Liability Dollarization and Exchange Rate Pass-Through to Domestic Prices

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Abstract

We explore the negative balance sheet effect of foreign currency borrowing on the exchange rate pass-through to domestic prices. Exploiting a large, unexpected depreciation episode in Korea in 1997, we show that firms with higher foreign currency debt experience balance sheet deterioration and face lower growth rates of net worth, sales, and markups. We then empirically document that sectors populated by firms with higher foreign currency debt exposure prior to the depreciation exhibit larger price increases. Building a heterogeneous-firm model with financial constraints, we quantify the role of foreign currency debt in explaining the exchange rate pass-through to prices and find that 10% to 44% of sectoral price changes during the depreciation episode can be explained by the balance sheet effect of foreign currency debt alone. We emphasize the role of strategic complementarity in amplifying sectoral price increases.

JEL classification: D22, E31, E44, F31, F34

Keywords: Exchange rate pass-through, Financial constraints, Strategic complementarity, Balance sheet effects, Price setting, Asian Financial Crisis

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1 Introduction

A sharp appreciation of the U.S. dollar is not a rare phenomenon. Such episodes have often concerned policymakers around the globe, given the dollar's dominant role in international trade and finance. Because many countries, especially emerging markets, depend heavily on imported intermediate inputs in their production of goods and services, a sharp dollar appreciation raises the cost of these inputs, which in turn feeds through to higher domestic prices and the overall cost of living.

Moreover, many emerging economies are alarmed by the rapid strengthening of the U.S. dollar because their corporate sectors have high levels of dollar-denominated debt. When emerging market currencies depreciate against the dollar, the negative balance sheet effects of the dollar debt can significantly affect firms' activities – reducing their net worth, sales, and investment – and may, in turn, generate sizable macroeconomic consequences. While the adverse consequences of foreign currency indebtedness and their contractionary impact on aggregate economic activity are well documented in the literature (Krugman, 1999; Céspedes et al., 2004; Aguiar, 2005; Kim et al., 2015; Bruno and Shin, 2023; Kalemli-Ozcan et al., 2016), their very effect on prices, specifically domestic inflation, remains largely neglected.

Given the prevalence of liability dollarization in emerging markets, this paper seeks to answer two key questions. First, after a domestic currency depreciation, how do firms' price-setting decisions vary with the extent of their foreign currency indebtedness? Second, how much of the sectoral domestic producer inflation can be explained by the often-neglected balance sheet effects of foreign currency debt? In answering these two questions, we would like to advance our understanding of how the exchange rate depreciation shock passes through to domestic prices, not just through a well-documented imported input channel (Goldberg and Campa, 2010; Amiti et al., 2019), but also via the deterioration of firms' balance sheets due to their exposure to foreign currency debt.

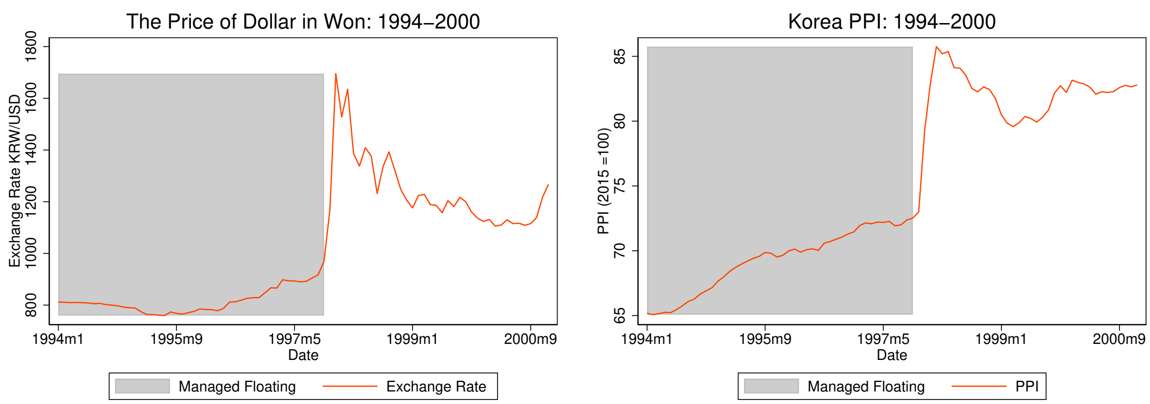
To answer these questions, we exploit a large, unexpected depreciation in Korea at the end of 1997 and different foreign currency debt exposure across firms and thereby sectors. We examine how higher foreign currency debt exposure affects firms' net worth, sales, and markup dynamics, and, in turn, sectoral domestic price dynamics, following the large depreciation of the Korean won against the U.S. dollar. At the end of 1997, the Korean won price of the U.S. dollar increased sharply from around 800 to 1,695 as Korea adopted a free-floating exchange rate regime, and the average producer price index (PPI) rose by about 20 percent as depicted in Figure 1.[1] The currency

[1]The policy reforms deregulating financial markets and opening capital accounts fueled a rapid rise in external borrowing from abroad. In particular, eased regulations on short-term foreign currency borrowing increased the dollar share of corporate loans. Moreover, the deregulation of the financial sector lowered the entry barriers to the financial sector, increasing the number of merchant banks from six to thirty from 1993 to 1996. These merchant banks borrowed in dollars to finance dollar credits to domestic firms.

crisis in Korea caught market participants by surprise. Shown in Park (2001), the 30-day offshore forward rate, a proxy for the expected future spot exchange rate, tracked the spot exchange rate closely and remained stable until very late in 1997. The close co-movement of forward and spot rates underscores the largely unanticipated nature of the sharp depreciation.[2]

Moreover, financial hedging against foreign exchange risk was virtually nonexistent at the time, as the exchange for trading financial derivatives was only established in 1999 in Korea, after the Asian Financial Crisis.[3] Consequently, most foreign currency loans were extended to firms without any foreign exchange hedging. Firms' accumulation of *unhedged foreign currency liabilities*, together with an unexpected and large depreciation, provides a quasi-natural experiment environment that allows us to identify the negative balance sheet effects on firms' price setting.

Figure 1: Korean Won Against U.S. Dollar and PPI: 1994 – 2000



Notes: The gray shaded area represents the period when Korea was adopting the managed floating exchange rate regime. Under this system, the interbank spot exchange rate was allowed to move within an upper and a lower limit around each day's basic exchange rate. In December 1997, the daily fluctuation limits for the interbank exchange rate were abolished and, thus, Korea's exchange rate system was shifted to a free-floating system.

We employ a unique dataset that merges the Korean firm-level balance sheet data, which contains the maturity and currency composition of debt, with industry producer price indices.[4] With the rich information on firm-level variables in our novel dataset, we first investigate whether and to what extent firms with higher foreign currency debt exposure experience deterioration of their balance sheets during the 1996-98 period. We distinguish between short-term and long-term foreign currency debt and examine potential asymmetries across debt maturities. This distinction is motivated by empirical evidence in the literature that short-term foreign currency debt amplifies

[2]The BIS chair, Alfons Verplaetse, visited the Bank of Korea in September 1997 and said: "Korea has strong fundamentals, unlike Latin American countries and Thailand; therefore, the probability of Korea facing a currency crisis is abysmal."

[3]More than 97% of FX transactions in Korea were trading spot exchange rate contracts before the large depreciation.

[4]We focus on the manufacturing sector because of the sectoral price data availability.

firm-level contractions upon depreciation, as well as theoretical work pinpointing its higher rollover risk during periods of financial stress.

Our empirical results corroborate the negative balance sheet effects of foreign currency debt, particularly short-term foreign currency debt, documented in the existing literature: firms with a higher foreign currency share of short-term debt exhibit lower growth of their net worth and domestic sales. These effects are more pronounced for smaller firms. The deterioration of their balance sheets constrains their production, lowering their sales. We then examine how firms' markups change after a large depreciation when they are more indebted in foreign currency. We use market share as our measure of markup, since under a broad class of demand structures (for instance, Atkeson and Burstein, 2008; Kimball, 1995; Amiti et al., 2019), a firm's optimal markup is increasing in its market share. We find that firms with a higher foreign currency share of short-term debt experience lower markup growth, particularly among smaller firms. On top of these results, we also examine how short-term foreign currency debt exposure affects firms' capital and liquid asset holdings, where the latter reflects the working capital available for production. We find that firms with greater short-term foreign currency debt exposure exhibit lower growth in both capital and liquid assets, with the adverse impact amplified for smaller firms.

We then analyze the sectoral price changes after a large depreciation. We find that industries with higher short-term foreign currency debt exposure show a larger increase in their sectoral producer prices from 1996 to 1998 than those with lower short-term foreign currency debt exposure. Specifically, one percentage point increase in industry-level foreign debt exposure leads to a 0.57 percentage point increase in sectoral price change. These heterogeneous price responses across industries are robust even after controlling for other channels of the pass-through, such as the degree of product differentiation, imported input share, price stickiness, and the weighted average of firm-level characteristics and two-digit sector fixed effects.

The sectoral price response is consistent with firm-level evidence: when firms with foreign currency debt face higher debt burdens following the depreciation, their balance sheets deteriorate, lowering net worth and tightening the financial constraint. The decline in capital and tighter working capital constraints increase the explicit and implicit cost of production, pushing prices upward and sales downward. The resulting increase in relative prices leads their markups to adjust downward.

Based on the empirical findings, we build a heterogeneous firm model with working capital and financial constraints to study an industry equilibrium and quantify the role of the balance sheet channel in shaping the price dynamics across industries. Firms face a demand structure with a Kimball aggregator, which generates endogenous variable markups that depend on firms' market shares. We build a model where heterogeneous firms owned by entrepreneurs produce differentiated goods with domestic inputs, foreign inputs, and capital accumulated in the previous period. Firms borrow in domestic and foreign final goods and the currency choice is exogenous given by a parameter λ, a share of the foreign currency debt. The variations across industries in our model are twofold: (i) the *industry-specific* distribution of firms' foreign currency debt shares and (ii) the *industry-specific* imported input share that is common across all firms within an industry. Both are disciplined by their empirical counterparts. Each firm faces a financial constraint on how much debt it can issue, where the maximum amount that it can borrow is a fraction of its physical capital. In addition, each firm faces a working capital constraint requiring it to hold liquid assets to cover a fraction of domestic inputs and imported intermediate inputs before production and sales take place.

In our model, currency depreciation inflates the domestic currency value of foreign currency debt, thereby raising firms' debt burdens. Consequently, firms reduce their liquid asset holdings, tightening working capital constraints in the next period and increasing the implicit cost of production. Furthermore, firms that face tighter financial constraints reduce their investment, which lowers their productivity of variable inputs in the next period and leads to higher production costs. Both margins imply that firms with substantial foreign currency borrowing charge higher prices, and these effects are more pronounced when firms are more financially constrained.

We assess the quantitative fit of the calibrated model by running both industry-level and firm-level regressions on model-simulated data and comparing the estimated coefficients with their empirical counterparts. At the industry level, we regress sectoral price changes on foreign currency debt exposure and the imported input share, and find that the model explains around 24% of the observed mean effect of the short-term foreign currency debt share on sectoral price changes and around 19% of the cross-industry variation in price changes. Moreover, we run the same firm-level regression specifications as in our empirical analysis. The model-estimated marginal effects of foreign currency debt exposure on the growth rates of net worth, domestic sales, and markups are similar in magnitude to the empirical estimates, and the heterogeneous effects across firm size are likewise comparable. The firm-level responses of capital stock and liquid asset holdings are also consistent with the empirical patterns, capturing our key model mechanism.

Lastly, we quantify the balance sheet channel in sectoral price dynamics following a domestic currency depreciation shock. We find that around 10% to 44% of sectoral price changes after the depreciation can be explained by foreign currency debt exposure alone, conditional on borrowing in foreign currency. Moreover, 29% to 73% of this balance sheet effect can be attributed to strategic complementarity in firms' price setting, i.e., general equilibrium effects arising from firms' strategic responses to other firms' price increases due to their foreign currency debt exposure. The quantitative importance of the balance sheet channel in explaining heterogeneous sectoral price dynamics has an important implication for optimal monetary policy, especially for emerging economies with dollarized liabilities.

The rest of the paper is organized as follows. Section 2 discusses the related literature and elaborates how our work complements existing research. Section 3 introduces our dataset and reports key summary statistics of firm-level and aggregate industry-level data. This section also presents the motivating facts and the results of our empirical analyses on firm-level outcomes and sectoral price dynamics after the depreciation, depending on exposure to foreign currency debt. Section 4 presents our heterogeneous firm model. Section 5 calibrates our model to analyze the qualitative and quantitative role of the balance sheet channel in shaping price dynamics across industries, and Section 6 illustrates the model mechanism using policy functions. Section 7 compares the patterns of the model-simulated data with their empirical counterparts. Section 8 quantifies the role of the balance sheet effects of foreign currency debt in driving sectoral price dynamics. Concluding remarks follow in Section 9.

2 Literature Review

This paper bridges two important strands of literature in international macroeconomics: the exchange rate pass-through to prices and the contractionary effects of liability dollarization.

The degree of exchange rate pass-through to prices has been extensively studied in the literature.[5] Some of the factors that previous papers have focused on are: nominal and real rigidity, currency of invoicing, pricing to market, market structure, and imported input share. A large theoretical and empirical literature has explored the role of invoicing currency and its implications for the exchange rate pass-through to prices (see, for example, Devereux and Engel, 2002; Engel, 2006; Goldberg and Tille, 2008; Gopinath et al., 2010; Goldberg and Tille, 2016; Mukhin, 2022; Corsetti et al., 2022; and Drenik and Perez, 2021). Goldberg and Campa (2010) and Amiti et al. (2019) emphasize the role of imported inputs in shaping the degree of exchange rate pass-through to domestic prices. By investigating how foreign currency debt deteriorates firms' balance sheets upon a large depreciation, this paper identifies an under-explored channel through which exchange rate shocks pass through to domestic prices.

On a related note, there is a vast literature on the relationship between the nominal exchange rate and the real exchange rate: Engel (1993), Engel (1999), Crucini and Telmer (2020), Gopinath et al. (2011), and Burstein et al. (2005). Specifically, Burstein et al. (2005) find that movements in the real exchange rate of tradable goods constructed with border prices are smaller than the overall decline in the CPI-based real exchange rates after a large depreciation and argue that the slow adjustment in non-traded goods prices is the reason behind a large fall in the real exchange rate during the crisis. As the extent to which the real exchange rate is affected by the nominal exchange rate crucially depends on the degree of exchange rate pass-through to prices, our study

[5] See a comprehensive survey of this topic in Burstein and Gopinath (2014).

provides an additional factor, the balance sheet channel of foreign currency debt, that explains real exchange rate fluctuations.

The other strand of literature that we are bringing into the exchange rate pass-through literature is the macroeconomic consequence of liability dollarization. There is a large empirical and theoretical literature investigating the contractionary effects of liability dollarization in emerging economies when their currencies depreciate. Many past studies have both empirically and theoretically uncovered the contractionary effect of liability dollarization when the domestic currency crashes, including Krugman (1999), Céspedes et al. (2004), Gilchrist and Sim (2007), Kim et al. (2015), Kalemli-Ozcan et al. (2016), and Bruno and Shin (2023). Specifically, Kim et al. (2015) show that Korean firms holding higher foreign currency debt suffered more during the Asian Financial Crisis, and Gilchrist and Sim (2007) investigate the role of financial factors and foreign currency denominated debt in accounting for the drop in investment during the Asian Financial Crisis in Korea.[6] Moreover, Kohn et al. (2020) and Bruno and Shin (2023) study the role of firms' foreign currency debt holdings and their exports.[7] The literature, however, has overlooked how liability dollarization may affect firms' *pricing decisions* as firms' balance sheets deteriorate upon a large depreciation of the domestic currency. Investigating the interaction between foreign currency debt exposure and price dynamics, this paper provides another important aggregate implication, price dynamics after a large depreciation.[8]

There are several papers that investigate the determination of the currency denomination of corporate borrowing in emerging economies. Salomao and Varela (2022) study the role of firms' foreign currency borrowing on economic growth with endogenous currency debt compositions. They find that firms with a high marginal product of capital borrow more in foreign currency. Using Peruvian data, Gutierrez et al. (2023) find that firms in emerging economies are willing to borrow dollar-denominated loans because doing so is cheaper even after controlling for expectations of exchange rate movement. Bruno and Shin (2017), Huang et al. (2024), Hardy and Saffie (2024) and Lee and Wu (forthcoming) argue that firms seem to engage in carry trades when borrowing in foreign currency. Kedia and Mozumdar (2003), Yang and Kwon (2023), and Colacito et al. (2022) show empirically that the currency choice in debt issuance is driven by natural hedging motives

[6] Some focus on how bank credit supply shock affects firms' investment: Amiti and Weinstein (2018) and Alfaro et al. (2021).

[7] Casas et al. (2023) explore how the exchange rate affects exports and imports through the financial channel using the Colombian customs data. Casacuberta and Licandro (2023) study the pass-through of large devaluations to firm-level real exchange rates, measured using firm-level export and domestic prices, and find a negative correlation between export shares and real exchange rates among Uruguayan exporters. They explain this empirical pattern through the lens of financial constraints that exporters face.

[8] There are recent papers after the Global Financial Crisis, studying the role of financial frictions in firms' pricing in the closed economy setting: Christiano et al. (2015), Del Negro et al. (2015), Gilchrist et al. (2017) and Kim (2021). In an open economy setting, a recent paper by Ma and Schmidt-Eisenlohr (2025), contemporaneous with our work, explores a similar channel in determining the exchange rate pass-through to export prices.

from business operations. We take the distribution of foreign currency debt holdings prior to the depreciation as exogenous in our model, but we address potential endogeneity bias by controlling for various firm-level characteristics documented in the literature in our empirical analyses.

3 Empirical Analysis

Exploiting a sharp and largely unexpected depreciation episode at the end of 1997, combined with firms' accumulation of unhedged short-term foreign currency liabilities, we first show that firms indeed experience balance sheet deterioration when more indebted in short-term foreign currency debt. We then empirically investigate how an industry populated by firms with higher short-term foreign currency debt exposure changes its price compared to other industries upon a large depreciation.

3.1 Data and Summary Statistics

Our analysis employs Korean firm-level data from the NICE (formerly the Korea Information Service Inc., KIS). Our dataset includes firms with assets exceeding 7 billion won (around 5.3 million dollars at the current exchange rate), as they are required to report their balance sheet information to the Financial Supervisory Commission.[9] The data are then compiled by the KIS.[10] As shown in Kim et al. (2015), the dataset coverage of firms is extensive, and firm-level data exhibit patterns consistent with aggregate macroeconomic dynamics.[11]

The KISVALUE dataset has a number of advantages over other datasets: first, it covers a large number of not only large listed but also small, medium-sized non-listed firms, in total around 3,000 manufacturing firms (vs. 760 publicly listed firms in *all* sectors); secondly, it contains the foreign currency split for short-term and long-term debt.[12] Importantly, foreign currency debt does not include trade credit, such as foreign currency accounts payable for imported inputs. The relationship documented later in this section therefore does not capture a spurious correlation between imported input share and price changes. Lastly, rich firm-level balance sheet information, including exports and foreign currency liquid assets, allows us to address potential endogeneity issues.

For the industry-level analyses, we map each firm to a sector defined by the Bank of Korea's producer price index (PPI) classification. In our KISVALUE dataset, each firm's industry is identified

[9]Some firms voluntarily report their balance sheet information even when the assets are less than 7 billion won as of 1996, and the threshold has gone up to 10 billion won.

[10]All balance sheet information after 2000 is publicly available at http://dart.fss.or.kr/.

[11]Lee and Wu (forthcoming) closely examine the coverage of firm-level variables and the similarity between firm-level and aggregate dynamics from 2001 – 2017 in Section 2 of their paper.

[12]Bonds are not included in the data.

with a five-digit KSIC code (Korea Standard Industrial Classification). Since the PPI is reported at a four-digit industry code, we map each KSIC code to the closest PPI industry classification.[13] A *sector* in our empirical analysis corresponds to a four-digit industry defined by the Bank of Korea for its PPI.

We employ short-term and long-term foreign currency debt exposure prior to the large depreciation as the main regressors, the ratio of short-term foreign currency debt to total short-term debt and the ratio of long-term foreign currency debt to total long-term debt, to capture the degree of firms' balance sheet deterioration following the exchange rate shock. At the sector level, we measure foreign currency debt exposure as the weighted average of firm-level ratios, where the weight is firm size.[14] Other industry-level variables are aggregated similarly. As we show in Sections 3.3 and 3.4, our results are robust to an alternative measure of foreign currency indebtedness.

Table 1 presents the summary statistics of firm-level foreign currency debt exposure. It is noticeable that 43.7% of firms hold foreign currency debt and 35.4% of firms hold short-term foreign currency debt in 1996, indicating that foreign currency borrowing is not limited to a few large firms. Short-term debt is the amount of debt due within twelve months. Moreover, conditional on holding a positive amount of foreign currency debt, the mean of the foreign currency share of short-term debt is 18.1% in 1996. In 1996, considering both the extensive and intensive margins of foreign currency borrowing, a large fraction of firms borrow in foreign currency, and a substantial fraction of the total debt is denominated in foreign currency among firms that issue foreign currency debt.

In Table 2, we report the summary statistics of firm-level variables that we employ in the empirical analysis and their correlations with the foreign currency share of short-term debt. Firm size is positively correlated with the short-term foreign currency debt ratio, confirming that larger firms do borrow more in foreign currency debt. While the export share and the foreign currency share of liquid assets are also positively related to the foreign currency share of short-term debt, their correlations are much weaker. Nonetheless, we control for all these firm-level variables in the firm-level regressions and the weighted average of them in the sector-level regressions.

3.2 Motivating Facts: Imported Input vs. FC Debt Channel

Before presenting our empirical specifications, we first demonstrate that the imported input channel, even under the strong assumption of a complete exchange rate pass-through of marginal cost shocks, cannot account for the magnitude of domestic producer price changes observed during

[13] There is no matching code between KSIC codes and PPI industry classification; therefore, we manually map these two. We map each KSIC code to one PPI industry classification, i.e., one PPI industry classification is mapped to one or a few KSIC codes. More details can be found in the Appendix.

[14] We use the log of real sales to limit the effects of the outliers.

