written as industry–time-specific (i,t), the Cobb–Douglas specification recovers a single coefficient per industry, so in practice $\xi^{M}_{i,t} = \xi^{M}_{i}$ is *time-invariant*. This has an important implication: because the elasticity contributes only a constant term per industry, any time variation in the estimated markup must come entirely from the share, and the *level* of the markup can inherit spurious price-driven trends.

To see this, we write the share explicitly in nominal terms,

$$s_{f,t} \;=\; \frac{P^{M}_{f,t} M_{f,t}}{P^{Y}_{f,t} Y_{f,t}}, \tag{34}$$

where the numerator is the expenditure in materials. The denominator is the firms' total revenue. We decompose the input and output prices into a common (e.g., exchange-rate-driven)

aggregate trend and an idiosyncratic component,

$$\ln P^M_{f,t} = \pi^M_t + \tilde{p}^M_{f,t}, \qquad \ln P^Y_{f,t} = \pi^Y_t + \tilde{p}^Y_{f,t}. \tag{35}$$

Substituting into the markup definition gives

$$\ln \mu_{fj,t} \;=\; \underbrace{\ln \xi^M_i}_{\text{(A) fixed elasticity}} \;-\; \underbrace{\left(\pi^M_t - \pi^Y_t\right)}_{\text{(B) relative-price trend}} \;+\; \underbrace{\left[\tilde{p}^Y_{f,t} - \tilde{p}^M_{f,t} + \ln Y_{f,t} - \ln M_{f,t}\right]}_{\text{(C) real / idiosyncratic variation}}. \tag{36}$$

Term (A) is a constant industry-specific level shift and absorbs any error in the estimated elasticity. Term (B) is a common time trend in the level of the markup, driven purely by the differential movement of input and output prices—for example, a depreciation that raises material-input prices faster than output prices lowers the measured markup—and has no structural interpretation. Only term (C) reflects genuine markup variation.

Because the estimated markup level confounds real variation with a fixed elasticity component (A) and a spurious relative-price trend (B), we recover changes in the markup by first-differencing. Differencing eliminates the industry-specific component (A), since $\Delta \ln \xi^M_i = 0$, and reduces the relative-price trend (B) to a common time shock that can be absorbed by time fixed effects:

$$\Delta \ln \mu_{fj,t} \;=\; \underbrace{\Delta \ln \xi^M_j}_{=0} \;-\; \underbrace{\Delta\left(\pi^M_t - \pi^Y_t\right)}_{\text{common time effect}} \;+ \Delta\left[\tilde{p}^Y_{f,t} - \tilde{p}^M_{f,t} + \ln Y_{f,t} - \ln M_{f,t}\right], \tag{37}$$

where the first term is zero by the time-invariance of the elasticity.

Table D12: Production function estimates and markups by sector

ISIC	Sector	Estimating observations			Products CPC4	Output elasticity				Markup			
		Multi-product	Single-product	All firms		Labor	Materials	Capital	RTS	Mean	Median	Min.	Max.
151	Meat, fish, fruit, vegetable & oil products	1,919	949	1,598	3	0.455	0.335	0.164	0.953	0.567	0.536	0.381	1.164
154	Other food products	3,237	501	2,870	3	0.271	0.724	0.110	1.105	1.227	1.218	0.730	2.853
155	Beverages	7,356	1,726	6,286	4	0.233	0.809	-0.027	1.015	1.900	1.832	1.333	3.226
158	Other food products n.e.c. (dairy, coffee, etc.)	3,403	704	2,940	2	0.029	0.971	0.016	1.016	1.530	1.548	1.021	3.027
181	Wearing apparel, except fur	5,856	4,148	5,148	5	-0.107	1.034	0.041	0.968	2.275	2.186	1.462	4.823
192	Footwear	992	1,858	1,557	9	0.196	0.566	0.222	0.984	1.321	1.244	0.835	3.331
221	Publishing	3,811	408	3,482	3	0.034	0.957	-0.049	0.943	2.663	2.475	1.601	5.239
222	Printing & related services	3,984	593	3,545	4	0.102	0.840	0.020	0.962	2.220	2.126	1.438	3.975
241	Basic chemicals	2,848	486	2,509	5	0.224	0.592	0.058	0.874	1.391	1.368	0.816	2.328
242	Other chemical products	6,484	1,185	5,672	3	-0.236	1.096	0.195	1.054	3.400	3.137	1.748	9.733
252	Plastics products	1,671	1,437	1,598	3	0.340	0.644	0.190	1.174	1.634	1.513	0.901	3.536
269	Non-metallic mineral products n.e.c.	446	434	440	10	0.144	0.865	-0.035	0.974	2.079	1.996	1.180	4.942
271	Basic iron & steel	1,526	577	1,266	11	0.195	0.853	0.021	1.070	1.947	1.834	1.219	3.701
281	Structural metal products, tanks & generators	685	378	592	12	0.411	0.494	0.107	1.011	2.485	1.429	0.719	13.245
289	Other fabricated metal products	2,122	766	1,756	5	0.285	0.687	0.135	1.106	1.699	1.514	0.826	3.959
291	General purpose machinery	2,459	908	2,041	6	-0.386	1.189	-0.017	0.786	2.946	2.740	1.774	6.523
292	Special purpose machinery	1,519	416	1,282	5	0.228	0.742	0.102	1.072	2.037	1.908	1.070	6.595
361	Furniture	6,599	1,012	5,897	6	0.647	0.091	0.194	0.932	0.270	0.245	0.137	0.839
Average		3,162	1,027	2,804	6	0.170	0.750	0.080	1.000	1.870	1.710	1.070	4.610