Table 1: Firm-level Summary Statistics: FC Debt Exposure

	1994	1995	1996	1997	1998
Extensive Margin					
Number of firms	2623	3517	4143	5025	5850
Fraction of firms with FC debt (%)	52.5	45.5	43.7	42.4	36.1
Fraction of firms with short-term FC debt (%)	43.3	36.8	35.4	33.1	28.6
Intensive Margin					
FC share of short-term debt (%)	15.8	16.7	18.1	22.2	24.6
	(21.7)	(23.6)	(24.5)	(25.9)	(29.2)
FC share of long-term debt (%)	38.3	37.8	41.0	50.0	48.2
	(29.0)	(29.4)	(29.7)	(30.7)	(31.5)
Short-term FC debt to total debt (%)	8.9	9.6	10.0	11.9	12.4
	(13.7)	(15.4)	(15.2)	(15.5)	(16.7)
Long-term FC debt to total debt (%)	14.9	15.2	17.0	23.9	22.7
	(16.2)	(16.8)	(17.9)	(22.3)	(22.2)
Short-term FC debt to total assets (%)	2.7	3.0	3.5	4.6	4.2
	(4.3)	(5.3)	(6.2)	(7.1)	(6.2)
Long-term FC debt to total assets (%)	4.8	5.0	6.0	9.8	8.7
	(5.9)	(5.8)	(7.2)	(10.9)	(10.3)

Notes: Short-term debt is defined as debt with a remaining maturity of less than one year; long-term debt includes all other debt. Mean values are reported, and standard deviations are shown in parentheses.

Table 2: Foreign Currency Debt and Other Firm-level Characteristics

	Mean	*Stdev*	*Corr with Short-term FC Debt Ratio*
	(1)	(2)	(3)
Export Share (%)	7.19	19.68	0.11
Size	23.83	1.56	0.29
Leverage (%)	36.42	26.66	-0.11
Short-term Debt Ratio (%)	58.43	30.13	-0.09
FC Cash Ratio (%)	0.14	1.40	0.13

Notes: The table shows the summary statistics for firm-level variables in 1996. Columns (1) and (2) show the average and standard deviation of each variable, respectively, and Column (3) shows the correlations with short-term FC debt. Firm-level variables that we examine are: export share (export to sales ratio), size (log of real sales), leverage ratio (total debt to total assets ratio), short-term debt ratio (short-term debt to total debt ratio), and foreign currency cash ratio (foreign currency cash to total current assets ratio).

large depreciation episodes.[15]

In Table 3, we report, for each country, the average increase in marginal cost following the devaluation, calculated by multiplying the change in import price indices by the pre-crisis share of imported intermediate inputs. Under a complete pass-through, the average domestic producer price would rise by the same proportion as the marginal cost increase.[16] Yet, in the data, we observe a much larger increase in domestic producer prices, an order of magnitude larger for some countries.[17]

[15] We also assume a production function with constant returns to scale.

[16] In fact, the exchange rate pass-through of marginal cost shocks is incomplete in the data.

[17] If firms substitute toward domestic inputs, which become relatively cheaper following the depreciation, the implied

Table 3: PPI Changes vs. Hypothetical PPI Implied Via Imported Input Channel

	Year (i)	ΔImport Price Index (ii)	Imported Input Share (iii)	ΔMC (iv)	ΔPPI (v)
Brazil	1999	64.08	6.0	3.84	33.00
Mexico	1994	165.39	13.2	21.87	47.11
Korea	1997	40.37	11.0	4.44	16.46
Thailand	1997	20.09	22.0	4.43	17.86
Argentina	2002	169.87	6.1	10.39	122.22

Notes: All price changes are measured from one year prior to the devaluation to one year after. The marginal cost change from imported inputs, Column (iv), is the product of the imported input price change, Column (ii), and the pre-devaluation imported input share, Column (iii), assuming constant returns to scale. The imported input share is defined as the share of imported intermediate inputs in total inputs, where total inputs include domestic intermediate inputs, imported intermediate inputs, and value added from labor and capital. The imported input share is from the year prior to the crisis for most countries; for Mexico, we use 1995 (one year after the devaluation), and for Korea, 1995 (two years prior). Import price indices are from Burstein et al. (2005), PPI changes are from the IMF IFS, and imported input shares are from OECD and Bank of Korea input–output tables. The country sample follows Burstein et al. (2005).

Moreover, Figure 2 shows that, following the large depreciation at the end of 1997 in Korea, most manufacturing sectors experience domestic producer price increases that far exceed those predicted by higher marginal costs from their imported inputs, even under the assumption of a complete pass-through of marginal cost shocks.[18] Notably, more than 70% of sectors show PPI increases in 1996-98 greater than the hypothetical PPI changes implied by the imported input channel, even with a *100% pass-through* of higher marginal costs from imported inputs.

More strikingly, the residual PPI changes, defined as actual PPI changes minus the hypothetical changes implied by the imported input channel, are strongly and positively correlated with the pre-depreciation foreign currency (FC) share of short-term debt, as illustrated in Figure 3. In this figure, sectors are grouped into seven bins: the first includes sectors with zero short-term foreign currency debt, and the remaining six represent equally sized intervals of foreign currency debt shares. For example, the second bin covers sectors with a foreign currency share greater than 0 and less than or equal to 0.1. We compute the mean residual PPI change within each bin and find that sectors with higher short-term foreign currency debt shares exhibit, on average, larger residual PPI changes, i.e., larger price increases unexplained by the imported input channel.[19] This finding strongly hints at the relevance of our balance sheet channel in explaining domestic price dynamics.

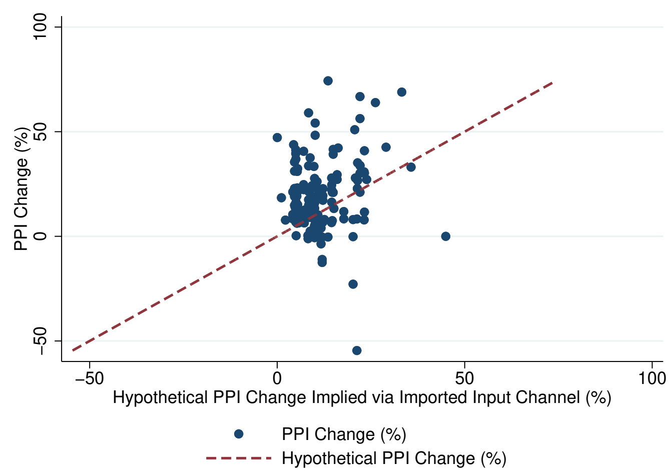
These cross-country and cross-sectoral back-of-the-envelope calculations strongly suggest that there is an additional mechanism at work beyond the imported input channel that the literature

price increase would be even smaller.

[18]Each sector has varying levels of marginal cost increases from imported inputs as (i) each imported input price increases by a different magnitude, and (ii) each sector uses a different amount of *each* imported input in production.

[19]The relationship is substantially weaker when using the share of long-term foreign currency debt shown in Figure A1 in the Appendix, consistent with the regression results in Table 6 where only short-term foreign currency debt yields a positive and statistically significant estimate.

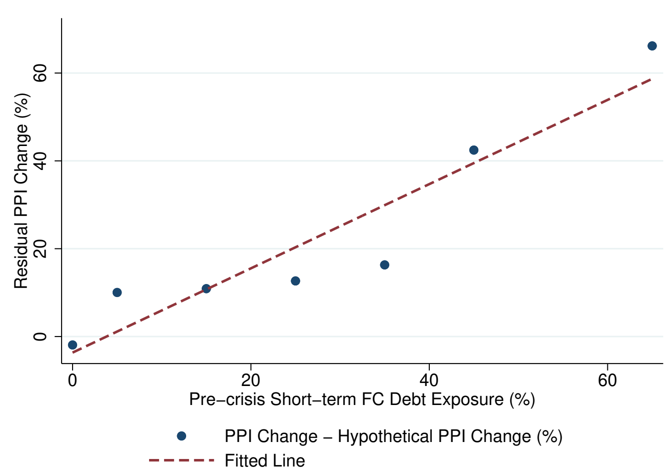
Figure 2: PPI Changes vs. Hypothetical PPI Changes



Notes: A dot represents a manufacturing sector in our analysis. The y-axis shows sectoral PPI changes in 1996-98. The x-axis shows the hypothetical PPI changes implied by the imported input channel, computed as the product of each imported input's price change from 1996 to 1998 and its share in production in 1995. Dots above the 45-degree line represent sectors whose realized PPI changes exceed the hypothetical PPI changes, i.e., sectors where price increases cannot be fully explained by the imported input channel even under a complete pass-through.

has mostly focused on. We show in subsequent sections that the deterioration of firms' balance sheets due to foreign currency debt exposure accounts for the much more pronounced increases in domestic producer prices following a sharp depreciation of the domestic currency.

Figure 3: Residual PPI Changes and Short-term FC Debt Exposure



Notes: The residual PPI changes are the actual PPI changes in 1996-98 minus the hypothetical PPI changes implied by the imported input channel, assuming a complete pass-through of marginal cost shocks to prices. We define seven equally-sized bins of short-term FC debt to short-term total debt ratio in 1996. For instance, the first bin includes sectors with a zero FC share of short-term debt, and the second bin contains sectors with a FC share of short-term debt between 0 and 0.1. The rest of the bins are defined similarly. We compute the mean of residual PPI changes over sectors in each bin.

3.3 Negative Balance Sheet Effects of FC Debt: Firm-level Regression

Using information on firm-level variables from our novel dataset, we investigate whether and to what extent firms more indebted in foreign currency actually experience deterioration of their balance sheets following the depreciation. We examine the growth rates of net worth and sales, following Kim et al. (2015), to quantify the degree of balance sheet deterioration. In addition, we analyze how this balance sheet channel would affect firm-level markups following the depreciation.

Below is the empirical specification that we adopt for the firm-level analyses.

$$\begin{aligned}\Delta y_{j,96-98} = \beta_0 + \beta_1 \text{ST FC}_{j,1996} + \beta_2 \text{LT FC}_{j,1996} + \beta_3 \text{Size}_{j,1996} \\ + \beta_4 \text{ST FC}_{j,1996} \cdot \text{Size}_{j,1996} + \beta_5 \text{LT FC}_{j,1996} \cdot \text{Size}_{j,1996} + \beta_6 \text{X}_{j,1996} + \epsilon_j\end{aligned} \tag{1}$$

As explained above, the dependent variables y_j that we examine are firm-level real net worth, real domestic sales, and markups. All nominal series are deflated by the CPI to compute real series. The dependent variable is the growth rate of y_j from 1996 to 1998, capturing the change over one year before and one year after the large depreciation. Net worth can be negative, and therefore, changes in real net worth from 1996 to 1998 are computed and normalized by real domestic sales. We proxy firm-level markups using their market shares, following the theoretical relationship shown under a broad class of CES and non-CES demand structures (for instance, Atkeson and Burstein, 2008; Amiti et al., 2019), as well as its empirical use as a markup proxy in De Ridder et al. (2026) and Adao et al. (2025).[20] A firm's market share is computed as the ratio of a firm's real domestic sales to the average real domestic sales within the same three-digit sector and year, conditional on positive sales.

ST FC and LT FC denote the firm-level foreign currency share of short-term debt and the foreign currency share of long-term debt, respectively. We investigate their marginal effects separately to capture potential asymmetries in the impact of foreign currency exposure across debt maturity structures. This distinction is motivated by empirical evidence showing that short-term indebtedness leads to stronger adjustments in firm-level sales and investment, particularly when debt is denominated in foreign currency (Aguiar, 2005; Kim et al., 2015), and more broadly for overall short-term leverage (Kalemli-Özcan et al., 2022). These empirical findings are consistent with theoretical work emphasizing that short-term debt carries greater rollover risk, especially during periods of financial stress and economic downturns (Chang and Velasco, 1999; He and Xiong, 2012; Diamond and He, 2014). Nonetheless, long-term foreign currency debt may also affect firm

[20] In our model, the demand structure follows that in Amiti et al. (2019), and they show that the optimal markup is a function of the firm's market share and increases with market share. Our model implies a very strong positive correlation between the optimal markup and the market share, estimated at around 0.98. The nested CES demand structure of Atkeson and Burstein (2008) also implies that the optimal markup is an increasing function of the firm's market share, as long as the within-sector elasticity of substitution is higher than the across-sector elasticity.

performance following a sharp decline in the value of the domestic currency, as firms should service higher interest and principal payments.

Moreover, we interact foreign currency debt variables with firm size, measured by the log of real sales, to see if this balance sheet channel would be smaller for large firms that are less financially constrained compared to small ones, following Kim et al. (2015). Other firm-level characteristics X_j – the export to sales ratio, the leverage ratio (total debt to total assets), the short-term debt to total debt ratio, the foreign currency cash to total current assets ratio, and the interactions of short-term foreign currency debt exposure with the log of total short-term debt and long-term foreign currency debt exposure with the log of total long-term debt – are controlled to address potential endogeneity issues.[21] Importantly, we control for both the export to sales ratio and the foreign currency share of liquid assets, as both can be determinants of the currency composition of debt, capturing natural hedges. All regressors are measured at their pre-depreciation (1996) values. We also include *two-digit industry fixed effects* to absorb differences across two-digit industries and control for other industry-level shocks, such as demand shocks. Our main coefficients of interest are β_1 and β_4 in each regression.

Table 4 summarizes the firm-level regression results. As we can see in Columns (1) and (2), firms with higher short-term foreign currency debt exposure suffer a larger decline in net worth and sales, indicating a deterioration of their balance sheets following the depreciation. The negative effect is more pronounced when firm size is smaller, since smaller firms are more financially constrained. Specifically, a one percentage point rise in the short-term foreign currency ratio leads to a 0.19 percentage point reduction in net worth for an average-sized firm. When firm size decreases by one standard deviation, the negative effect gets larger in magnitude by 0.32 percentage points. For real domestic sales, a one percentage point increase in the short-term foreign currency ratio is associated with a 0.49 percentage point decrease in domestic sales of an average-sized firm. This negative impact becomes more pronounced, rising by 0.52 percentage points, when firm size decreases by one standard deviation.[22] This finding is consistent with the result of Kim et al. (2015).

Column (3) shows how each firm's markup growth changes, proxied by market share changes, when it is more indebted in short-term foreign currency debt. The regression result indicates that deterioration of the balance sheet reduces firms' markups. The decline in markups among firms indebted in foreign currency debt, combined with higher average prices among them, shown in Figure 3 in Section 3.2, hints that firms' marginal costs rise. It motivates our structural model in

[21] The inclusion of the last two control variables is motivated by our structural model, where the effect of the foreign currency debt share depends on the size of debt shown in Section 6. For ease of comparison with the model counterparts, we standardize the log of short-term debt as we do with the model simulated data in Section 7. The key empirical results reported in this section do not depend on this normalization, and results without normalization as well as results excluding the last two control variables are available upon request.

[22] The mean and the standard deviation of firm size are 24.1 and 1.4, respectively.

Table 4: Firm Performance and FC Debt

	Net Worth Growth (1)	Domestic Sales Growth (2)	Markup Growth (3)
ST FC	-5.6555***	-9.4335**	-10.1687**
	(1.5268)	(4.1259)	(4.8512)
LT FC	-0.0652	-0.7135	-0.5857
	(0.7161)	(2.2891)	(2.6808)
Size	-0.0420***	-0.2495***	-0.3202***
	(0.0101)	(0.0279)	(0.0336)
ST FC x Size	0.2269***	0.3710**	0.3980**
	(0.0628)	(0.1651)	(0.1941)
LT FC x Size	-0.0256	-0.2074	-0.2107
	(0.0408)	(0.1350)	(0.1560)
Leverage Ratio	0.1600***	0.1511	0.2185
	(0.0524)	(0.1150)	(0.1458)
Export to Sale Ratio	0.7703***	1.4090***	1.7561***
	(0.0823)	(0.2007)	(0.2629)
ST Debt Ratio	0.0133	0.0465	0.0516
	(0.0318)	(0.0948)	(0.1135)
FC Cash Ratio	-1.5078*	-3.1991***	-4.0065***
	(0.7740)	(1.1927)	(1.5057)
ST FC x ln(ST Debt)	-0.2462**	-0.0332	0.1075
	(0.0998)	(0.1805)	(0.2316)
LT FC x ln(LT Debt)	0.0362	0.2823***	0.2864***
	(0.0290)	(0.0858)	(0.0952)
Adjusted R^2	0.1571	0.1881	0.1536
N	3135	3135	3133

Notes: The dependent variables are the growth rates of net worth, domestic sales, and markups from 1996 to 1998. We use a firm's market share as a proxy for its markup. All the nominal series are deflated with the CPI. The main regressors are the firm-level short-term foreign currency debt ratio (ST FC) and the interaction between firm size and ST FC in 1996. Firm size is measured as the log of real sales. We include two-digit industry fixed effects. Robust standard errors are reported in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

which the balance sheet channel tightens financial and working capital constraints, increasing the explicit and implicit cost of production as shown in Section 4.

Figure A2 in the Appendix shows a complete picture of how the marginal effects of short-term foreign currency debt exposure on the growth of firm-level variables vary with firm size.[23]

We conduct robustness checks using alternative definitions of foreign currency debt exposure, the ratios of short-term and long-term foreign currency debt to total debt and to total assets (Tables A4 and A5 in the Appendix), and including five-digit industry fixed effects (Table A6 in the Appendix). The results are qualitatively and quantitatively similar to the baseline estimates in Table 4.

Moreover, we examine the dynamic effects of foreign currency debt exposure on net worth growth, sales growth, and markup growth before and after the large depreciation. We estimate Equation (2), following Jordà (2005):

$$\frac{y_{j,1996+h} - y_{j,1996}}{y_{j,1996}} = \beta_{0,h} + \beta_{1,h}\text{ST FC}_{j,1996} + \beta_{2,h}\text{LT FC}_{j,1996} + \beta_{3,h}\text{Size}_{j,1996} \quad (2)$$

$$+ \beta_{4,h}\text{ST FC}_{j,1996} \cdot \text{Size}_{j,1996} + \beta_{5,h}\text{LT FC}_{j,1996} \cdot \text{Size}_{j,1996} + \beta_{6,h}\text{X}_{j,1996} + \epsilon_j, \quad (3)$$

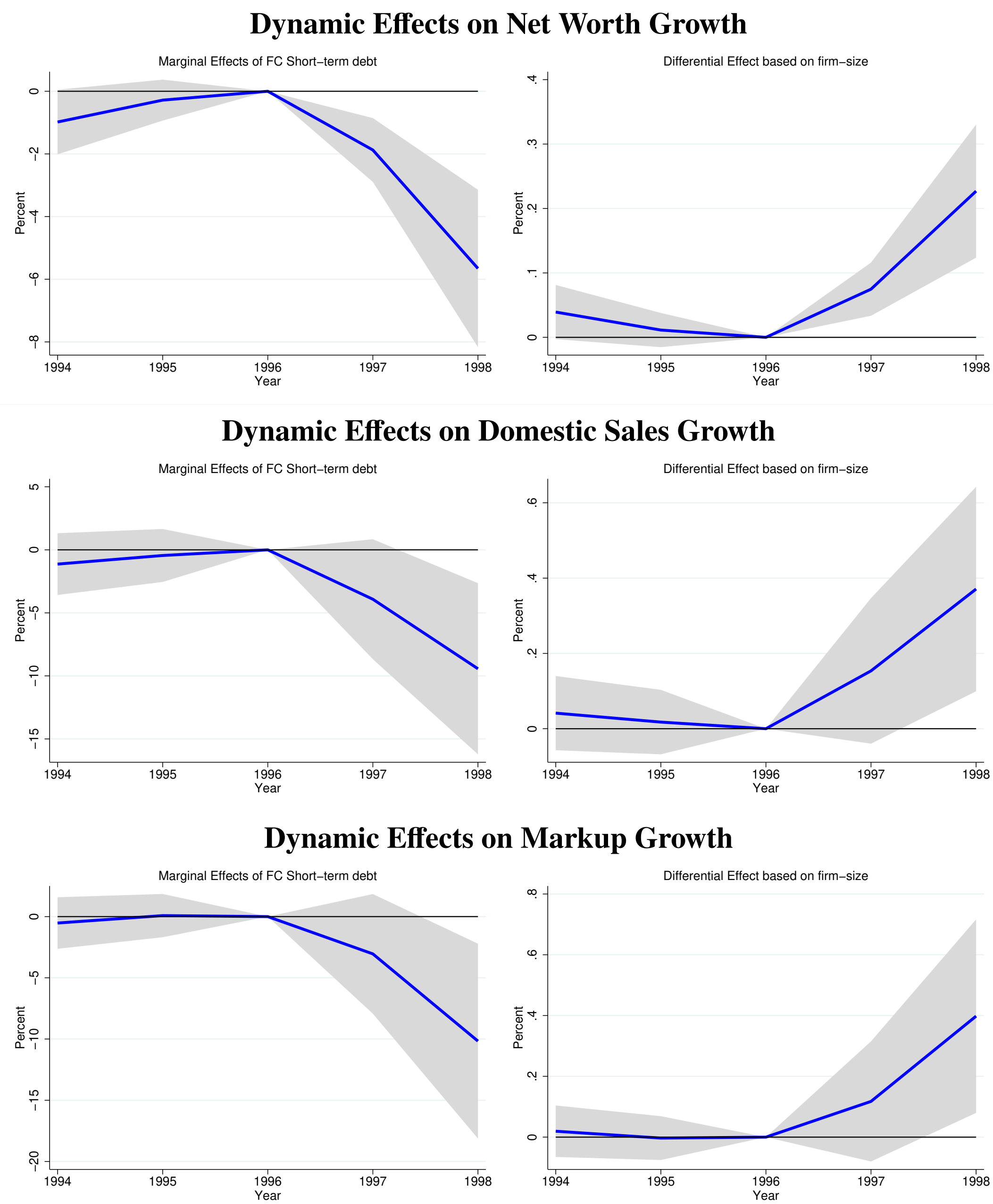
where $h = \{-2, -1, 1, 2\}$. The dependent variable is the growth rate of firm-level variable y_j over h years relative to its value in 1996. We aim to explore if and how firms' net worth, sales and markups, relative to their values in 1996, have shown different dynamics depending on their short-term foreign currency debt exposure in 1996. Our key coefficients of interest are $\beta_{1,h}$ and $\beta_{4,h}$.

Figure 4 illustrates the dynamic effects of foreign currency debt on firm net worth, sales and markups around 1996. The left panels show that prior to 1996, short-term foreign currency debt exposure had no systematic relationship with any of the three outcome variables; the marginal effects of short-term foreign currency debt exposure are not significantly different from zero for $h < 0$, confirming parallel pre-trends. Following the depreciation, the effects turn sharply negative in 1997, particularly for firms' net worth, and continue to grow in magnitude through 1998. This pattern confirms that the adverse effect of foreign currency debt on firm-level outcomes grows stronger over time. The right panels reveal that smaller firms are significantly more vulnerable to foreign currency debt exposure after the depreciation. The differential size effect remains close to zero before 1996 and becomes positive for net worth in 1997 and for sales and markups in 1998. This set of dynamic patterns reveals that the balance sheet effect manifests first in net worth and

[23] The marginal effect of short-term foreign currency debt exposure is evaluated conditional on short-term debt being at its mean value.

subsequently in sales and markups.

Figure 4: Dynamic Effects of Short-term FC Exposure on Firm Performance



Notes: We use a firm's market share as a proxy for its markup. The solid blue lines depict the dynamic estimates on short-term FC exposure (left panel) and the interaction term between short-term FC debt exposure and firm size (right panel). We include two-digit industry fixed effects. The grey areas show the 90 percent confidence intervals, computed with robust standard errors.

On top of these results, we also examine the effect of short-term foreign currency debt exposure on other firm-level variables: capital (defined as total assets minus liquid assets minus inventories) and liquid assets (the sum of cash and cash equivalents, short-term financial instruments and ac-

Table 5: Other Firm-level Outcomes and FC Debt

	Capital Growth (1)	Liquid Assets Growth (2)
ST FC	-5.4521***	-8.6206**
	(1.7197)	(4.0127)
LT FC	-0.0302	0.7378
	(0.7647)	(1.8844)
Size	-0.0160	-0.1141***
	(0.0114)	(0.0196)
ST FC x Size	0.2184***	0.3398**
	(0.0706)	(0.1627)
LT FC x Size	0.0034	-0.1302
	(0.0312)	(0.1075)
Leverage Ratio	-0.0499	-0.0004
	(0.0535)	(0.1076)
Export to Sale Ratio	0.0544	0.3175***
	(0.0441)	(0.0946)
ST Debt Ratio	0.0259	-0.2085**
	(0.0477)	(0.0816)
FC Cash Ratio	0.6892	-2.5175***
	(0.5911)	(0.7137)
ST FC x ln(ST Debt)	-0.0941	-0.1604
	(0.1006)	(0.1961)
LT FC x ln(LT Debt)	-0.0029	0.1233**
	(0.0243)	(0.0623)
Adjusted R^2	0.0216	0.0632
N	3136	3129

Notes: The dependent variables are the growth rates of (1) capital (total assets minus liquid assets minus inventories) and (2) liquid assets (the sum of cash and cash equivalents, short-term financial instruments and accounts receivable) from 1996 to 1998. All the nominal series are deflated with the CPI. The main regressors are the firm-level short-term foreign currency debt ratio (ST FC) and the interaction between firm size and ST FC in 1996. Firm size is measured as the log of real sales. We include two-digit industry fixed effects. Robust standard errors are reported in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

counts receivable), which reflects the working capital available for production.[24] Shown in Table 5, we find that firms indebted in short-term foreign currency experience lower growth rates of capital and liquid asset holdings, and the magnitude of these negative effects increases as firm size decreases. The empirical results are aligned with our model mechanisms, elaborated in detail in Section 6. We also run analogous regressions with our model simulated data and show that these estimates, the non-targeted moments, are qualitatively and quantitatively aligned with what we have found empirically in Tables 4 and 5.

[24]Capital and liquid assets are deflated by the CPI.

3.4 FC Debt Exposure and Price Dynamics: Industry-level Regression

Turning to the effect of foreign currency debt exposure on domestic prices, we estimate Equation (4):

$$\Delta p_{I,1996-98} = \beta_0 + \beta_1 \text{ST FC}_{I,1996} + \beta_2 \text{LT FC}_{I,1996} + \beta_3 \text{X}_{I,1996} + \epsilon_I. \tag{4}$$

The dependent variable is the growth rate of sector I's domestic producer price from 1996 to 1998. The main regressors are sector-level short-term foreign currency debt exposure (ST FC) and long-term foreign currency debt exposure (LT FC) in 1996. We measure a sector's short-term foreign currency debt exposure as the weighted average of the firm-level foreign currency share of short-term debt, where the weight is firm size.[25] Following the firm-level regression (1) in Section 3.3, we investigate the marginal effects of short-term and long-term foreign currency debt exposure separately. We use the pre-depreciation (1996) value of regressors.[26]

To mitigate the concerns about endogeneity, we control for X_I, the weighted average of firm-level characteristics and other key industry-level pass-through determinants. For sectoral characteristics, we include the level of product differentiation, the imported intermediate input share prior to the depreciation, and price stickiness. We classify each industry as selling homogeneous or differentiated goods, based on the method of Rauch (1999). When the Rauch dummy variable is equal to one, the sector is characterized as selling differentiated products. The imported input share for each sector is the ratio of imported intermediate inputs to the total amount of inputs, which include all intermediate inputs and value added from labor and capital. We use the 1995 Input-Output table due to the data availability. The degree of price stickiness for each industry is measured as the median frequency of price adjustment, documented by Nakamura and Steinsson (2008); a higher value indicates less sticky prices. We also include the weighted average values of firm-level characteristics: firm size (log of real sales), the export to sales ratio, the leverage ratio (total debt to total assets), the short-term debt to total debt ratio, and the foreign currency cash to total current assets ratio. We use firm size as the weight when computing the weighted averages of firm-level variables. We also include two-digit PPI sector fixed effects to control for some sector-level shocks during this period and unobservable sectoral characteristics.

Table 6 summarizes the regression estimates of Equation (4). Column (1) summarizes the estimates using only the foreign currency share of short-term debt. When a sector has higher short-term foreign currency debt exposure, it shows a larger price increase following the large depreciation.

[25] Using firm size as the weight may raise endogeneity concerns, as firm size could be correlated with outcome variables. As a robustness check, Table A14 in the Appendix reports results using simple (unweighted) averages of firm-level foreign currency debt exposure, which yield qualitatively and quantitatively similar results.

[26] The ten industries with highest foreign currency share of short-term debt are reported in Table A2 in the Appendix. Summary statistics of industry-level controls are included in Table A3 in the Appendix.

Table 6: Sectoral Price Dynamics and FC Debt

	(1)	(2)	(3)	(4)	(5)	(6)
ST FC	0.6950***		0.7109***	0.6722***	0.6565***	0.5685***
	(0.1607)		(0.1856)	(0.1783)	(0.2162)	(0.2038)
LT FC		0.1858	-0.0295	-0.1302	-0.1899	-0.1846
		(0.1285)	(0.1173)	(0.1245)	(0.1351)	(0.1365)
Size					0.0063	0.0024
					(0.0183)	(0.0181)
Export to Sales Ratio					-0.0243	-0.0469
					(0.1583)	(0.1543)
Leverage Ratio					0.3611**	0.3351**
					(0.1452)	(0.1589)
ST Debt Ratio					0.0778	0.1255
					(0.1172)	(0.1253)
FC Cash Ratio					0.3556	-0.2252
					(3.0707)	(3.1429)
Rauch Dummy						0.0075
						(0.0447)
Imported Input Share						0.2830*
						(0.1656)
Degree of Price Stickiness						0.0317*
						(0.0168)
Broad Sector FE	No	No	No	Yes	Yes	Yes
Adjusted R^2	0.1400	0.0185	0.1348	0.4245	0.4439	0.4513
N	156	156	156	156	156	156

Notes: This table shows the results from regression 4. The dependent variable is the growth rate of sectoral domestic producer prices from 1996 to 1998. The main regressors are the sector-level short-term foreign currency debt exposure (ST FC) and the long-term foreign currency debt exposure (LT FC) in 1996. We include two-digit sector fixed effects. Robust standard errors are reported in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Specifically, a one percentage point increase in short-term foreign currency debt exposure is associated with a 0.70 percentage point increase in prices. After controlling for other sector-level characteristics, the estimate declines to 0.57, yet remains statistically significant, indicating that short-term foreign currency debt exposure still has an important effect on price changes even after accounting for other pass-through determinants documented in the literature.

As expected, sectors with a higher imported intermediate input share exhibit larger increases in domestic producer prices. In addition, sectors with a lower average degree of price stickiness are associated with greater increases in domestic prices. By contrast, the level of product differentiation does not have a significant effect on price dynamics after controlling for two-digit sector fixed effects and the weighted average of firm-level characteristics.

Overall, the industry-level price responses echo our firm-level findings: sectors populated by firms with greater short-term foreign currency debt experience a larger deterioration of their balance sheets following the depreciation, lowering their net worth. The resulting tightening of financial constraints lowers investment, and tighter working capital constraints raise both the explicit and implicit costs of production, pushing prices upward and sales downward. The associated increase in relative prices induces a downward adjustment in markups, but under a broad class of demand structures, including Kimball preferences, this adjustment only partially offsets the cost increase, leaving a net positive effect on sectoral prices. This property is formally shown in Kimball (1995) and Gopinath and Itskhoki (2010), and is exploited in Amiti et al. (2019) to rationalize incomplete exchange rate pass-through in the data.

We conduct several robustness checks on the industry-level baseline regression. The results, reported in the Appendix, are robust to (i) controlling for changes in the number of firms in each industry (Table A8), (ii) controlling for the imported output share (Table A9), (iii) using a subsample of non-exporting firms (Table A10), (iv) alternative definitions of foreign currency debt exposure using ratios to total debt and total assets (Tables A11 and A12), (v) an alternative aggregation of sectoral foreign currency debt exposure (Table A13 and A14), and (vi) restricting the sample to industries with at least four firms (Table A15).

Furthermore, we explore the dynamic and higher frequency responses of monthly sectoral PPI, 18 months before and after the large depreciation. We estimate Equation (5), following Jordà (2005):

$$\frac{p_{I,1997\text{m}9+h} - p_{I,1997\text{m}9}}{p_{I,1997\text{m}9}} = \beta_h + \beta_{1,h}\text{ST FC}_{I,96} + \beta_{2,h}\text{LT FC}_{I,96} + \beta_{3,h}\text{X}_{I,96} + \epsilon_{I,h}, \tag{5}$$

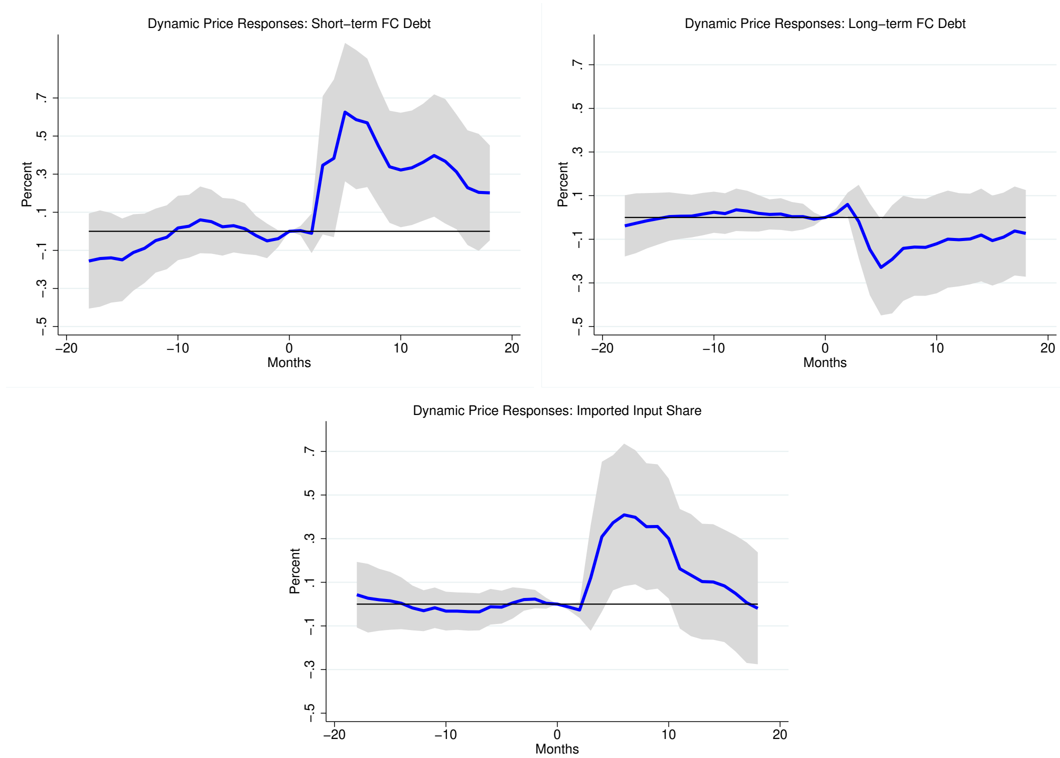
where $h = \{-18, ..., -1, 0, 1, ..., 18\}$. Our key coefficients of interest are $\beta_{1,h}$.

Figure 5 shows the dynamic effects of short-term foreign currency debt exposure, long-term foreign currency debt exposure, and the imported input share. We see that industries show persistently higher levels of monthly PPIs for around a year when they are more indebted in short-term foreign currency; however, we see no differential responses of monthly PPIs for those sectors borrowing more in long-term foreign currency debt. Importantly, we see that coefficients are not significantly different from zero at the 10% significance level before December 1997 when Korea finally decided to float the exchange rate. We also observe positive dynamic effects of the imported input share on sectoral monthly PPIs, lasting for around ten months. The results are robust to using quarterly PPIs, shown in Figure A3 in the Appendix.

Lastly, we also examine the exchange rate pass-through to sectoral prices in more recent periods from 2000–2019. The panel regression results, reported in Table A17 in the Appendix, reaffirm that the balance sheet channel plays an important role in determining the degree of exchange rate pass-through to domestic prices.[27]

[27] We re-estimate the panel regression with two subsample periods: periods of KRW appreciation against USD and

Figure 5: Monthly PPI Before and After the Depreciation of Korean Won



Notes: The figure plots the dynamic effects $\beta_{1,h}$, $\beta_{2,h}$, and $\beta_{3,h}$ of short-term FC debt exposure, long-term FC debt exposure, and the imported input share on monthly sectoral PPIs, estimated in regression 5. We include two-digit sector fixed effects. The shaded areas represent the 90% confidence intervals with robust standard errors.

In sum, from the empirical analyses, we find that during the large depreciation episode, firms with higher foreign currency debt exposure indeed experience balance sheet deterioration and a larger drop in their markups. Moreover, at the industry level, we document that industries populated by firms with higher foreign currency debt exposure increase their domestic producer prices more. Based on these results, we develop a structural model, in which high foreign currency debt exposure, together with a large depreciation, increases the explicit and implicit cost of production for firms. We aim to quantify how important the balance sheet effect of foreign currency debt is in channeling the exchange rate shock to domestic producer prices.

periods of KRW depreciation against USD. Our estimation results shown in Table A18 in the Appendix corroborate that it is the depreciation of the domestic currency that balloons firms' foreign currency debt burden, constrains their production, and raises their prices.

4 Model

In this section, we build a heterogeneous firm model to rationalize our empirical findings and quantify the balance sheet effects of foreign currency debt exposure on industry price dynamics following the depreciation. Even though our industry- and firm-level empirical analyses provide clear evidence for the negative balance sheet effect, this evidence mainly relies on the cross-sectional variation in the data and focuses on the relative changes across industries and firms. Hence, the model provides a clear understanding of the underlying channel based on the empirical analysis and helps us to quantify the importance of balance sheet deterioration in explaining the aggregate industry-level price dynamics upon a large depreciation.

Our theoretical framework is close to Kohn et al. (2020) in modeling the financial frictions and the balance sheet effects of foreign currency debt.[28] We build an industry equilibrium model, where heterogeneous firms, owned by entrepreneurs, produce differentiated goods and issue one-period non-defaultable debt, of which a fraction (firm-specific) is denominated in foreign final goods. Each firm has a different foreign currency debt ratio, exogenously given in our model.[29] We focus on short-term debt because our empirical analysis shows that short-term foreign currency debt drives the balance sheet effects, consistent with its higher rollover risk during periods of financial stress. Including long-term debt would introduce an additional state variable, substantially raising the computational cost while leaving the core mechanism unchanged.

The variations across industries in our model are (i) the *industry-specific* firm-level distribution of foreign currency debt ratios and (ii) the *industry-specific* imported input share common across all firms in the same industry. Both of these are disciplined by their empirical counterparts. Each firm faces two types of financial frictions. First, firms face financial constraints on how much debt they can issue, determined by a fraction of capital. Second, when firms produce output, they face a working capital constraint that requires non-interest-bearing liquid assets to pay for domestic input and imported intermediate input, as seen in Uribe and Yue (2006). We also introduce exogenous firm entry and exit into the model following Khan and Thomas (2013) and Ottonello and Winberry (2020). This feature prevents firms from excessively accumulating capital, ensuring that financial constraints remain relevant.[30] We will assume that the economy is in the stationary equilibrium before an unexpected real exchange rate depreciation. Our key focus is on the transition dynamics

[28]Our framework differs from theirs in the timing assumption. In their model, firms make their next period debt and capital decisions after observing the next period productivity and the exchange rate. The depreciation shock directly tightens the collateral-based financial constraint. In contrast, our model captures the heightened debt burden that arises following an unexpected depreciation shock, where firms do not expect the exchange rate shock when choosing debt and capital.

[29]In the model, the foreign currency debt ratio is equivalent to the short-term foreign currency debt ratio, since all debt is assumed to be short-term; therefore, we use the two terms interchangeably from this point onward.

[30]The modeling assumption also helps us to generate a more realistic distribution of firm-level sales.

of the industry prices.

4.1 Market Structure

We assume that each industry I faces an exogenous CES demand, where the demand for industry I's composite goods is given by:[31]

$$Y_I = P_I^{-\nu}\bar{Y}.$$

Each industry is populated by a continuum of entrepreneurs indexed by j with a measure of 1. The technology of transforming intermediate goods into industry I's composite goods is characterized by the Kimball (1995) aggregator:

$$\int \Upsilon\left(\frac{y_j}{Y_I}\right)dj = 1.$$

The Kimball demand structure gives the demand for an intermediate good produced by an entrepreneur j:

$$y_j = \psi\left(D_I\frac{p_j}{P_I}\right)Y_I \quad \text{, where} \quad \psi(.) = \Upsilon'^{-1}(.),\ D_I \equiv \int \Upsilon'\left(\frac{y_j}{Y_I}\right)\frac{y_j}{Y_I}dj.$$

Following the functional forms as in Gopinath and Itskhoki (2010), the Kimball demand function faced by firms in industry I is as follows:[32]

$$y = \left(1 - \epsilon\ln(\frac{p}{P_I})\right)^{\sigma/\epsilon} P_I^{-\nu}. \tag{6}$$

The implied optimal markup for firm j is

$$\mu_j = \frac{\sigma}{\sigma - 1 + \epsilon\ln(p_j/P_I)}, \tag{7}$$

which equals the standard CES markup $\frac{\sigma}{\sigma-1}$ in the symmetric equilibrium where $p_j = P_I$. For $\epsilon > 0$, the markup is decreasing in the firm's relative price and therefore increasing in its market share.

[31]We normalize the aggregate price $\bar{P}$ and aggregate output $\bar{Y}$ to one without loss of generality.
[32]Detailed information on the functional form of Kimball demand can be found in the Appendix.

4.2 Firms' Problem

Each firm j in industry I produces a differentiated intermediate good, $y_{j,I}$ and sells it at price $p_{j,I}$ in a monopolistically competitive market.[33] We assume that each firm faces a Kimball demand structure, which is characterized by two parameters, σ and ϵ. Firms produce differentiated goods with the production technology,

$$y_t = z_t k_t^{\alpha} x_t^{\kappa} n_t^{1-\alpha-\kappa}. \tag{8}$$

Firms hire domestic input n_t, imported intermediate input x_t and physical capital k_t.[34] z_t is an idiosyncratic productivity that follows AR(1) process, $ln(z_t) = (1-\rho_z)\mu_z + \rho_z \ln(z_{t-1}) + \epsilon_t$, where ϵ_t is normally distributed with a mean of zero and a standard deviation of σ_ϵ. We discretize the idiosyncratic shock process following Tauchen (1986). We assume that firms in the model import intermediate inputs but do not export their products. We focus on domestic sales and domestic price dynamics.[35]

Each entrepreneur owns a firm and receives instantaneous utility from final goods consumption, c_t. We assume a CRRA utility function with relative risk aversion, γ. An entrepreneur is endowed with one unit of labor and supplies that labor inelastically. Each entrepreneur accumulates physical capital, which is subject to a convex adjustment cost,

$$\Phi(k_t, k_{t+1}) = \frac{\phi}{2}\left(\frac{k_{t+1} - (1-\delta)k_t}{k_t}\right)^2 k_t, \tag{9}$$

by investing i_t amount of final goods as capital. Physical capital in the model has two modes: production and collateral.

At the start of each period, entrepreneurs learn this period's productivity z_t and the exchange rate ξ_t. The exchange rate ξ_t is exogenous and defined as the price of foreign final goods in units of domestic final goods. With probability π_d, each firm receives an i.i.d. exit shock and must exit the economy after producing as in Ottonello and Winberry (2020). Firms hire domestic input n_t and import intermediate goods x_t, a fraction of which they need to pay for with their working capital a_t, which is chosen in the previous period. With those inputs, they produce and sell differentiated goods y_t at price p_t. Exiting firms liquidate their remaining assets, consume all available resources, and exit the economy. An equal mass of new firms π_d enter the economy. New entrants are endowed with k_{ini} units of capital and start with no debt and no working capital, aligned with the assumptions in Ottonello and Winberry (2020). Upon entry, they choose capital, debt, and working capital for the following period, and at the beginning of the next period, they draw an idiosyncratic productivity

[33] From here on, we will simplify the notation by dropping industry and firm indices I and j, and we will use them only when needed for clarification.

[34] Domestic input is a composite of domestic intermediate input and labor. The aggregate wage and the domestic intermediate input price, denoted by w, are also normalized to one.