Notes: Production functions are estimated at the 3-digit CIIU Rev. 3 A.C. (Colombian adaptation of ISIC Rev. 3) sector level following the methodology of Blum et al. (2024). Output elasticities are the Cobb–Douglas coefficients on labor, capital and intermediate inputs, and are therefore time-invariant within sector; RTS denotes returns to scale (their sum). Markups are recovered as the ratio of the intermediate-input elasticity to the fitted intermediate share. Sector labels follow CIIU Rev. 3 A.C. descriptions; codes 154, 155 and 158 are Colombian sub-divisions of the ISIC food-products division.

Table D13: Pass-Through of Exchange Rate Shocks
BCHR

	Δ Log(price) (1)	Δ Log(cost) (2)	Δ Log(markup) (3)
Δ Log(exchange rate)	0.015	0.071***	−0.056***
	(0.021)	(0.022)	(0.007)
Observations	32,477	32,477	32,477
Firm-product FE	yes	yes	yes
Estimation	OLS	OLS	OLS

Notes: The dependent variable is indicated in the column headers. The regressions exclude outliers in the top and bottom 3% of the distributions of markups, unit prices, and marginal costs. The log nominal exchange rate is defined as Colombian pesos per US dollar. The observations use the same sample of firms with markups estimated using BCHR, they are different due to product aggregations in both methodologies. Standard errors are clustered two-way at the firm and year levels. *** indicates significance at the one percent level.

E Model

E.1 Illustrative Demand Families

Table E1 summarizes how common demand systems map into the (ε, ρ) space and what they imply for *marginal cost pass-through* $\kappa \equiv d\ln p/d\ln c$ and exchange rate effects for markups when $d\ln c = \alpha\, d\ln e$ and $d\ln \Lambda = \beta\, d\ln e$. Because Λ scales inverse demand multiplicatively, it does not enter the local statistics (ε, ρ), so the manifold mapping for each family is unchanged.

Table E1: Manifold for Various Demand Families

Demand family	**Manifold relation**	**Region vs CES**	**Cost pass-through** $\kappa \equiv d\ln p/d\ln c$	**Markup response to depreciation** $d\ln\mu/d\ln e = (1-\kappa)(\beta-\alpha)$
Linear (inverse)	$\rho = 0$	Subconvex	$\kappa = \dfrac{\varepsilon-1}{2\varepsilon}$	$\dfrac{\varepsilon+1}{2\varepsilon}(\beta-\alpha)$
CARA/negative exponential	$\rho = \frac{1}{\varepsilon}$	Subconvex	$\kappa = \dfrac{\varepsilon-1}{2\varepsilon-1}$	$\dfrac{\varepsilon}{2\varepsilon-1}(\beta-\alpha)$
Stone–Geary/LES	$\rho = \frac{2}{\varepsilon}$	Subconvex	$\kappa = \dfrac{1}{2}$	$\dfrac{1}{2}(\beta-\alpha)$
Translog	$\rho = \dfrac{3\varepsilon-1}{\varepsilon^2}$	Subconvex	$\kappa = \dfrac{\varepsilon}{2\varepsilon-1}$	$\dfrac{\varepsilon-1}{2\varepsilon-1}(\beta-\alpha)$
CES	$\rho = 1+\frac{1}{\varepsilon}$	CES locus	$\kappa = 1$	0

Notes. The admissible set for a local maximum is given by (15), where $\rho < 2$ with $\varepsilon > 1$. For $\varepsilon > 1$, all listed non-CES families lie strictly below the CES locus $\rho = 1 + 1/\varepsilon$, so that $0 < \kappa < 1$. In this subconvex region, a depreciation raises markups if and only if $\beta > \alpha$ (competition exposure dominates cost exposure), and compresses markups if $\beta < \alpha$, consistent with (30).