[35] We have a detailed discussion on this modeling assumption in Section 4.3.

from the ergodic distribution implied by the AR(1) process of z_t.

All the continuing firms choose how much new debt d_{t+1} they want to issue, and decide the next period's level of capital k_{t+1} and working capital a_{t+1}. Each firm chooses to borrow d_{t+1} (in units of domestic final goods) at the price $\frac{1}{1+r}$, where $(1-\lambda)\frac{d_{t+1}}{1+r}$ is denominated in domestic final goods. Then, each entrepreneur holds $\lambda\frac{d_{t+1}}{1+r}\frac{1}{\xi_t}$ amount of the foreign debt in units of foreign final goods in period t. At the start of period $t+1$, each entrepreneur pays back $(1-\lambda)d_{t+1}$ for domestic debt and $\lambda d_{t+1}\frac{\xi_{t+1}}{\xi_t}$ for foreign debt in units of domestic final goods. We abstract away from the portfolio choices, and the share of foreign debt is exogenous and pre-determined at the **firm level**. Since the agents in the economy expect that the exchange rate will be constant before and after a one-time unexpected exchange rate depreciation, the currency composition of debt cannot be determined in the model, justifying our assumption of exogeneity of the foreign currency debt share.

Entrepreneurs face a borrowing constraint whereby they can only borrow up to a fraction θ_k of the capital. Thus, the amount that each entrepreneur can borrow is given by:

$$\frac{d_{t+1}}{1+r} \leq \theta_k k_{t+1}. \tag{10}$$

It is important to note that the exchange rate does not *directly* affect the constraint. That is, the borrowing constraint does not mechanically tighten upon the depreciation of the domestic currency. We would like to explore firms' pricing decisions when facing a higher debt burden due to their foreign currency debt exposure, while abstracting away from direct effects of the exchange rate and foreign currency debt exposure on the financial constraint itself. Nonetheless, allowing for such extensions would make our mechanism even stronger.

In addition, each entrepreneur faces a working capital constraint. Specifically, in order to finance a $\frac{1}{\theta_a}$ fraction of their domestic input payment $w_t n_t$ and imported intermediate input $\xi_t^{\omega} x_t$, firms need to hold a non-interest-bearing asset a_t that is chosen in the previous period. Note that ω captures the degree of exchange rate pass-through to import prices, and ω equal to one implies a complete exchange rate pass-through to import prices. Hence, the amount of domestic inputs and imported intermediate inputs that each entrepreneur can pay is limited by the amount of the non-interest bearing liquid asset a_t:

$$w_t n_t + \xi_t^{\omega} x_t \leq \theta_a a_t. \tag{11}$$

Each entrepreneur, continuing, exiting, or new, maximizes utility subject to the following budget constraints and financial frictions. A *continuing entrepreneur* maximizes lifetime utility subject to the following budget constraint,

$$c_t + k_{t+1} + \Phi(k_t, k_{t+1}) + a_{t+1} + d_{t+1}\big((1-\lambda) + \lambda \frac{\xi_t}{\xi_{t-1}}\big) = p_t y_t - w_t n_t - \xi_t^{\omega} x_t + (1-\delta) k_t + \frac{d_{t+1}}{1+r_t} + w_t, \tag{12}$$

and the collateral constraint, Equation (10), and the working capital constraint, Equation (11). An *exiting entrepreneur* maximizes utility from current period consumption subject to

$$c_t = p_t y_t - w_t n_t - \xi_t^{\omega} x_t + (1-\delta) k_t + a_t - \Phi(k_t, 0) - d_t\big((1-\lambda) + \lambda \frac{\xi_t}{\xi_{t-1}}\big) + w_t, \tag{13}$$

and the working capital constraint, Equation (11).

A *new entrant* maximizes future lifetime utility subject to

$$k_{t+1} + a_{t+1} + \Phi(k_{ini}, k_{t+1}) = k_{ini} + \frac{d_{t+1}}{1+r}, \tag{14}$$

and the collateral constraint, Equation (10).

Since we solve for an industry equilibrium, the wage and import prices are exogenous to the industry: both domestic inputs n_t and imported intermediates x_t are supplied elastically at the given factor prices, so there are no separate market-clearing conditions for these inputs. Each industry has a different firm-level distribution of foreign currency debt exposure λ and a different imported input share κ.

We define a recursive stationary industry equilibrium as (i) industry I's price P_I and output Y_I, (ii) a set of policy functions $\{d'_c, k'_c, a'_c, c_c, n_c, x_c, y_c, p_c\}$ and value functions v_c for continuing firms, (iii) a set of policy functions $\{c_x, n_x, x_x, y_x, p_x\}$ and value functions v_x for exiting firms, (iv) a set of policy functions $\{d'_e, k'_e, a'_e\}$ for new entrants, and (v) a measure of firms ψ_I on $(k, d, a, z, \lambda, \kappa)$ such that (a) all firms optimize, (b) industry output market clears, (c) the measure ψ_I is stationary and consistent with decision rules and exogenous processes. Detailed formulations of the value functions, policy functions, the industry price, and the stationary measure are provided in the Appendix.

We assume that the economy is in a stationary industry equilibrium prior to the unexpected depreciation of the real exchange rate. We study the transition dynamics of different industries upon the exchange rate shock, where industries are characterized by varying levels of foreign debt exposure and different imported input shares.

4.3 Discussion of Model Assumptions

4.3.1 No Export Decision

Our model assumes that firms sell only to domestic markets and do not choose how to allocate their sales between domestic and foreign destinations. A potential concern is that exporting firms may borrow more in foreign currency and use foreign revenues as a natural hedge, which could weaken the balance sheet effects of foreign currency debt we document. However, the empirical evidence indicates that the natural hedging motive is *not* a key determinant of the currency composition of debt, and consequently, exporters indebted in foreign currency also experienced a large decline in their domestic sales. Moreover, a reallocation of sales toward export markets may reduce domestic sales, which could reinforce, rather than weaken, the balance sheet effects of foreign currency debt on domestic sales and prices.

Using confidential Korean Customs data merged with firm-level balance-sheet information, Kim et al. (2024) show that export-intensive firms do not borrow more in foreign currency. The correlation between the export to sales ratio and the foreign currency share of debt is close to zero, which is consistent with our own firm-level estimate of roughly 0.1. Kim et al. (2024) further shows that net exports are *negatively* correlated with the foreign currency share of debt. Hence, firms with higher imports relative to exports tend to borrow more in foreign currency — the opposite of what the natural hedging motive would predict.

Consequently, exporters do experience these negative balance sheet effects following a large depreciation. To assess whether exporters are affected to the same extent as domestic firms, we examine how their domestic sales respond to short-term foreign currency debt exposure, relative to domestic firms. We include an interaction term between a firm's foreign currency debt ratio and its export status (or export to total sales ratio) in our baseline regression model. Shown in Table A19 in the Appendix, exporters indeed experience a large decline in their domestic sales, even larger than that of domestic firms. This empirical pattern could reflect the potential reallocation of sales towards export markets following a devaluation, as exports become more profitable relative to domestic sales, particularly when liquidity needs rise due to a higher foreign currency debt burden. While this export reallocation channel is not modeled explicitly, it would likely amplify rather than mitigate our mechanism: if *financially constrained* firms divert output away from domestic markets to generate foreign currency revenues, domestic sales would decline further, putting upward pressure on domestic prices. Incorporating such endogenous reallocation decisions would be an interesting extension but would significantly complicate the model without altering the core mechanism.

4.3.2 Two Financial Frictions in the Model

Our model features two types of financial constraints. With only the working capital constraint, firms can offset the increase in their debt burden by borrowing more to repay their foreign currency debt. As a result, the increase in their debt burden following a depreciation would have a more limited impact on their investment and working capital decisions. With the collateral constraint only, the investment response would need to be *unrealistically* large to generate a quantitatively meaningful price response after the depreciation of domestic currency.[36] Therefore, we include both types of financial constraints in the model.

5 Calibration

Table 7 summarizes the parameter values that we use for the quantitative exercise. The first half of the parameters are either from the literature or directly computed from the data we have, and the second half of the parameters are estimated via the simulated method of moments.

There are two important variations across industries, the average imported input share κ_I and the distribution of foreign currency debt ratios across firms π^I_m. We use data from the 1995 Korean Input–Output Table to calculate each industry's imported input share in total costs (intermediate inputs plus value added) κ_I. Most importantly, we set λ_m and π^I_m to match the cross-sectional distribution of foreign currency debt ratios across firms in each industry. We first set $\{\lambda_m : m = 1, 2, \ldots, 21\}$ = $\{0\%, 2.5\%, 7.5\%, 12.5\%, ...97.5\%\}$, which are the median values of 21 bins: $\{\lambda = 0\%, 0\% < \lambda \leq 5\%, 5\% < \lambda \leq 10\%, \ldots, 95\% < \lambda \leq 100\%.\}$ Then, for each industry we compute the probability mass function $\{\pi^I_m : m = 1, 2, \ldots, 21\}$ using the firm-level short-term foreign currency debt to total short-term debt ratios in each industry I. We calibrate π^I_m using the weighted probability mass function, where the weight is firm size. $\bar{\lambda}_I = \sum_m \lambda_m \pi^I_m$ represents the average industry-level foreign currency debt exposure. It is consistent with how we have computed the average foreign currency debt ratio for each industry in the industry-level empirical analysis. To check for any substantial rounding errors, we compare $\bar{\lambda}_I$ and the data counterpart, the actual weighted mean of each firm's ratio of short-term foreign currency debt to total short-term debt, using firm size as the weight. We find that their correlation is close to one.

The degree of exchange rate pass-through to import prices ω is calibrated to 0.353, obtained by taking the ratio of the growth rate of Korea's average import price to the growth rate of the

[36]For instance, in a steady state with a representative firm, investment equals depreciation: $I = \delta K$. A 100% drop in investment (during the 1996-98 period, the aggregate investment dropped by 58%) would only imply a 10% drop in capital stock (with $\delta = 0.1$), and effectively the same as lowering the next period's effective productivity by 2.4% with the capital share equal to 0.24. Then, even under a complete pass-through to prices, the increase in prices would be 2.4%.

KRW/USD exchange rate during 1996-98. The Cobb–Douglas production parameter α is calibrated to match the aggregate capital share in the total inputs used (domestic and imported intermediate inputs used plus value added from labor and capital), using the 1995 input-output table. Due to data availability, we use monthly observations of three-year government bond yields and realized inflation rates in 1996. We compute the real interest rate r by subtracting the mean of the realized year-over-year inflation rates from the mean of the annualized three-year government bond yields, which yields a real interest rate of approximately 8%.

Following Ackerberg et al. (2006), we estimate the firm-level productivity process using our data outside the model. We estimate ρ_z and σ_z as 0.9 and 0.1, respectively.[37] We discretize the productivity process following Tauchen (1986). The exit probability p is calibrated to match an exit rate of 4.7% for all industries in Korea in 1996. The capital adjustment cost ϕ is set to 0.9569, following Gilchrist and Sim (2007), who employ the same Korean firm-level balance sheet dataset as this study. The risk aversion parameter γ, the depreciation of capital δ, and the elasticity of substitution across sectors ν are set to standard values used in the literature.

For the parameters estimated within the model, i.e., the discount factor β, the fraction of capital used as collateral θ_k, the tightness of working capital constraint θ_a, the elasticity of substitution within the sector σ, the super-elasticity of demand ϵ, and the initial capital of the entrant firm k_0, we estimate them with the simulated method of moments, minimizing the distance between the model and data moments.[38] We target the six model moments in the stationary equilibrium summarized in Table 8: the average liquid assets to capital ratio, the average debt to capital ratio, the average capital to sales ratio, the average log of markup, and the interquartile range of market shares, and the ratio of average capital of firms aged 0 and 1 to the average capital. All moments are computed using firm-level data from 1991 to 1996, except for the average domestic markup in Korea from 1991 to 1996, which is taken from Choi et al. (2024).[39]

[37]We estimate the AR(1) process using z_t estimates from 1980 to 1996. For more details on the productivity estimation, please refer to the Appendix.

[38]When estimating the parameters, we set the imported input share κ to match the aggregate imported input share at 0.11.

[39]In Figure B5 of Choi et al. (2024), the average domestic markup is 1.26 in 1991-1996. The log of markup that we target, therefore, is ln(1.26) = 0.23.

Table 7: List of Parameter Values

Parameter	Value	Description
Predetermined & Calibrated Outside Model		
λ_m	$\in [0, 0.975]$	Distribution of FC Debt Share for
π_m^I	$\in [0, 1]$	Each Sector
κ_I	$\in [0, 1]$	Sector-level Imported Input Share
ω	0.353	Degree of FX Pass-through to Import Prices
r	0.08	Real Interest Rate
α	0.24	Capital Share
ρ_z	0.9	AR Coefficient of z
σ_z	0.1	Stdev of z
p	0.047	Exit Probability
ϕ	0.9569	Physical Capital Adjustment Cost
γ	2.0	Relative Risk Aversion
δ	0.1	Depreciation Rate of Physical Capital
ν	2.0	Elasticity of Substitution Across Sectors
Estimated Parameters Simulated Method of Moments		
Parameter	**Value**	**Description**
β	0.892	Time Discount Factor
θ_k	0.703	Fraction of Capital as a Collateral
θ_a	0.928	Tightness of Working Capital Constraint
σ	5.05	Elasticity of Substitution Within A Sector
ϵ	3.5	Super Elasticity of Demand
k_0	0.0256	Initial Capital for Entrant Firm

Table 8: Targeted Moments from Data and Model

Targeted Moments	Data	Model
Average Liquid Assets to Capital, $\frac{a}{k}$	0.77	0.77
Average Debt to Capital, $\frac{d}{k}$	0.71	0.71
Average Capital to Sales, $\frac{k}{y}$	0.80	0.80
Average Log of Markup	0.23	0.23
Interquartile Range of Market Share	0.70	0.70
Ratio of Average Capital of Firms 0 and 1 to Average Capital	0.09	0.09

Although the six parameters are jointly determined to match six moments, we can still provide a heuristic description of how each parameter is mostly inferred from an empirical moment. The time discount factor β determines the extent to which firms value future production and therefore influences the average capital to sales ratio. The tightness of the financial constraints θ_k affects the amount of debt that firms can issue given their capital, so the average debt to capital ratio disciplines this parameter. The tightness of working capital θ_a governs the amount of liquid assets that firms must hold to finance next period's working capital relative to the scale of production; thus, the average liquid assets to capital ratio informs θ_a. k_0 naturally is linked to the ratio of average capital of firms aged 0 and 1 to average capital. The elasticity of substitution within sector σ and the super-elasticity of demand ϵ disciplines the average markup and dispersion of market share. Moreover, our identification strategy is further supported by Table A21 in the Appendix, which reports the elasticities of the targeted moments with respect to each of the six parameters.

For the exchange rate shock, we compute the Korean won price of dollar percentage growth rate from 1996 to 1997. Following the actual dynamics of the exchange rate after the depreciation, we simulate the economy upon the unexpected shock where ξ increases from 1 to 2.0 in the first period and ξ remains at 2.0 afterwards. We effectively assume a one-time unexpected shock to the exchange rate *returns* but assume zero expected returns afterwards.[40] Hence, there will be no deviation from the Uncovered Interest Parity condition. Upon this so-called MIT shock, we compute the transition dynamics, focusing on the industry-level prices.

6 Inspecting Mechanism: Policy Function Analysis

We first examine firm-level policy functions to explore the underlying mechanism of firms' pricing decisions. We abstract from the imported input channel in this section to focus on illustrating the balance sheet effects of foreign currency debt exposure. Specifically, we assume that a firm's debt burden increases while the price of imported inputs remains constant following a large depreciation, i.e., $\omega = 0$. All other parameters are set to our calibrated values summarized in Table 7. We start with a firm's optimal pricing decision from the model,

$$p_{j,t} = \mu_{j,t} mc_{j,t}(1 + \eta_{2,j,t}), \tag{15}$$

where $\mu_{j,t}$ is a firm's optimal markup, $mc_{j,t}$ is the marginal cost of production, and $\eta_{2,j,t}$ is the value of the Lagrangian multiplier on the working capital constraint.

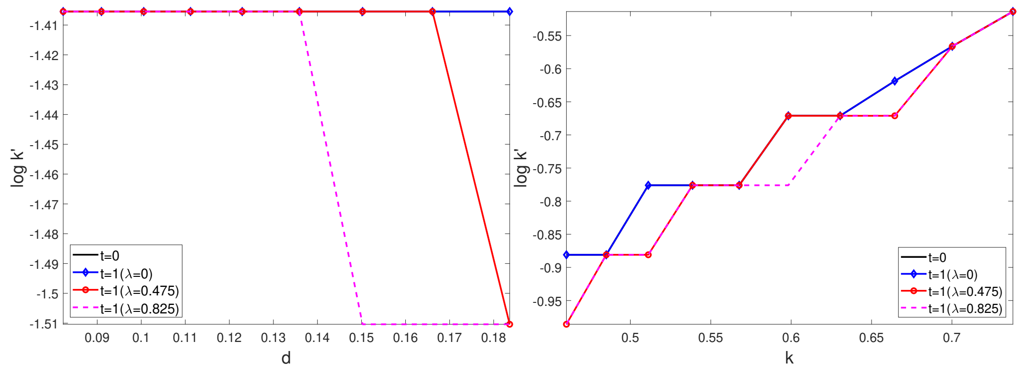
Following a large depreciation, firms face higher debt burdens, which affect their pricing decisions through two channels: (i) investment adjustment and (ii) liquid asset adjustment. First, firms lower their investment and become less productive in the next period, increasing the marginal cost of production $mc_{j,t+1}$. Second, firms lower their liquid asset savings and face a tighter working capital constraint in the next period, resulting in a higher value of the Lagrangian multiplier $\eta_{2,j,t+1}$, which puts upward pressure on prices.

Our analysis examines these two margins, investment decisions and working capital constraints, both in the steady state and along the transition path. Specifically, we plot policy functions against the debt level d and the capital stock k, as firms with higher debt burdens or lower capital stocks are

[40] The depreciation in the first period is unexpected and they know that in the future $\xi/\xi_{-1} = 1$.

more likely to experience severe balance sheet deterioration and tighter financial constraints.[41] We also consider policy functions for different levels of foreign currency debt exposure λ to capture the balance sheet effects of foreign currency debt exposure following a large depreciation. To illustrate the mechanism, we focus on an industry with a non-degenerate cross-sectional distribution of foreign currency debt ratios across firms and productivity z at the median level.[42]

Figure 6: k' against (i) d (Left) and (ii) k (Right).



Notes: The solid black lines are the policy functions in the stationary equilibrium. The blue diamond lines, red circle lines, and dashed magenta lines are policy functions for firms with 0, 0.475, and 0.825 of foreign currency debt ratio, respectively.

Figure 6 shows the policy functions of k' against k and d.[43] When a firm's reliance on foreign currency debt is large prior to the depreciation, the increase in its debt burden is more pronounced, further lowering investment and, consequently, capital in the next period. In addition, when debt is sufficiently low or capital is sufficiently high, the balance sheet effect of foreign currency debt does not lead to a significant adjustment in investment.

To understand the working capital channel, we begin the analysis with the firm's Euler equations regarding debt choice d' and working capital a', as follows:

$$\beta E_{z'|z}[(c')^{-\gamma}(1+r)\big((1-\lambda)+\lambda\frac{\xi'}{\xi})] + \eta_1 = \beta E_{z'|z}[(c')^{-\gamma} + \theta_a \eta_2'], \tag{16}$$

where η_1 and η_2 are the Lagrangian multipliers on the collateral constraint, Equation (10), and the working capital constraint, Equation (11), respectively. Equation (16) shows that even when the collateral constraint is not binding ($\eta_1 = 0$), any positive value of the expected net interest rate r implies that the working-capital constraint always binds, i.e., $E_{z'|z}[\eta_2'] > 0$.[44] More importantly, when the collateral constraint becomes tighter, i.e., $\eta_1 > 0$ increases, it has a direct effect on the

[41] We plot the log of each choice variable against d and k, except for $E_{z'|z}[\eta_2']$.

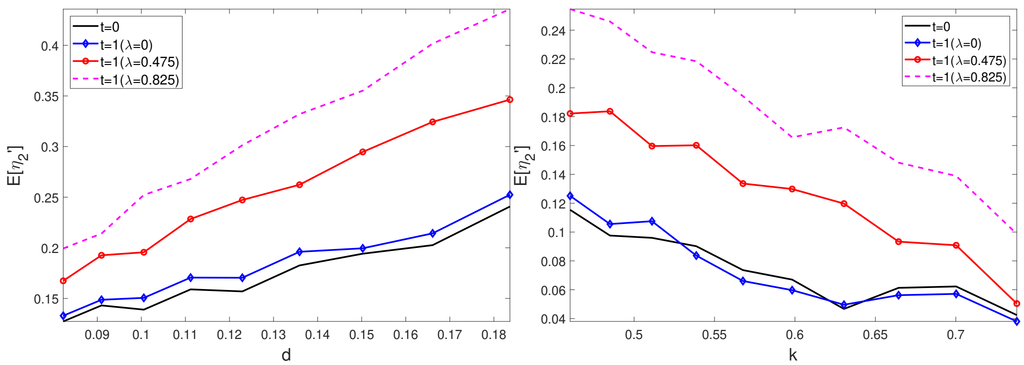
[42] We set k and d at their mode values in the stationary distribution and a at its lowest 10th percentile value such that financial constraints meaningfully bind for the policy function illustration.

[43] Note that the policy function is the same for all λ in the stationary equilibrium.

[44] Agents expect the exchange rate to be held constant all the time: $\frac{\xi'}{\xi} = 1$.

Lagrangian multiplier, $E_{z'|z}[\eta_2']$, on the working capital constraint. Given the firm's optimal pricing decision in Equation (15), a tighter collateral constraint (higher η_1) in this period implies higher next-period shadow costs η_2', leading to higher next-period prices.

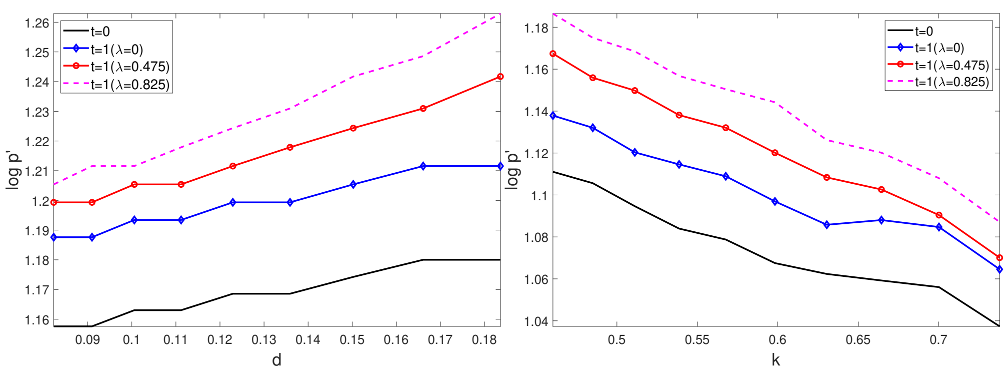
Figure 7: $E_{z'|z}[\eta_2']$ against (i) d (Left) and (ii) k (Right).



Notes: The solid black lines are the policy functions in the stationary equilibrium. The blue diamond lines, red circle lines, and dashed magenta lines are the policy functions for firms with 0, 0.475, and 0.825 of foreign currency debt ratio, respectively.

Figure 7 plots the Lagrangian multiplier: $E_{z'|z}[\eta_2']$. When a firm's reliance on foreign currency debt is larger prior to the depreciation, the working capital constraint becomes even tighter, thereby increasing the implicit cost of production. As with investment, the effect attenuates for firms with lower debt or higher capital. Figure A4 in the Appendix shows the policy functions of liquid assets against d and k, corroborating that firms choose to hold less liquid assets when indebtedness in foreign currency is high.

Figure 8: p' against (i) d (Left) and (ii) k (Right).



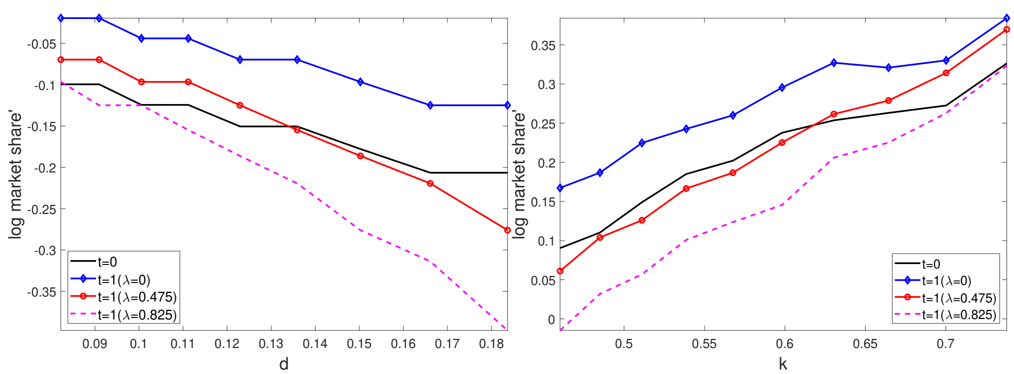
Notes: The left panel shows the pricing decision in the next period as a function of this period's debt level, and the right panel shows the pricing decision as a function of the initial capital stock. The solid black lines are the price policy functions in the stationary equilibrium. Blue diamond lines, red circle lines, and dashed magenta lines are policy functions for firms with 0, 0.475, and 0.825 of foreign currency debt ratio, respectively.

Then, we explore how this period's debt d and capital stock k affect the price and the markup in the next period, the ultimate objects of our interest.

Figure 8 illustrates how firms change their prices following a large depreciation. Firms that have higher foreign currency debt exposure (i.e., higher λ) increase their prices even more after a large depreciation. This result echoes the findings in Figures 6 and 7, namely that a higher debt burden in the current period translates into a lower level of capital stock and liquid asset savings. If a firm invests less in this period, it becomes less productive in the next period, raising its cost of production. Furthermore, lower liquid assets tighten the working capital constraint, raising the implicit cost of production. Both channels put upward pressure on prices. Finally, the impact on prices is limited when firms carry little debt or hold sufficient capital.

In addition to the negative balance sheet effect, we find that strategic complementarity plays an important role in determining firm-level pricing decisions. Even if firms with zero foreign currency debt are not directly affected by the depreciation (the blue diamond lines in both panels), they still choose to set prices above the steady-state level (the solid black lines in both panels). This result arises from strategic complementarity embedded in the Kimball preference, whereby firms raise their prices in response to higher prices set by competitors. Thus, in our model, firms increase their prices both in response to their own balance sheet deterioration and as a strategic reaction to competitors' pricing decisions.

Figure 9: Market Share against (i) d (Left) and (ii) k (Right).



Notes: The left panel shows the market share in the next period as a function of this period's debt level, and the right panel shows the market share decision as a function of the initial capital stock. The solid black lines in both graphs show the market share policy functions in the stationary equilibrium. The blue diamond lines, red circle lines, and dashed magenta lines are the policy functions for firms with 0, 0.475, and 0.825 of foreign currency debt ratio, respectively.

Lastly, we investigate how firm-level markups change following a large depreciation. Figure 9 presents the policy function of market share, which serves as an empirical proxy for the optimal markup in Section 3. Figure A5 in the Appendix confirms that the policy function for the optimal markup derived from the model yields very similar patterns. As with prices, the decline in markups is more pronounced for those with greater foreign currency exposure. For firms indebted in foreign currency, the decline in capital raises marginal costs while tighter working capital constraints increase the implicit cost of production, both pushing prices upward. The resulting rise in their relative prices reduces their market shares and hence their optimal markups.

On top of that, firms with zero foreign currency debt, ceteris paribus, increase their markups following the depreciation. That is, policy functions of markups for firms with zero foreign currency debt exposure have shifted up (from the solid black lines to the blue diamond lines) as they are unaffected directly by the depreciation of the domestic currency and become more competitive in their sector. Moreover, some firms with positive foreign currency debt set their markups higher than what they would have chosen before the depreciation, while others set theirs lower; that is, the red and the magenta lines cross the black lines. Specifically, firms with lower debt or higher capital set higher markups in the next period than what they would have charged in the stationary equilibrium. These firms are not affected by the large depreciation and are relatively better off than their competitors; therefore, they increase their market shares and markups and charge higher prices.[45]

7 Quantitative Analysis

7.1 Model Simulations of Industry Price Dynamics

This section summarizes the results from the model simulations of 156 sectors with the calibrated parameter values. We first investigate the transition path of sectoral prices following a large unexpected depreciation in period 1. Figure 10 depicts the transition path of prices for two sectors with the same imported input share of 13%, but different average shares of foreign currency debt to total debt, $\bar{\lambda}_I$: 33% and 12%. After a large depreciation of the domestic currency, those sectors experience price increases of around 6.7% and 3.6%, respectively, over the course of two years. Thus, sectors with greater exposure to foreign currency debt raise their prices more following an unexpected exchange rate depreciation.

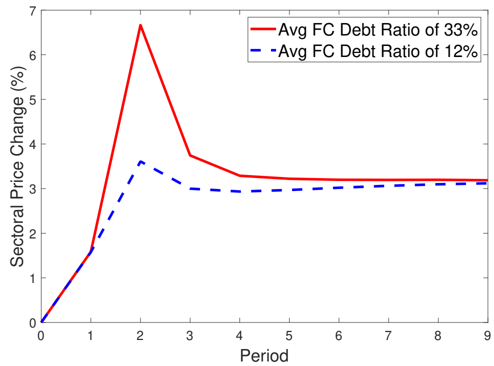
Table 9: Marginal Effect of Short-term FC Debt Ratio on Sectoral Price Changes

	Data	Model
ST FC	0.5685	0.1353
	(0.2038)	
Imported Input Share	0.2830	0.1965
	(0.1656)	
R^2	0.4316	0.9966
N	156	156

Notes: The left column shows the regression result from our empirical analysis. The right column shows the result from the model simulated data.

[45] Additionally, we empirically confirm that firms with zero short-term foreign currency debt increase their markups, as shown in Table A7 in the Appendix.

Figure 10: Impulse Response Functions of Sectoral Prices



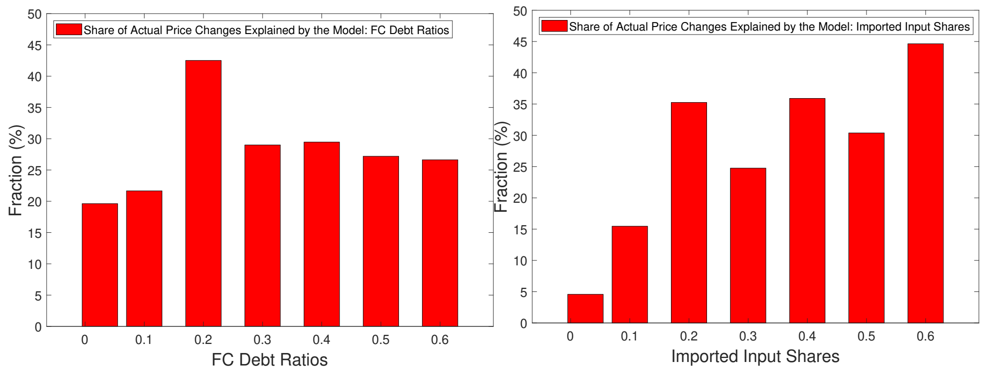
Notes: The red solid line and blue dashed line show the price responses of sectors with foreign currency debt shares of 33% and 12%, respectively. Both sectors have the same imported input share of 13%. An unexpected large depreciation happens in period 1.

We regress PPI changes on both $\bar{\lambda}_I$ and the imported input share κ_I. As shown in Table 9, the coefficient estimate on the sectoral foreign currency debt ratio is 0.1353, and the data counterpart is 0.5685. The model explains around 24% of the mean effect of short-term foreign currency debt exposure on sectoral price changes across industries. The model also reproduces the untargeted empirical estimate of the sectoral price changes on the imported input share, where the estimate from the model is within the 95% confidence interval of the empirical estimate.

Given that the model underestimates the impact of foreign currency debt exposure on sectoral price changes, the quantitative significance of foreign currency debt on sectoral price changes in Section 8 can be thought of as a lower bound. The quantitative fit could improve if the cost of working capital or the tightness of financial constraints were modeled as a function of firms' net worth, as in Céspedes et al. (2004), or as a function of foreign currency debt and the exchange rate, as in Kohn et al. (2020) and Drenik and Perez (2021). In such settings, a depreciation of the domestic currency, particularly for firms indebted in foreign currency, would raise the cost of working capital or tighten the financial constraints. This feature would further amplify the balance sheet effect of foreign currency debt. In this paper, we currently focus on the direct consequences of a heightened debt burden following the depreciation, holding the tightness of financial constraints fixed.

We also compute the standard deviation of the growth rate of domestic producer prices from 1996 to 1998 across industries and its model counterpart and find 17.1% and 3.2%, respectively. Our simple model, with two variations across industries regarding foreign currency exposure and imported input share, can explain 19% of the observed variation in price changes during the large depreciation episode. We emphasize that none of these moments were targeted in our calibration; therefore, their quantitative magnitudes demonstrate that our model captures reasonably well both sectoral price dynamics after the depreciation and the cross-sectional variation in price changes across industries with differing exposure to foreign currency debt and imported input shares.

Figure 11: Share of Sectoral Price Changes in the Data Explained by the Model
Across FC Debt Ratios and Imported Input Shares



Notes: The figure plots the share of sectoral price changes in the data that are explained by the baseline model. We first group the 156 sectors into bins based on (i) foreign currency debt ratios (left panel) and (ii) imported input shares (right panel): $[0\%, 5\%), [5\%, 15\%), \ldots, [45\%, 55\%), [55\%, 70\%)$. Within each bin, we compute the average price change in the data and in the model and plot the share explained by the model (i.e., the ratio of model-generated to data-based averages).

Lastly, we assess how much of the observed sectoral price movements from 1996 to 1998 can be accounted for by the model across different levels of (i) foreign currency debt exposure and (ii) imported input shares in Figure 11. We first group 156 sectors into bins based on their average foreign currency debt ratios: $[0\%, 5\%), [5\%, 15\%), \ldots, [45\%, 55\%), [55\%, 70\%)$. Then, we compute, for each bin, the share of the average price change in the data that is explained by the model. Across these bins, the model explains between 20% and 43% of the realized price movements. We then group sectors into bins of imported input shares, and find that the model accounts for approximately 5% to 45% of observed sectoral price movements. For an average industry, 28% of sectoral price changes that we see in the data can be explained by the model. The quantitative magnitude implied by the model should therefore be interpreted as a conservative estimate of the mechanism's role.

7.2 Model Simulations of Firm Dynamics

Using our structural model, we simulate firm-level data for 156 industries ($15,600,000$ firms), pool all the simulated data, and run the regression to quantitatively compare with the data patterns. With the simulated data, we also investigate the role of foreign currency debt in shaping the price dynamics following the depreciation shock.[46]

We run the following regression specifications, analogous to our empirical regression in Equa-

[46] We restrict the sample to firms that survive for at least one year.

tion (1):

$$\Delta y_j = \beta_{I(j)} + \beta_1 \text{ST FC}_j + \beta_3 \text{Size}_j + \beta_4 \text{ST FC}_j \cdot \text{Size}_j + \beta_6 \text{X}_j + \epsilon_j \tag{17}$$

ST FC denotes the short-term foreign currency debt ratio of firm j in industry I, which corresponds to λ in our model. We interact the short-term foreign currency debt ratio with firm size, measured as the log of total sales. Firm size is standardized. X_j contains the interaction between the short-term FC debt ratio and the log of total short-term debt, in line with the controls used when estimating Equation (1).[47] Sector fixed effects are also included.

Our goal is to examine how well the model reproduces the observed data patterns, with a particular focus on the role of financial constraints in amplifying the negative balance sheet effect of foreign currency debt on firm-level outcomes after a large depreciation of the domestic currency. β_1 and β_4 are the coefficients of our interest. To make the model-estimated coefficients directly comparable to the empirical estimates, we rescale the estimated coefficients, β_1 and β_4, using the *empirical* mean and standard deviation of firm size. We report $\beta_1^{reported} = \beta_1 - \beta_4 \frac{Mean(Size)}{Std(Size)}$ and $\beta_4^{reported} = \frac{\beta_4}{Std(Size)}$ in Table 10.[48]

Table 10 shows that our model successfully replicates the empirical results. Across all firm-level outcomes - domestic sales, net worth and markups - the estimated marginal effects are similar in order of magnitude, and heterogeneous effects are likewise comparable. In particular, all model-based estimates fall within, or only slightly outside, the 95 percent confidence interval implied by the data. Nonetheless, it is worth noting that the model tends to underpredict the response of net worth, sales and markup growth, which may help explain why it also underestimates the effect of foreign currency debt exposure on sectoral prices.

In the data, firms that are one standard deviation smaller than the average exhibit more negative marginal effects of foreign currency debt, by 0.32, 0.52, and 0.56 percentage points for net worth, domestic sales and market share, proxying markup, respectively. In the model, the corresponding magnitudes are 0.28, 0.45 and 0.46 percentage points, respectively.

Table 11 reports the regression estimates for capital stock and cash holdings that are central to our model mechanism. Similar to the results shown in Table 10, the estimated marginal effects from the model-simulated data are quantitatively close to their empirical counterparts, with all model-based estimates falling within or near the 95% confidence interval. In the data, when firm size decreases by one standard deviation, the marginal effects of foreign currency debt become more

[47] We standardize the log of short-term foreign currency debt, in line with our empirical analysis.

[48] In the empirical section, we do not normalize firm size, as our primary interest is in how strongly smaller firms are affected by short-term foreign currency debt exposure. The coefficient on ST FC captures the marginal effect for very small firms. Nonetheless, this is analogous to comparing the coefficients when firm size is normalized in both the empirical and model regressions. The empirical mean and standard deviation of firm size are 24.1 and 1.4, respectively.

Table 10: Firm Performance and FC Debt: Model vs. Data

	ΔNet Worth		ΔSales		ΔMarkup	
	Data	Model	Data	Model	Data	Model
ST FC	-5.6555***	-4.9960	-9.4335**	-7.9573	-10.1687**	-8.0556
	(1.5268)		(4.1259)		(4.8512)	
Size × ST FC	0.2269***	0.2032	0.3710**	0.3223	0.3980**	0.3263
	(0.0628)		(0.1651)		(0.1941)	
R^2	0.1571	0.2595	0.1881	0.2692	0.1536	0.2616

Notes: For each outcome variable, the left column shows the regression result from our empirical analysis. The right column shows the result from the model simulated data. We estimate $\Delta y_j = \beta_{I(j)} + \beta_1 \text{ST FC}_j + \beta_3 \text{Size}_j + \beta_4 \text{ST FC}_j \cdot \text{Size}_j + \beta_6 \text{X}_j + \epsilon_j$ using standardized firm size in the model. We use a firm's market share as a proxy for its markup in Section 3.3, as well as in Section7.2, where we compare model and data regressions. We then rescale the estimated coefficients β_1 and β_4, using the empirical mean and standard deviation of firm size. That is, we report $\beta_1^{scaled}$and β_4^{scaled}: $\beta_1^{scaled} = \beta_1 - \beta_4 \frac{Mean(Size)}{Std(Size)}$ and $\beta_4^{scaled} = \frac{\beta_4}{Std(Size)}$.

negative, by 0.31 percentage points for capital stock and 0.48 percentage points for liquid asset holdings. In the model, the corresponding effects are 0.63 and 0.20 percentage points, respectively.

Our model overpredicts the effect of capital adjustment but underpredicts the effect of working capital relative to what we observe empirically. These findings may suggest that the relatively muted response of industry-level prices could be related to the weak adjustment of firms' working capital. An alternative model assumption in which the cost of working capital increases more for firms with greater foreign currency debt exposure following the exchange rate depreciation as in Drenik and Perez (2021), may allow our model to better capture the response of working capital.

Table 11: Other Firm-level Outcomes and FC Debt: Model vs. Data

	ΔCapital		ΔLiquid Assets	
	Data	Model	Data	Model
ST FC	-5.4521***	-10.9556	-8.6206**	-3.5541
	(1.7197)		(4.0127)	
Size × ST FC	0.2184***	0.4517	0.3398**	0.1430
	(0.0706)		(0.1627)	
R^2	0.0216	0.2800	0.0632	0.2426

Notes: For each outcome variable, the left column shows the regression result from our empirical analysis. The right column shows the result from the model simulated data. We estimate $\Delta y_j = \beta_{I(j)} + \beta_1 \text{ST FC}_j + \beta_3 \text{Size}_j + \beta_4 \text{ST FC}_j \cdot \text{Size}_j + \beta_6 \text{X}_j + \epsilon_j$ using standardized firm size in the model. We then rescale the estimated coefficients β_1 and β_4, using the empirical mean and standard deviation of firm size. That is, we report $\beta_1^{scaled}$and β_4^{scaled}: $\beta_1^{scaled} = \beta_1 - \beta_4 \frac{Mean(Size)}{Std(Size)}$ and $\beta_4^{scaled} = \frac{\beta_4}{Std(Size)}$.

Lastly, using the firm-level model-simulated data, we confirm that the negative balance sheet effect puts upward pressure on firm-level prices, shown in Table 12. Firms with higher foreign currency debt exposure increase their prices more, and, moreover, smaller and more financially constrained firms increase their prices more than unconstrained firms with the same level of foreign currency debt exposure. Even with the same amount of short-term foreign currency debt exposure, larger firms are less financially constrained than smaller firms, and therefore their production is less restricted following an exchange rate depreciation. Consequently, the price increase is considerably more muted for these large unconstrained firms.

Table 12: Marginal Effect of Firm-level Short-term FC Debt Ratio on Firm-level Price Changes

	ΔPrice
ST FC	1.3806
Size × ST FC	-0.0550
R^2	0.3061

Notes: The dependent variable is the firm-level price changes computed with the model simulated data. We estimate $\Delta y_j = \beta_{I(j)} + \beta_1 \text{ST FC}_j + \beta_3 \text{Size}_j + \beta_4 \text{ST FC}_j \cdot \text{Size}_j + \beta_6 \text{X}_j + \epsilon_j$ using standardized firm size in the model. We then rescale the estimated coefficients β_1 and β_4, using the empirical mean and standard deviation of firm size. That is, we report $\beta_1^{scaled}$and β_4^{scaled}: $\beta_1^{scaled} = \beta_1 - \beta_4 \frac{Mean(Size)}{Std(Size)}$ and $\beta_4^{scaled} = \frac{\beta_4}{Std(Size)}$.

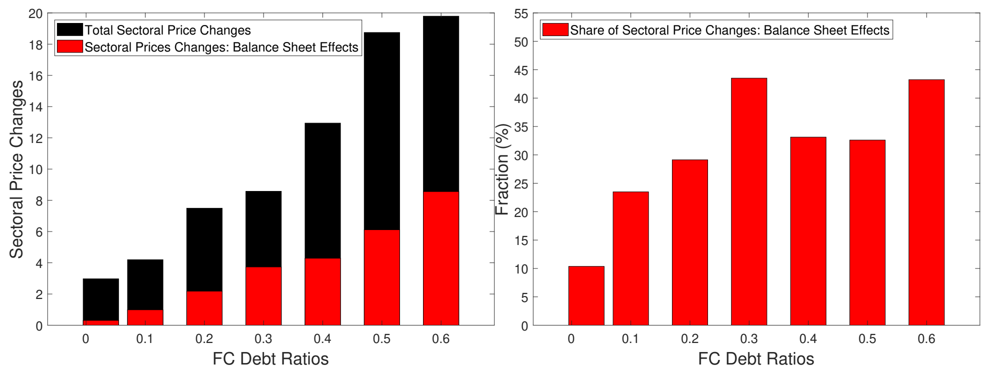
8 Counterfactuals: Quantifying Balance Sheet Effects

While the firm-level regression with simulated data shows that firms within the same sector experience *significantly larger* price increases due to their foreign currency borrowing, it is hard to infer how much of each sectoral price change can be attributed to the balance sheet channel once firms' strategic interactions within the industry are taken into account. Each sector faces a different firm-level distribution of foreign currency debt ratios and imported input shares, and both channels put upward pressure on sectoral prices, further amplified by firms' strategic complementarity in their pricing decisions. To quantify the role of the balance sheet channel of foreign currency debt in explaining sectoral price dynamics, we run a counterfactual exercise, assuming that the imported input price stays constant following a depreciation shock. That is, we set $\omega =$0.

We compute the average sectoral price changes across foreign currency debt ratios in the baseline model and in the counterfactual economy, shutting down the effect of the exchange rate shock on imported input prices. We group sectors with foreign currency debt ratios in $(0\%, 5\%)$, $[5\%, 15\%)$, $\ldots$, $[45\%, 55\%)$, $[55\%, 70\%)$. Figure 12 shows that the balance sheet effect of foreign currency debt alone explains around 10% to 44% of sectoral price changes observed in the baseline model. For an average industry with positive short-term foreign currency debt, 31% of sectoral price changes can be attributed to the balance sheet effect of foreign currency debt.

Alternatively, we turn off the balance sheet effect of foreign currency debt by assuming $\lambda = 0$ following the exchange rate depreciation, and then compute the average price changes explained by the imported input channel. We then quantify how much of the average sectoral price changes in the baseline economy *cannot* be accounted for by higher marginal costs due to imported inputs. We subtract the average sectoral price changes from the counterfactual exercise setting $\lambda = 0$ from the average price changes in the baseline economy to back out the balance sheet effects of foreign currency debt. As seen in Figure A6 in the Appendix, the results are very similar to what we have seen in Figure 12.

Figure 12: Counterfactual Exercise I: Quantitative Size of the Balance Sheet Effect at the Sector-level



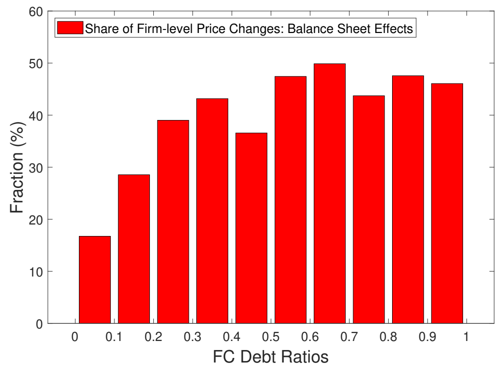
Notes: The figure plots the two sets of sectoral price changes: one computed in the baseline model and the other computed in the counterfactual model with $\omega = 0$, shutting down the effect of exchange rate shock on imported input prices. We group sectors with foreign currency debt ratios in $(0\%, 5\%), [5\%, 15\%), \dots, [45\%, 55\%), [55\%, 70\%)$. We first compute (i) the average sectoral price changes in the baseline model and (ii) that in the counterfactual exercise across sectoral foreign currency debt ratios. The figure on the left shows (i) in black bars and (ii) in red bars across sectoral foreign currency debt ratios. The figure on the right shows the ratio of (ii) to (i) across sectoral foreign currency debt ratios.

Furthermore, we quantify the share of the balance sheet effect that reflects the general equilibrium forces arising from strategic complementarity in price setting. We decompose the balance sheet effect of foreign currency debt on firm-level price changes into two components: *direct* effects from firms' own foreign currency debt exposure on their pricing decisions and the *general equilibrium* effects arising from firms strategically responding to *other firms' price changes* due to *other firms'* foreign currency debt exposure.

To compute the direct effect of foreign currency debt, we feed in the path of the exchange rate ξ, but hold the *sectoral price fixed* at the steady-state level, while muting the imported input channel (i.e., setting $\omega = 0$). This approach follows how Ottonello and Winberry (2020) quantify the general equilibrium effect in their model. It captures the effect of a firm's own foreign currency debt exposure on its own pricing decision. We then calculate the *general equilibrium* component of the balance sheet effect of foreign currency debt on firm-level price changes. To ensure comparability of firm-level price changes across different model economies, we normalize firm-level price changes relative to the average response of firms with zero foreign currency debt in the counterfactual economy that features only the balance sheet channel with the sectoral price fixed.

We compute, across foreign currency debt ratio bins, the average firm-level price changes in three model economies: the baseline economy; the counterfactual economy with only the balance sheet channel active; and the counterfactual economy with only the balance sheet channel active and sectoral prices held fixed. Shown in Figure 13, 17% to 50% of firm-level price changes can be

Figure 13: Counterfactual Exercise I: Quantifying Balance Sheet Effects of FC Debt at the Firm-level



Notes: The figure is plotted with the model-simulated firm-level price data. To ensure comparability of firm-level price changes across different model economies, we normalize firm-level price changes relative to the average response of firms with zero foreign currency debt in the counterfactual economy that features only the balance sheet channel, with the sectoral prices held fixed. We first compute (i) the average firm-level price changes in the baseline economy and (ii) those in the counterfactual economy with only the balance sheet channel active, across firm-level foreign currency debt ratio bins. The figure shows the ratio of (ii) to (i) for each foreign currency debt ratio bin.

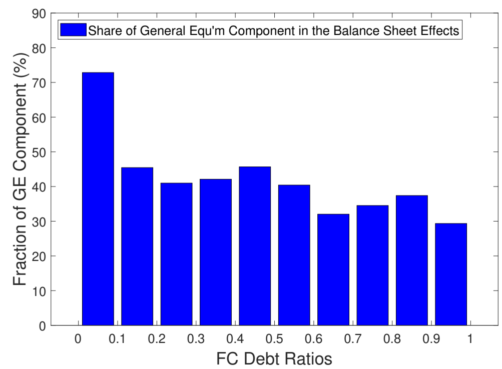
attributed to the balance sheet channel of foreign currency debt. These magnitudes are aligned with what we have shown with sector-level price changes in the baseline model and in the counterfactual economy, depicted in Figure 12. To compute the *general equilibrium* component of the balance sheet effect, for each foreign currency debt ratio bin, we subtract the average direct effect of a firm's own foreign currency debt exposure from the average firm-level price changes in the counterfactual economy with only the balance sheet channel active. The relative contributions of the direct vs. indirect components are shown in Figure 14, where 29% to 73% of the balance sheet effect of foreign currency debt is accounted for by strategic complementarity in firms' price setting.

In sum, we construct a heterogeneous firm model that links foreign currency debt and the exchange rate pass-through to domestic prices after a large depreciation. The model is able to account for the industry-level empirical patterns: larger price increases in industries with higher average foreign currency debt ratios. Moreover, from firm-level simulations, we confirm that the model captures key features of observed firm behavior after a large depreciation. The counterfactual exercise affirms the quantitatively sizable role of the balance sheet channel in explaining sectoral price dynamics and highlights the significance of strategic complementarity in firms' price setting.

9 Conclusion

Using a unique firm-level and aggregated industry-level dataset, our empirical findings suggest that the balance sheet channel of foreign currency debt, whose role is understudied in the exchange rate pass-through literature, plays an important role in explaining how the exchange rate affects

Figure 14: Counterfactual Exercise II: Share of General Equilibrium Effects in the Balance Sheet Effects of FC Debt



Notes: The figure is plotted with the model-simulated firm-level price data. To ensure comparability of firm-level price changes across different model economies, we normalize firm-level price changes relative to the average response of firms with zero foreign currency debt in the counterfactual economy that features only the balance sheet channel, with sectoral prices held fixed. The figure shows the share of the balance sheet effect accounted for by the general equilibrium forces arising from strategic complementarity in price setting. We first compute (i) the average firm-level price changes in the counterfactual economy with only the balance sheet channel active and (ii) those in the counterfactual economy with only the balance sheet channel active while sectoral prices are held fixed, across firm-level foreign currency debt ratio bins. The figure shows the ratio of (i) - (ii) to (i) for each foreign currency debt ratio bin.

domestic prices, especially for emerging economies with dollarized liabilities. During a large depreciation in Korea, we first find that firms indeed suffer from lower sales and net worth growth when they are indebted in foreign currency. The negative balance sheet effect is stronger for smaller firms, which are more financially constrained. Moreover, our firm-level analysis shows that their markups have *declined* more when indebted in foreign currency, especially for smaller firms.

We then find that industries populated by firms with higher foreign currency debt exposure raise their prices more following a large depreciation. The industry-level price responses are consistent with the findings from our firm-level analyses. When firms with high foreign currency debt exposure experience a larger deterioration of their balance sheets following the depreciation, the resulting tightening of financial constraints lowers their investment and working capital, raising the implicit and explicit costs of production and pushing their prices upward.

Based on these empirical findings, we build a quantitative heterogeneous firm model to study an industry equilibrium and its transition path following an unexpected exchange rate depreciation. We analyze the qualitative and quantitative implications of the financial frictions in explaining the average changes in sectoral prices and their dispersion. With the industry-specific firm-level distribution of foreign currency debt and the industry-specific imported input share, the model can explain around 24% of the mean effect of the foreign currency debt ratio on sectoral price changes and 19% of the variation in price changes across industries.

Moreover, we decompose the two distinct channels of exchange rate pass-through to domestic prices, the balance sheet channel and the imported input channel, and show that both are significant contributors to the sectoral price dynamics following the depreciation of the domestic currency. We find that on average, 31% of sectoral price changes and 40% of firm-level price changes can be attributed to the balance sheet channel of foreign currency debt. We also emphasize the role of strategic complementarity in price-setting in explaining these price responses. Approximately 29% to 73% of these balance sheet effects of foreign currency debt can be attributed to firms responding to the price changes of other firms.

Our empirical and quantitative analyses highlight the importance of incorporating balance sheet effects, an often overlooked channel, when studying how exchange rate fluctuations transmit to domestic prices in economies with dollarized liabilities. These findings carry policy implications for optimal monetary policy and the currency composition of external borrowings, which we leave for future research.

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Appendix

Data Sources

The following table summarizes the data sources of variables that we use in the empirical section.

Table A1: Data Sources

Data	Data Source	Note
Firm-level variables	KISVALUE	
Producer Price Index	Bank of Korea (1991 2000)	Base year of 2015
Consumer Price Index	Bank of Korea (1991 2000)	Base year of 2015
Imported Price Index	Bank of Korea	Base year of 2015
Rauch Classification	Rauch (1999)	4-digit SITC Rev. 2 commodities
Imported Input Share	Bank of Korea	Input-Output table
Price Stickiness	Nakamura and Steinsson (2008)	Median Frequency, Table 12

Data Cleaning

In the firm-level data (both in industry-level and firm-level regressions), we exclude observations with the following properties:

- Missing value of sales, total assets, total liability, and net worth
- Negative or zero value of sales, total assets, total liability
- Not included in manufacturing sector ($KSIC \in [10, 34]$)
- For short-term foreign currency debt exposure and long-term foreign currency debt exposure: (i) values greater than 1, and then (ii) the top 0.5 percent of the remaining distribution
- Foreign currency cash to total current assets ratio larger than 1
- Leverage (total debt to total assets ratio) greater than 10

In each of the firm-level regression analyses, we exclude firms whose dependent variables (e.g., sales growth, net worth growth, etc.) are above the top or below the bottom 1 percent of the distribution. We do not drop industries in a similar manner, as the number of industries we employ in the analysis is more limited. Nonetheless, all the results are robust to dropping the industries whose price changes are above the top 1 percent or below the bottom 1 percent of the distribution. These results are included in Table A16 in the Appendix.

Data Merging

Our analysis focuses on the manufacturing sector. A *sector* in our empirical analysis corresponds to the most narrowly defined group that the Bank of Korea uses to compute each PPI, which we will call a PPI industry classification. In other words, *a sector is a PPI industry classification*. All the matching work is done to merge data at the PPI industry-level.

Firm-Level Data Matching

In the KISVALUE dataset, each firm's industry is identified with a five-digit KSIC (Korea Standard Industrial Classification) code. There is no matching code available between KSIC codes and PPI industries. We manually map those two datasets. We map each KSIC code to the closest PPI industry classification. As a result, one PPI industry classification is now matched to none, one, or a few KSIC codes. Hence, those firms that have different KSIC codes mapped to the same PPI industry classification are now treated as if they are in the same sector. For each sector, S, we compute X_S, the weighted average of a firm-level variable of interest, x_i, as:

$$X_S = \sum_{i \in S} x_i \frac{y_i}{Y_S} \text{ and } Y_S = \sum_{i \in S} y_i$$

, where S is a sector (PPI industry classification) and y_i is firm i's size[49] and Y_S is the sum of y_is in sector S.

Rauch Classification

For each of the commodities at the 4–digit SITC Rev.2 level, Rauch (1999) defines whether it is a differentiated product or not. Following Affendy et al. (2010), we map each 4–digit SITC code to an ISIC Rev.3 code. This mapping means that one ISIC Rev.3 code is mapped to none, one, or a few 4–digit SITC codes. Then, following the United Nations' conversion table, we map each ISIC Rev.3 code to *one or more* ISIC Rev.4 codes. This implies not only that one ISIC Rev.3 code is mapped to one or a few ISIC Rev.4 codes but also that one ISIC Rev.4 code is now mapped to one or a few ISIC Rev.3 codes.[50] Next, we map each ISIC Rev.4 code to a KSIC Rev.10 code, following Kim (2008). In this mapping, exactly one ISIC Rev.4 code is matched with one KSIC Rev.10 code. From the above section, we describe that one PPI industry classification is mapped with none, one, or a number of KSIC Rev.10 codes. Hence, we now map one PPI industry classification to none, one, or a few 4–digit SITC Rev.2 codes.

[49]We use the log of real sales when computing firms' sales share to limit the effects of the outliers.
[50]This is an N:N matching.

For each commodity at the 4–digit SITC code Rev.2 level, we define a dummy variable that is equal to 1 if it is a differentiated product. Then, for each sector (PPI industry classification), we take the weighted average of those binary values, where the weights are the commodities' trade shares in 1996.[51] We define each sector's product as *differentiated* when this weighted average is above 0.5 and *homogeneous* otherwise.

Input-Output Table and Import Price Index

We use the 1995 Input-Output (IO) table from the Bank of Korea. We map each PPI industry classification to one or two closely related items in the IO table. [52] For each item j in the IO table, we compute the share of imported intermediate inputs in the total inputs (all intermediate inputs and value-added from labor and capital) used for the production of IO item j:

$$\textit{Imported Input Share}_j = \frac{\textit{Imported Input}_j}{\textit{Total Inputs}_j}$$

Then, for each PPI sector S, we compute the weighted average of those imported input shares across each item j, where the weight of item j is the total inputs used in the production of item j, divided by the total inputs used in the production of all items in sector S. This is essentially the same as the imported inputs used for the items in Sector S, divided by the total inputs used for the items in Sector S.

$$\begin{aligned}\textit{Imported Input Share}_S &= \sum_{j\in S} \textit{Imported Input Share}_j \times \frac{\textit{Total Input}_j}{\textit{Total Inputs}_S} \\ &= \frac{\sum_{j\in S} \textit{Imported Input}_j}{\textit{Total Inputs}_S} \\ \textit{,where Total Input}_S &= \sum_{j\in S} \textit{Total Inputs}_j\end{aligned}$$

Price Stickiness

We use the median frequency of price changes in Table 12 of Nakamura and Steinsson (2008) to measure price stickiness. We map each PPI industry classification to a broad group over which the price stickiness is measured in Table 12 of Nakamura and Steinsson (2008).[53]

[51] This is following Rauch's method. Each commodity's trade share is its imports and exports divided by the sum of total imports and exports of all the commodities in that sector. We implicitly assume that each commodity's importance in a sector is proportional to its trading volume.

[52] Since the IO table contains fewer and broader categories, we map PPI industries to IO items —not the other way around— and some PPI industries are therefore matched to the same IO item(s).

[53] In this mapping, the number of groups in Table 12 of Nakamura and Steinsson (2008) is much smaller, so many of PPI industries are matched to the same broad groups, over which the price stickiness is defined.

Additional Tables

Table A2: Ten Sectors with Highest FC Share of Short-term Debt

Sector	FC Share of Short-term Debt (%)
Naphtha	67
Sugars & starches	49
Nonferrous metal primary products	40
Gold & silver bullion	35
Other manufacturing products	33
Reinforced & reproduced wood	33
Bags & handbags	28
Other electronic components	24
Wooden products	23
Crude steel	23

Note: The table shows the top 10 industries with the highest FC share of short-term debt in 1996.

Table A3: Summary Statistics of Industry-level Control Variables

	Mean	*Stdev*	[Min,Max]	Corr with Short-term FC Debt Ratio
	(1)	*(2)*	(3)	(4)
Short-term FC Debt Ratio	10%	10%	[0%, 67%]	1
Long-term FC Debt Ratio	20%	13%	[0%, 53%]	0.4037
Import Share (%)	18%	12%	[0%, 60%]	0.4932
Rauch Dummy	0.82	0.38	[0, 1]	-0.3310
Price Stickiness	7.70	6.67	[4.07, 35.98]	0.1984

Notes: The table shows the summary statistics of industry-level control variables in 1996. Columns (1) and (2) show the average and standard deviation of each variable, respectively.

Table A4: Firm Performance and FC Debt
Alternative Definition of Foreign Currency Debt Exposure, FC Debt to *Total Debt*

	Net Worth Growth	Domestic Sales Growth	Markup Growth
	(1)	(2)	(3)
ST $FC_{TotalDebt}$	-8.7812**	-20.9089***	-19.7874**
	(3.6515)	(7.5414)	(9.2116)
LT $FC_{TotalDebt}$	-0.5494	-1.1446	-4.5357
	(1.3023)	(3.5995)	(3.9017)
Size	-0.0404***	-0.2313***	-0.3058***
	(0.0095)	(0.0284)	(0.0338)
ST $FC_{TotalDebt}$ x Size	0.3528**	0.8518***	0.8031**
	(0.1535)	(0.3130)	(0.3807)
LT $FC_{TotalDebt}$ x Size	0.0139	-0.7320**	-0.3450
	(0.1469)	(0.3672)	(0.3233)
Leverage Ratio	0.1714***	0.1332	0.3950**
	(0.0536)	(0.1174)	(0.1613)
Export to Sale Ratio	0.7730***	1.4394***	1.8872***
	(0.0820)	(0.2007)	(0.2580)
ST Debt Ratio	0.0290	0.1198	0.1094
	(0.0315)	(0.0937)	(0.1138)
FC Cash Ratio	-1.4048*	-2.8961**	-3.0300*
	(0.7832)	(1.2276)	(1.6365)
ST $FC_{TotalDebt}$ x ln(ST Debt)	-0.3738	-0.6315	-0.3880
	(0.2751)	(0.5150)	(0.6300)
LT $FC_{TotalDebt}$ x ln(LT Debt)	0.0175	0.8681***	0.6060**
	(0.1173)	(0.3076)	(0.2596)
Adjusted R^2	0.1555	0.1912	0.1593
N	3135	3135	3133

Notes: The dependent variables are the growth rates of net worth, domestic sales, and markups from 1996 to 1998. We use a firm's market share as a proxy for its markup. All the nominal series are deflated with the CPI. We use an alternative definition of the foreign currency exposure. Short-term foreign currency debt exposure is defined as the ratio of short-term foreign currency debt to *total debt*, and long-term foreign currency debt exposure as the ratio of long-term foreign currency debt to total debt. We include two-digit industry fixed effects. Robust standard errors are reported in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table A5: Firm Performance and FC Debt
Alternative Definition of Foreign Currency Debt Exposure, FC Debt to *Total Assets*

	Net Worth Growth	Domestic Sales Growth	Markup Growth
	(1)	(2)	(3)
ST FC_{TOAS}	-36.6359***	-54.7598**	-68.1333***
	(10.8123)	(23.7650)	(25.6737)
LT FC_{TOAS}	2.1096	4.7515	9.8417
	(4.3242)	(11.1394)	(13.0381)
Size	-0.0344***	-0.1973***	-0.2575***
	(0.0093)	(0.0276)	(0.0327)
ST FC_{TOAS} x Size	1.5222***	2.2801**	2.8390***
	(0.4582)	(1.0053)	(1.0877)
LT FC_{TOAS} x Size	-0.1287	-2.3309***	-2.2896**
	(0.5211)	(0.8308)	(0.8912)
Leverage Ratio	0.1729***	0.1382	0.2028
	(0.0495)	(0.1167)	(0.1489)
Export to Sale Ratio	0.7778***	1.4689***	1.8245***
	(0.0821)	(0.2006)	(0.2628)
ST Debt Ratio	0.0217	0.0380	0.0572
	(0.0305)	(0.0911)	(0.1082)
FC Cash Ratio	-1.3439*	-2.3057*	-2.9034*
	(0.7697)	(1.3807)	(1.7008)
ST FC_{TOAS} x ln(ST Debt)	-2.1795***	-2.4756	-2.8702
	(0.7698)	(1.7166)	(1.9207)
LT FC_{TOAS} x ln(LT Debt)	0.0621	2.2860***	2.0428***
	(0.3990)	(0.7616)	(0.7487)
Adjusted R^2	0.1574	0.1937	0.1524
N	3135	3135	3133

Notes: The dependent variables are the growth rates of net worth, domestic sales, and markups from 1996 to 1998. We use a firm's market share as a proxy for its markup. All the nominal series are deflated with the CPI. We use an alternative definition of the foreign currency exposure. Short-term foreign currency debt exposure is defined as the ratio of short-term foreign currency debt to *total assets,* and long-term foreign currency debt exposure as the ratio of long-term foreign currency debt to *total assets*. We include two-digit industry fixed effects. Robust standard errors are reported in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table A6: Firm Performance and FC Debt
Controlling for Five-Digit Industry FE

	Net Worth Growth	Domestic Sales Growth	Markup Growth
	(1)	(2)	(3)
ST FC	-5.7279***	-9.6019**	-11.1510**
	(1.6856)	(3.9780)	(4.6920)
LT FC	0.0960	0.1872	0.2513
	(0.7077)	(2.0475)	(2.3568)
Size	-0.0502***	-0.2791***	-0.3608***
	(0.0111)	(0.0305)	(0.0384)
ST FC x Size	0.2305***	0.3823**	0.4444**
	(0.0687)	(0.1591)	(0.1877)
LT FC x Size	-0.0400	-0.2320*	-0.2593*
	(0.0430)	(0.1212)	(0.1368)
Leverage Ratio	0.1456***	0.1057	0.1917
	(0.0561)	(0.1205)	(0.1548)
Export to Sale Ratio	0.7394***	1.3904***	1.7957***
	(0.0851)	(0.2020)	(0.2604)
ST Debt Ratio	0.0287	0.0464	0.0406
	(0.0363)	(0.1016)	(0.1207)
FC Cash Ratio	-1.8734*	-3.9079***	-4.7884***
	(0.9567)	(1.3612)	(1.5513)
ST FC x ln(ST Debt)	-0.2706**	-0.0643	0.0416
	(0.1071)	(0.1845)	(0.2367)
LT FC x ln(LT Debt)	0.0445	0.2674***	0.3027***
	(0.0323)	(0.0852)	(0.0929)
Adjusted R^2	0.1633	0.2257	0.2053
N	3092	3089	3089

Notes: The dependent variables are the growth rates of net worth, domestic sales, and markups from 1996 to 1998. We use a firm's market share as a proxy for its markup. All the nominal series are deflated with the CPI. We include five-digit industry fixed effects. Robust standard errors are reported in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table A7: Markup Growth for Firms with Zero FC Short-term Debt

	Markup Growth
	(1)
$D_{\text{ST FC=0}}$	0.2869***
	(0.0633)
LT FC	0.3610*
	(0.2009)
D_{size}	-0.1368
	(0.0845)
LT FC x D_{size}	-0.0878
	(0.2176)
Leverage Ratio	0.7490***
	(0.1564)
Export to Sale Ratio	1.6203***
	(0.2662)
ST Debt Ratio	-0.3533***
	(0.1037)
FC Cash Ratio	-4.5140***
	(1.4395)
ST FC x ln(ST Debt)	-0.6502
	(0.4054)
LT FC x ln(LT Debt)	0.0343
	(0.0521)
Adjusted R^2	0.0989
N	3134

Notes: The dependent variable is the growth rate of markups from 1996 to 1998. We use a firm's market share as a proxy for its markup. $D_{\text{ST FC=0}}$ is the dummy variable that is equal to one when firms' short-term FC debt in 1996 is zero and zero otherwise. D_{size} is the dummy variable that is equal to one when firm size is larger than its 95th percentile. We include two-digit industry fixed effects. Robust standard errors are reported in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table A8: Industry Price Dynamics and FC Debt
Accounting for Change in Number of Firms

	(1)	(2)
ST FC	0.6437***	0.5531***
	(0.2173)	(0.2060)
LT FC	-0.1920	-0.1830
	(0.1346)	(0.1363)
Size	0.0066	0.0023
	(0.0184)	(0.0183)
Export to Sale Ratio	-0.0169	-0.0413
	(0.1562)	(0.1526)
Leverage Ratio	0.3365**	0.3076*
	(0.1494)	(0.1645)
ST Debt Ratio	0.0929	0.1443
	(0.1176)	(0.1253)
FC Cash Ratio	0.4050	-0.1171
	(3.1391)	(3.2099)
Log Change in Number of Firms	1.0001**	1.0207*
	(0.4832)	(0.5382)
Rauch Dummy		-0.0020
		(0.0465)
Imported Input Share		0.2728
		(0.1675)
Degree of Price Stickiness		0.0327*
		(0.0167)
Adjusted R^2	0.4440	0.4515
N	156	156

Notes: This table shows the regression estimates from Equation (4) with the change in the number of firms in each sector as an additional control variable. The dependent variable is the growth rate of sectoral prices from 1996 to 1998. The main regressors are the sector-level short-term foreign currency debt exposure (ST FC) and the long-term foreign currency debt exposure (LT FC) in 1996. The number of firms in each sector is collected from the Korean Statistical Information Service (KOSIS). We include two-digit sector fixed effects. Robust standard errors are reported in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table A9: Industry Price Dynamics and FC Debt
Controlling for Imported Output Share

	(1)	(2)
ST FC	0.6255***	0.5717***
	(0.2083)	(0.2022)
LT FC	-0.1601	-0.1638
	(0.1364)	(0.1381)
Size	0.0031	0.0012
	(0.0163)	(0.0168)
Export to Sale Ratio	-0.0076	-0.0284
	(0.1569)	(0.1567)
Leverage Ratio	0.3158**	0.3072**
	(0.1384)	(0.1482)
ST Debt Ratio	0.0996	0.1287
	(0.1137)	(0.1204)
FC Cash Ratio	-0.8390	-1.0209
	(3.2153)	(3.2589)
Imported Output Share	0.2096**	0.1657
	(0.0901)	(0.1038)
Rauch Dummy		0.0106
		(0.0441)
Imported Input Share		0.2041
		(0.1769)
Degree of Price Stickiness		0.0250*
		(0.0150)
Adjusted R^2	0.4641	0.4608
N	156	156

Notes: This table shows the regression estimates from Equation (4) with the sectoral imported *output* share as an additional control variable. The dependent variable is the growth rate of sectoral prices from 1996 to 1998. The main regressors are the sector-level short-term foreign currency debt exposure (ST FC) and the long-term foreign currency debt exposure (LT FC) in 1996. We include two-digit sector fixed effects. Robust standard errors are reported in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table A10: Industry Price Dynamics and FC Debt
Domestic Firms Only

	(1)	(2)	(3)
ST FC	0.5862***	0.5808***	0.5602***
	(0.1386)	(0.1672)	(0.1587)
LT FC	-0.1370*	-0.1319*	-0.1336*
	(0.0794)	(0.0784)	(0.0778)
Size		0.0057	0.0025
		(0.0188)	(0.0192)
Leverage Ratio		0.3138**	0.2886*
		(0.1383)	(0.1518)
ST Debt Ratio		0.0247	0.0601
		(0.1077)	(0.1145)
FC Cash Ratio		-1.7904	-2.0874
		(4.5006)	(4.2077)
Rauch Dummy			0.0164
			(0.0477)
Imported Input Share			0.2298
			(0.1888)
Degree of Price Stickiness			0.0268*
			(0.0159)
Adjusted R^2	0.4157	0.4373	0.4365
N	155	155	155

Notes: This table shows the regression estimates from Equation (4) using a subsample of firms whose exports are zero. The dependent variable is the growth rate of sectoral prices from 1996 to 1998. The main regressors are the sector-level short-term foreign currency debt exposure (ST FC) and the long-term foreign currency debt exposure (LT FC) in 1996. We include two-digit sector fixed effects. Robust standard errors are reported in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table A11: Industry Price Dynamics and FC Debt
Alternative Definition of Foreign Currency Debt Exposure, FC Debt to *Total Debt*

	(3)	(4)	(5)
ST $FC_{TotalDebt}$	0.7497***	0.7598***	0.6780***
	(0.1597)	(0.2293)	(0.2099)
LT $FC_{TotalDebt}$	-0.0943	-0.4331	-0.4063
	(0.2991)	(0.3141)	(0.3288)
Size		0.0147	0.0120
		(0.0180)	(0.0196)
Export to Sale Ratio		0.0545	0.0414
		(0.1710)	(0.1614)
Leverage Ratio		0.3587**	0.3296*
		(0.1548)	(0.1744)
ST Debt Ratio		-0.1527	-0.1449
		(0.1463)	(0.1466)
FC Cash Ratio		-2.6870	-3.3565
		(2.4338)	(2.5768)
Rauch Dummy			0.0176
			(0.0486)
Imported Input Share			0.2549
			(0.1927)
Degree of Price Stickiness			0.0194
			(0.0231)
Adjusted R^2	0.4131	0.4452	0.4457
N	156	156	156

Notes: This table shows the regression estimates from Equation (4) using an alternative definition of foreign currency exposure. Short-term foreign currency debt exposure is defined as the ratio of short-term foreign currency debt to *total debt*, and long-term foreign currency debt exposure as the ratio of long-term foreign currency debt to total debt. The dependent variable is the growth rate of sectoral prices from 1996 to 1998. The main regressors are the sector-level short-term foreign currency debt exposure (ST FC) and the long-term foreign currency debt exposure (LT FC) in 1996. We include two-digit sector fixed effects. Robust standard errors are reported in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table A12: Industry Price Dynamics and FC Debt
Alternative Definition of Foreign Currency Debt Exposure, FC Debt to *Total Assets*

	(1)	(2)	(3)
ST FC_{TOAS}	1.8686***	1.6171***	1.4084***
	(0.4671)	(0.5555)	(0.5122)
LT FC_{TOAS}	-0.1756	-0.6506	-0.4908
	(0.6286)	(0.7393)	(0.7550)
Size		0.0120	0.0046
		(0.0165)	(0.0171)
Export to Sale Ratio		-0.0087	-0.0443
		(0.1641)	(0.1595)
Leverage Ratio		0.3219**	0.2903*
		(0.1523)	(0.1679)
ST Debt Ratio		-0.0028	0.0631
		(0.1258)	(0.1296)
FC Cash Ratio		0.9561	0.3937
		(3.0322)	(3.0606)
Rauch Dummy			-0.0041
			(0.0445)
Imported Input Share			0.2903*
			(0.1605)
Degree of Price Stickiness			0.0295
			(0.0180)
Adjusted R^2	0.4316	0.4372	0.4458
N	156	156	156

Notes: This table shows the regression estimates from Equation (4) using an alternative definition of foreign currency exposure. Short-term foreign currency debt exposure is defined as the ratio of short-term foreign currency debt to *total assets,* and long-term foreign currency debt exposure as the ratio of long-term foreign currency debt to *total assets*. The dependent variable is the growth rate of sectoral prices from 1996 to 1998. The main regressors are the sector-level short-term foreign currency debt exposure (ST FC) and the long-term foreign currency debt exposure (LT FC) in 1996. We include two-digit sector fixed effects. Robust standard errors are reported in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

We also use an alternative measure of sectoral foreign currency debt exposure instead of taking a weighted average of firm-level exposure. We define the sectoral short-term and long-term foreign currency debt exposure as:

$$\text{FC ST of Sector } S = \frac{\sum_{f\in S(f)} \text{FC ST Debt}_f}{\sum_{f\in S(f)} \text{Total ST Debt}_f}, \text{ and FC LT of Sector } S = \frac{\sum_{f\in S(f)} \text{FC LT Debt}_f}{\sum_{f\in S(f)} \text{Total LT Debt}_f}.$$

This is equivalent to a weighted average of each firm's short-term (long-term) foreign currency debt ratio, where the weight is the firm's share of total sector-level short-term (long-term) debt.

Table A13: Industry Price Dynamics and FC Debt
Alternative Aggregation I, Debt-Weighted Average

	(1)	(2)	(3)
ST FC	0.3382**	0.3590**	0.3131*
	(0.1636)	(0.1739)	(0.1646)
LT FC	0.0414	-0.0114	-0.0188
	(0.0943)	(0.0921)	(0.0884)
Size		0.0135	0.0058
		(0.0150)	(0.0160)
Export to Sale Ratio		-0.0718	-0.0971
		(0.1642)	(0.1584)
Leverage Ratio		0.3675**	0.3330**
		(0.1444)	(0.1654)
ST Debt Ratio		0.0851	0.1410
		(0.1154)	(0.1255)
FC Cash Ratio		-1.3302	-1.8078
		(3.2513)	(3.2500)
Rauch Dummy			-0.0009
			(0.0440)
Imported Input Share			0.3404**
			(0.1686)
Degree of Price Stickiness			0.0353*
			(0.0183)
Adjusted R^2	0.3847	0.4094	0.4268
N	156	156	156

Notes: This table shows the regression estimates from Equation (4) using an alternative aggregation of firm-level foreign currency exposure. We take the sum of short-term foreign currency debt and long-term foreign currency debt and normalize each by the corresponding sum of short-term and long-term debt. The dependent variable is the growth rate of sectoral prices from 1996 to 1998. The main regressors are the sector-level short-term foreign currency debt exposure (ST FC) and the long-term foreign currency debt exposure (LT FC) in 1996. We include two-digit sector fixed effects. Robust standard errors are reported in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table A14: Industry Price Dynamics and FC Debt
Alternative Aggregation II, Simple Average

	(1)	(2)	(3)
ST FC	0.6876***	0.6626***	0.5758***
	(0.1786)	(0.2184)	(0.2067)
LT FC	-0.1389	-0.2025	-0.1960
	(0.1253)	(0.1352)	(0.1361)
Size		0.0069	0.0030
		(0.0186)	(0.0184)
Export to Sale Ratio		-0.0204	-0.0415
		(0.1603)	(0.1569)
Leverage Ratio		0.3622**	0.3376**
		(0.1458)	(0.1593)
ST Debt Ratio		0.0722	0.1188
		(0.1162)	(0.1243)
FC Cash Ratio		0.8912	0.1377
		(3.4439)	(3.5287)
Rauch Dummy			0.0074
			(0.0446)
Imported Input Share			0.2761*
			(0.1655)
Degree of Price Stickiness			0.0310*
			(0.0167)
Adjusted R^2	0.4275	0.4467	0.4530
N	156	156	156

Notes: This table shows the regression estimates from Equation (4) using an alternative aggregation of firm-level foreign currency exposure. We measure a sector's short-term (long-term) foreign currency debt exposure as the simple, unweighted average of each firm's foreign currency share of short-term (long-term) debt across all firms in that sector. The dependent variable is the growth rate of sectoral prices from 1996 to 1998. The main regressors are the sector-level short-term foreign currency debt exposure (ST FC) and the long-term foreign currency debt exposure (LT FC) in 1996. We include two-digit sector fixed effects. Robust standard errors are reported in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table A15: Industry Price Dynamics and FC Debt
Subsample of Industries

	(1)	(2)	(3)
ST FC	0.4862**	0.5779**	0.4956**
	(0.2008)	(0.2529)	(0.2477)
LT FC	-0.2039	-0.2048	-0.1616
	(0.1530)	(0.1667)	(0.1695)
Size		-0.0145	-0.0219
		(0.0194)	(0.0185)
Export to Sale Ratio		0.0467	0.0414
		(0.1588)	(0.1508)
Leverage Ratio		0.3469**	0.2499
		(0.1461)	(0.1590)
ST Debt Ratio		-0.0444	-0.0406
		(0.2072)	(0.2028)
FC Cash Ratio		1.9991	1.7374
		(4.1867)	(4.0960)
Rauch Dummy			0.0076
			(0.0423)
Imported Input Share			0.3678**
			(0.1819)
Degree of Price Stickiness			0.0300
			(0.0187)
Adjusted R^2	0.4160	0.4360	0.4479
N	136	136	136

Notes: This table shows the regression estimates from Equation (4) using a subsample of sectors that have at least four firms. The dependent variable is the growth rate of sectoral prices from 1996 to 1998. The main regressors are the sector-level short-term foreign currency debt exposure (ST FC) and the long-term foreign currency debt exposure (LT FC) in 1996. We include two-digit sector fixed effects. Robust standard errors are reported in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table A16: Industry Price Dynamics and FC Debt
After Dropping Outliers

	(1)	(2)	(3)
ST FC	0.6338***	0.6722***	0.5376**
	(0.2239)	(0.2441)	(0.2278)
LT FC	-0.1564	-0.2245*	-0.2221
	(0.1219)	(0.1349)	(0.1368)
Size		0.0141	0.0088
		(0.0182)	(0.0181)
Export to Sale Ratio		-0.0574	-0.0695
		(0.1643)	(0.1591)
Leverage Ratio		0.3335**	0.2862*
		(0.1401)	(0.1572)
ST Debt Ratio		0.1179	0.1703
		(0.1135)	(0.1209)
FC Cash Ratio		-1.7927	-2.4333
		(2.4173)	(2.4438)
Rauch Dummy			0.0070
			(0.0441)
Imported Input Share			0.3095*
			(0.1698)
Degree of Price Stickiness			0.0352**
			(0.0170)
Adjusted R^2	0.3519	0.3750	0.3899
N	154	154	154

Notes: This table shows the regression estimates from Equation (4) after dropping outliers. We exclude industries whose price changes are in the top 1% and bottom 1% of the distribution. The dependent variable is the growth rate of sectoral prices from 1996 to 1998. The main regressors are the sector-level short-term foreign currency debt exposure (ST FC) and the long-term foreign currency debt exposure (LT FC) in 1996. We include two-digit sector fixed effects. Robust standard errors are reported in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table A17: Panel Regression

	(1)	(2)
ST FC	0.0074	0.0123
	(0.0265)	(0.0278)
LT FC	-0.0191	-0.0190
	(0.0160)	(0.0166)
ST FC $\times$dFX	0.4211**	0.5599***
	(0.1681)	(0.1906)
LT FC $\times$dFX	0.1967	0.1906
	(0.2442)	(0.2605)
Imported Input Share	-0.0149	-0.0220
	(0.0165)	(0.0177)
Size	-0.0086**	-0.0099**
	(0.0042)	(0.0046)
Export to Sale Ratio	0.0031	-0.0004
	(0.0201)	(0.0198)
Leverage Ratio	-0.0157	-0.0089
	(0.0214)	(0.0231)
ST Debt Ratio	0.0087	0.0139
	(0.0166)	(0.0176)
FC Cash Ratio	-0.0417	-0.0564
	(0.0526)	(0.0496)
Imported Input Share $\times$dFX		0.0830
		(0.1740)
Rauch Dummy $\times$dFX		0.1491*
		(0.0780)
Degree of Price Stickiness $\times$dFX		0.0042
		(0.0035)
Size $\times$dFX		-0.0073
		(0.0225)
Export to Sale Ratio $\times$dFX		-0.2665
		(0.1627)
Leverage Ratio$\times$dFX		-0.1364
		(0.2115)
Domestic ST Ratio$\times$dFX		0.0271
		(0.1908)
FC Cash Ratio$\times$dFX		0.2278
		(0.7283)
Adjusted R^2	0.2363	0.2451
N	3498	3300

Notes: This table shows the panel regression estimates from $\Delta p_{I,t} = \beta_I + \beta_t + \beta_1$ ST FC$_{I,t-1}$ + β_2LT FC$_{I,t-1}$ + $\beta_3 \Delta e_t \times$ ST FC$_{I,t-1}$ + $\beta_4 \Delta e_t \times$ LT FC$_{I,t-1}$ + β_5X$_{I,t-1}$ + $\epsilon_{I,t}$. The dependent variable is the annual growth rate of sectoral producer prices in year t. The exchange rate is defined as the Korean won price of the U.S. dollar. The main regressors are the interactions between the change in the exchange rate (dFX) and sectoral short-term foreign currency debt exposure (ST FC) as well as long-term foreign currency debt exposure (LT FC). We include sector and year fixed effects. Standard errors clustered at the sector level are reported in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table A18: Panel Regression, Appreciation vs. Depreciation

FX: KRW price of USD	Periods with dFX < 0	Periods with dFX > 0
	(1)	(2)
ST FC	-0.0447	-0.0094
	(0.0337)	(0.0309)
LT FC	-0.0215	0.0111
	(0.0247)	(0.0231)
ST FC $\times$dFX	-0.1408	0.8456***
	(0.5084)	(0.2353)
LT FC $\times$dFX	0.3100	0.0219
	(0.3205)	(0.4324)
Imported Input Share	-0.0561*	-0.0441
	(0.0326)	(0.0351)
Size	-0.0175***	-0.0112
	(0.0048)	(0.0073)
Export to Sale Ratio	-0.0174	0.0709**
	(0.0400)	(0.0283)
Leverage Ratio	-0.0311	-0.0191
	(0.0449)	(0.0407)
ST Debt Ratio	-0.0075	0.0153
	(0.0347)	(0.0256)
FC Cash Ratio	-0.0015	-0.0107
	(0.1063)	(0.0560)
Imported Input Share $\times$dFX	-0.4039**	0.3562
	(0.2030)	(0.3383)
Rauch Dummy $\times$dFX	0.1126	0.2224*
	(0.1416)	(0.1274)
Degree of Price Stickiness $\times$dFX	0.0103*	0.0057
	(0.0055)	(0.0068)
Size $\times$dFX	-0.1173**	0.0424
	(0.0518)	(0.0434)
Export to Sale Ratio $\times$dFX	0.1396	-0.7640**
	(0.4565)	(0.3368)
Leverage Ratio$\times$dFX	-0.6741	0.0346
	(0.4978)	(0.3632)
Domestic ST Ratio$\times$dFX	-0.2580	0.0601
	(0.3329)	(0.3300)
FC Cash Ratio$\times$dFX	2.0941	0.0603
	(1.2987)	(1.0167)
Adjusted R^2	0.2184	0.2719
N	1636	1662

Notes: This table shows the panel regression estimates from $\Delta p_{I,t} = \beta_I + \beta_t + \beta_1$ ST FC$_{I,t-1} + \beta_2$LT FC$_{I,t-1} + \beta_3 \Delta e_t \times$ ST FC$_{I,t-1} + \beta_4 \Delta e_t \times$ LT FC$_{I,t-1} + \beta_5$X$_{I,t-1} + \epsilon_{I,t}$ after dividing the sample into two sub-periods. The estimation results for KRW appreciation against the USD and KRW depreciation against the USD are reported in Columns (1) and (2), respectively. The dependent variable is the annual growth rate of sectoral producer prices. The exchange rate is defined as the Korean won price of the U.S. dollar. The main regressors are the interactions between the change in the exchange rate (dFX) and sectoral short-term foreign currency debt exposure (ST FC) as well as long-term foreign currency debt exposure (LT FC). We include sector and year fixed effects. Standard errors clustered at the sector level are reported in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

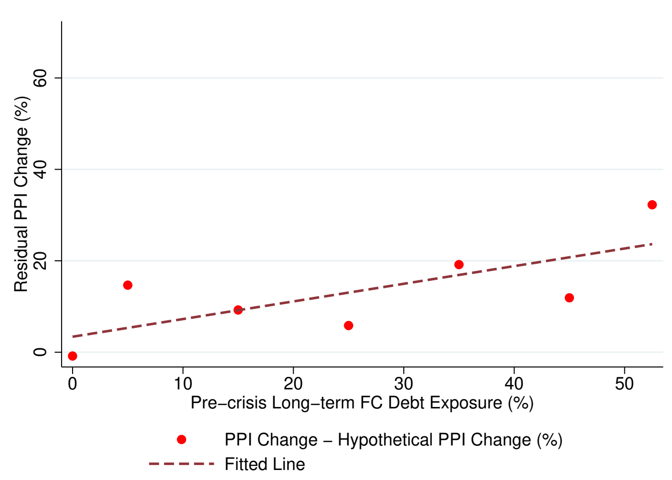
Table A19: Firm Performance and FC Debt
Exporters vs. Non-Exporters

	Domestic Sales Growth	
	(1)	(2)
ST FC	-8.6069**	-8.4576**
	(4.0502)	(3.9162)
ST FC x D_{Exporter}	-1.1125***	
	(0.2891)	
ST FC x Export to Sale Ratio		-2.3474***
		(0.6683)
LT FC	-0.5309	-0.7755
	(2.2887)	(2.2862)
Size	-0.2497***	-0.2553***
	(0.0279)	(0.0281)
ST FC x Size	0.3494**	0.3420**
	(0.1624)	(0.1569)
LT FC x Size	-0.2103	-0.2090
	(0.1348)	(0.1345)
Leverage Ratio	0.1407	0.1331
	(0.1145)	(0.1144)
Export to Sale Ratio	1.5685***	1.6476***
	(0.2198)	(0.2322)
ST Debt Ratio	0.0344	0.0365
	(0.0952)	(0.0949)
FC Cash Ratio	-2.9101***	-2.3009**
	(1.1225)	(1.1525)
ST FC x ln(ST Debt)	0.0555	0.0455
	(0.1765)	(0.1617)
LT FC x ln(LT Debt)	0.2767***	0.2866***
	(0.0855)	(0.0853)
Adjusted R^2	0.1929	0.1945
N	3135	3135

Notes: The dependent variable is the growth rate of domestic sales from 1996 to 1998. D_{Exporter} is equal to one when a firm is an exporter in 1996 and zero otherwise. We include two-digit industry fixed effects. Robust standard errors are reported in parentheses. * $p<0.1$, ** $p<0.05$, *** $p<0.01$.

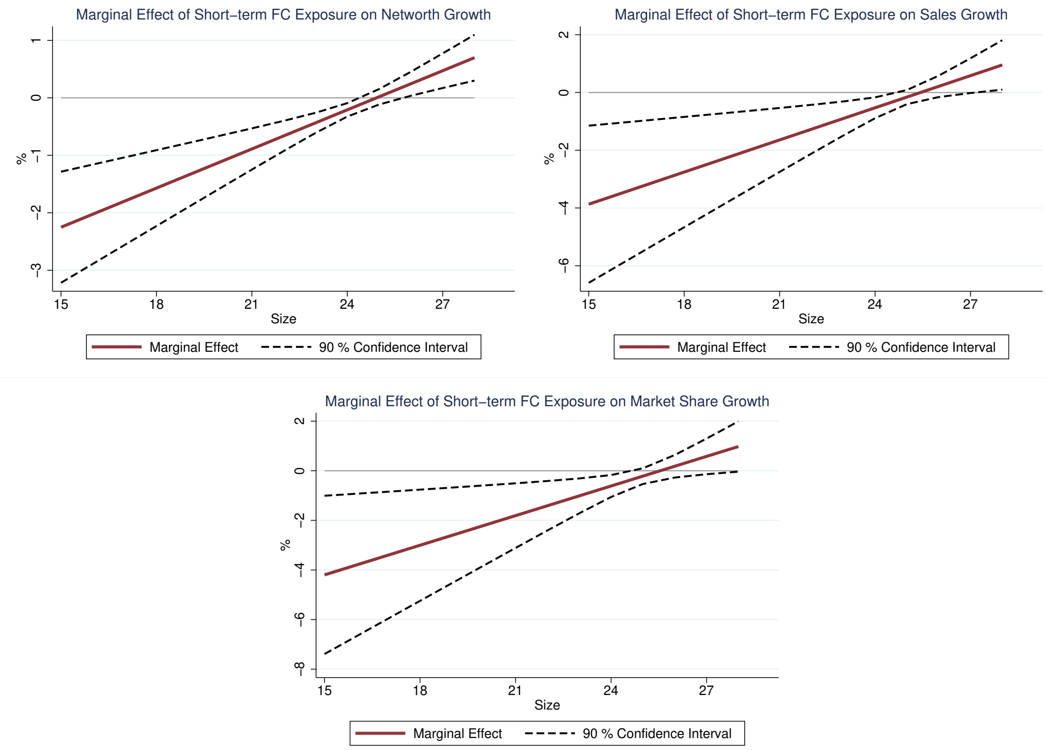
Additional Figures

Figure A1: Residual PPI Changes and Long-term FC Debt Exposure



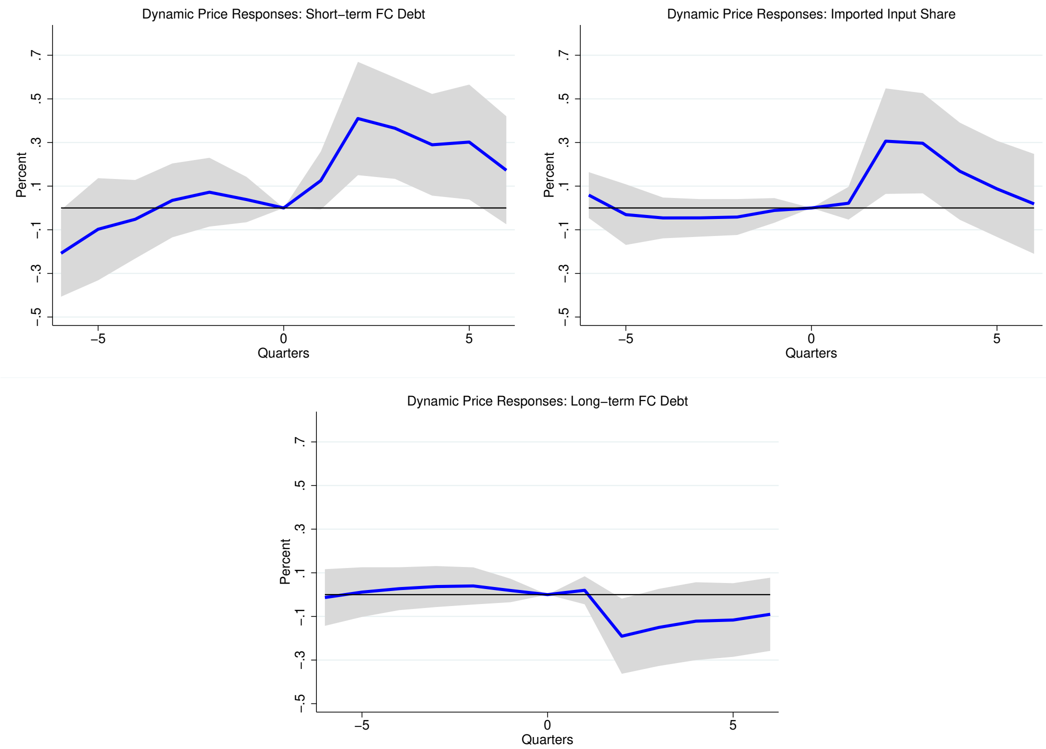
Notes: The residual PPI changes are the actual PPI changes in 1996-98 minus the hypothetical PPI changes implied from the imported input price changes, assuming a complete exchange rate pass-through of marginal cost shocks. We define seven equally-sized bins of long-term FC debt to long-term total debt ratio in 1996. For instance, the first bin includes sectors with a zero FC share of long-term debt, and the second bin contains sectors with a FC share of long-term debt between 0 and 0.1. The rest of the bins are defined similarly. We compute the mean of residual PPI changes over sectors in each bin.

Figure A2: Marginal Effects of Short-term FC Exposure on Firm-level Variables



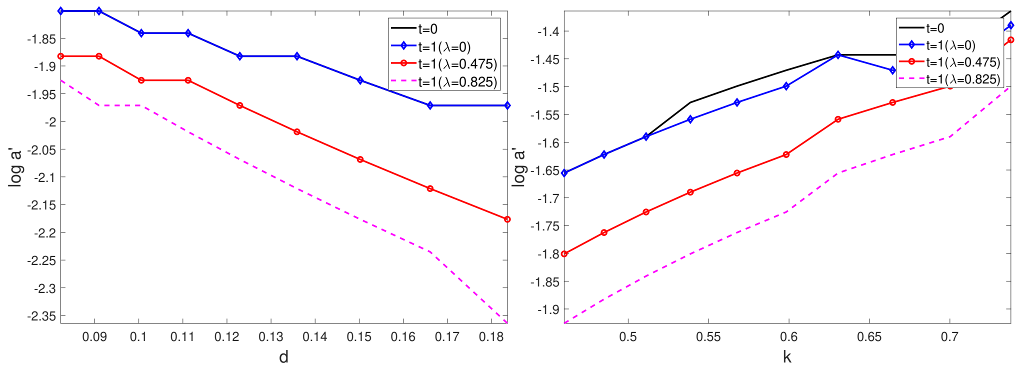
Notes: The solid red lines depict the marginal effects of short-term foreign currency debt exposure on firm-level variables across firm size. The navy dashed lines show the 90 percent confidence intervals of the marginal effects. The graphs are based on the results in Table 4.

Figure A3: Quarterly PPI Before and After the Depreciation of Korean Won



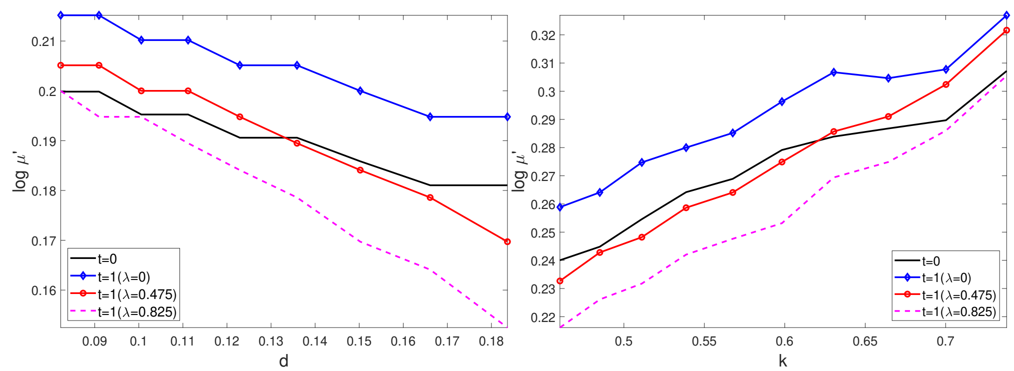
Notes: The figure plots the dynamic effects β_h of short-term FC debt exposure, long-term FC debt exposure and the imported input share on quarterly sectoral PPIs: $\frac{p_{I,1997Q3+h} - p_{I,1997Q3}}{p_{I,1997Q3}} = \beta_h + \beta_{1,h}\text{ST FC}_{I,96} + \beta_{2,h}\text{LT FC}_{I,96} + \beta_{3,h}\text{X}_{I,96} + \epsilon_{I,h}$. We include two-digit sector fixed effects. The area represents the 90% confidence intervals with robust standard errors.

Figure A4: a' against (i) d (Left) and (ii) k (Right).



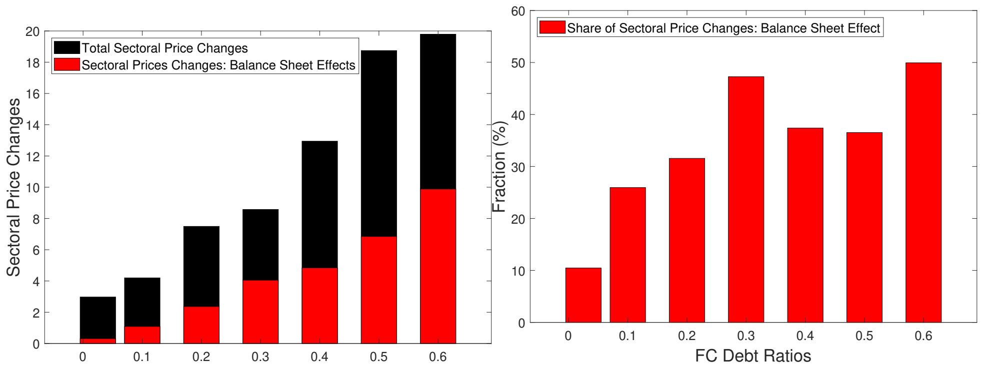
Notes: The solid black lines are the policy functions in the stationary equilibrium. The blue diamond lines, red circle lines, and dashed magenta lines are the policy functions for firms with 0, 0.475, and 0.825 of foreign currency debt ratio, respectively.

Figure A5: μ' against (i) d (Left) and (ii) k (Right).



Notes: The solid black lines are the policy functions in the stationary equilibrium. The blue diamond lines, red circle lines, and dashed magenta lines are the policy functions for firms with 0, 0.475, and 0.825 of foreign currency debt ratio, respectively.

Figure A6: Counterfactual Exercise
Quantitative Size of the Balance Sheet Effect at the Sector-level, Alternative Approach



Notes: The figure plots the two sets of sectoral price changes: one computed in the baseline model and the other computed in the counterfactual model with λ=0, shutting down the balance sheet effect of foreign currency debt following the exchange rate depreciation. We group sectors with foreign currency debt ratios in $(0\%, 5\%), [5\%, 15\%), \ldots, [45\%, 55\%), [55\%, 70\%)$. We first compute (i) the average sectoral price changes in the baseline model and (ii) that in the counterfactual exercise across sectoral foreign currency debt ratios. To back out (iii) the average sectoral price changes due to the balance sheet effect of foreign currency debt across sectoral foreign currency debt ratios, we subtract (ii) from (i). The figure on the left shows (i) in black bars and (iii) in red bars across sectoral foreign currency debt ratios. The figure on the right shows the ratio of (iii)/(i) across sectoral foreign currency debt ratios.

Productivity Shock Estimation

Estimation

Following Ackerberg et al. (2006), we assume the below production function in logs (variables with hat):

$$\hat{y}_{it} = \beta_k \hat{k_{it}} + \beta_\ell \hat{\ell}_{it} + \beta_m \hat{m}_{it} + \hat{z}_{it} + u_{it} \tag{18}$$

, where $\hat{y}_{it}$ is total output, $\hat{k}_{it}$ is capital stock, $\hat{l}_{it}$ is labor input, $\hat{m}_{it}$ is intermediate input, and $\hat{z}_{it}$ is a productivity shock that evolves according to a first order Markov process. Additionally, we assume that labor is "less variable" (chosen slightly before) than intermediate input $\hat{m}_{it}$.

$$\hat{m}_{it} = f_t(\hat{z}_{it}, \hat{k}_{it}, \hat{\ell}_{it}).$$

Then, we invert this function for $\hat{z}_{it}$ and substitute it into the value added production:

$$\hat{y}_{it} = \beta_k \hat{k}_{it} + \beta_\ell \hat{\ell}_{it} + \beta_m \hat{m}_{it} + f_t^{-1}(\hat{m}_{it}, \hat{k}_{it}, \hat{\ell}_{it}) + u_{it} \tag{19}$$

We can obtain an estimate of $\hat{\Phi}_{it}$, which represents the value added net of the unpredictable/untransmitted shock u_{it}:

$$\hat{\Phi}_{it} = \beta_k \hat{k}_{it} + \beta_\ell \hat{\ell}_{it} + \beta_m \hat{m}_{it} + f_t^{-1}(\hat{m}_{it}, \hat{k}_{it}, \hat{\ell}_{it}).$$

We approximate $f_t^{-1}(\hat{m}_{it}, \hat{k}_{it}, \hat{\ell}_{it})$ with a second-order polynomial function of $\hat{m}_{it}, \hat{k}_{it}, \hat{\ell}_{it}$. Given the first-order Markov assumption on $\hat{z}_{it}$, we have

$$\hat{z}_{it} = \mathbb{E}[\hat{z}_{it} | I_{i,t-1}] = \mathbb{E}[\hat{z}_{it} | \hat{z}_{i,t-1}] + \zeta_{it}$$

, where ζ_{it} is mean independent of all information known at time $t-1$. We then approximate $\mathbb{E}[\hat{z}_{it} | \hat{z}_{i,t-1}]$ with $\hat{z}_{i,t-1}$, its squared, and its cubed.

We then use the three moment conditions for the identification of β_k, β_l,and β_m:

$$\mathbb{E}[\zeta_{it} | \hat{k}_{it}] = 0$$

$$\mathbb{E}[\zeta_{it} | \hat{\ell}_{i,t-1}] = 0$$

$$\mathbb{E}[\zeta_{it} | \hat{m}_{i,t-1}] = 0.$$

Then, we back out the productivity shocks as:

$$\hat{z}_{it} = \hat{\Phi}_{it} - \hat{\beta}_k \hat{k}_{it} - \hat{\beta}_\ell \hat{\ell}_{it} - \hat{\beta}_m \hat{m}_{it}.$$

In our model, the output production function (in logs) is defined as

$$\hat{y}_{it} = \alpha\hat{k}_{it} + \kappa\hat{x}_{it} + (1 - \alpha - \kappa)\hat{n}_{it} + \hat{z}_{it} \tag{20}$$

where $\hat{k}_{it}$is capital stock, $\hat{x}_{it}$is imported intermediate input, $\hat{n}_{it}$is domestic input, and $\hat{z}_{it}$ is a productivity shock. When estimating productivity, however, firm-level data only allow us to separate labor input $\hat{l}_{it}$ and total intermediate input $\hat{m}_{it}$. As long as we assume (i) domestic input $\hat{n}_{it}$ as a composite of labor $\hat{l}_{it}$ and domestic intermediate input $\hat{d}_{it}$, i.e., $\hat{n}_{i,t} = \chi_1\hat{\ell}_{it} + (1 - \chi_1)\hat{d}_{it}$, and (ii) total intermediate input $\hat{m}_{it}$ as a composite of imported intermediate $\hat{x}_{it}$ and domestic intermediate $\hat{d}_{it}$, i.e., $\hat{m}_{i,t} = \chi_2\hat{x}_{it} + (1 - \chi_2)\hat{d}_{it}$, production function 20 can be expressed as a value added production function as in 18. Hence, the two production functions are equivalent for the purpose of estimating the productivity shocks.

Data

Table A20 summarizes a detailed description of the data used to estimate the productivity shocks to firms.

Table A20: Variables Used for Estimation: 1991-1996

		Data Used	Variable Descriptions
Total outputy_{it}	y_{it}= $ln((SALE_{it}) * 100/CPI_t)$	$SALE_{it}$	Sales
		CPI_t	Consumer Price Index
Capital k_{it}	k_{it}= $ln(K_{it}/CPI_t)$ $K_{i,t} = TOAS_{i,t} - LIQUID_{i,t} - INTR_{i,t}$ $LIQUID_{i,t} = CASH_{i,t} + STFI_{i,t} + AR_{i,t}$	$K_{i,t}$	Capital Stock
		$LIQUID_{i,t}$	Liquid Asset
		$INTR_{i,t}$	Inventory
		$CASH_{i,t}$	Cash and Cash Equivalents
		$STFI_{i,t}$	Short-term Financial Instruments
		$AR_{i,t}$	Account Receivables
		CPI_t	Consumer Price Index
Labor ℓ_{it}	ℓ_{it}= $ln(LCOST * 100/CPI_t)$	$LCOST$	Labor Cost
		CPI_t	Consumer Price Index
Raw Material Costs m_{it}	m_{it}= $ln(RCOST_{it} * 100/CPI_t)$	$RCOST_{it}$	Raw Material Costs
		CPI_t	Consumer Price Index

Model details

Functional form of Kimball demand

Following Gopinath and Itskhoki (2010), we assume the following functional forms:

$$\psi(x_j) = \left(1 - \epsilon \ln(\frac{\sigma x_j}{\sigma - 1})\right)^{\sigma/\epsilon} \text{ where } x_j = D_I \frac{p_j}{P_I}.$$

Then, the demand for an intermediate good produced by an entrepreneur j:

$$y_j = \left(1 - \epsilon \ln(\frac{\sigma x_j}{\sigma - 1})\right)^{\sigma/\epsilon} Y_I \text{ where } x_j = D_I \frac{p_j}{P_I}.$$

$$p_j = \frac{\sigma - 1}{\sigma} \exp\left(\frac{1}{\epsilon}\left(1 - (\frac{y_j}{Y_I})^{\epsilon/\sigma}\right)\right) \frac{P_I}{D_I}.$$

$$P_I = \int p_j \left(1 - \epsilon \ln(\frac{\sigma x_j}{\sigma - 1})\right)^{\sigma/\epsilon} dj$$

Using the Kimball aggregator, we introduce variable markups and would like to capture the strategic complementarity between firms' pricing decisions. FollowingGopinath and Itskhoki (2010), we do the first-order approximation of the industry price level.[54]

$$\ln P_I = \int \ln p_j dj.$$

The Kimball demand function faced by firms in industry I is therefore summarized as the following:

$$y_j = \left(1 - \epsilon \ln(\frac{p_j}{P_I})\right)^{\sigma/\epsilon} P_I^{-\nu}.$$

Recursive Formulation and Equilibrium

The aggregate state X_I is defined as

$$X_I = \{P_I, Y_I, \xi, \xi_{-1}\},$$

where P_I is the industry-level price, Y_I is the industry output, ψ_I is the distribution of firms, ξ is the exchange rate, and w is the price of domestic input. As aforementioned, the aggregate wage

[54]Gopinath and Itskhoki (2010) show that the first order deviation ofD_I from its steady state value $\bar{D} = \frac{\sigma-1}{\sigma}$ is zero.

and the domestic intermediate input price, denoted by w, are normalized to one. The Kimball demand function faced by firms in industry I, the production function and the capital adjustment cost function are summarized below:

$$(i)\ y = \left(1 - \epsilon \ln(\frac{p}{P_I})\right)^{\sigma/\epsilon} P_I^{-\nu},\ (ii)\ y = zk^{\alpha}x^{\kappa}n^{1-\alpha-\kappa},\ (iii)\ \Phi(k,k') = \frac{\phi}{2}(\frac{k' - (1-\delta)k}{k})^2 k,$$

Then, a continuing entrepreneur's problem is summarized as follows:

$$v_c(k,d,a,z,\lambda,\kappa;X_I) = \max_{c\geq 0,d',k',a',n,x,p} \frac{c^{1-\gamma}}{1-\gamma} + \beta E_{z'|z}[v(k',d',a',z',\lambda,\kappa;X_I')]$$

$$s.t.\quad (a)\ c + k' + \Phi(k,k') + a' + d\big((1-\lambda) + \lambda\frac{\xi}{\xi_{-1}}\big) = py - n - \xi^{\omega}x + (1-\delta)k + \frac{d'}{1+r} + 1$$

$$(b)\ \frac{1}{1+r}d' \leq \theta_k k', \quad (c)\ n + \xi^{\omega}x \leq \theta_a a,$$

The next period's value function $v(.)$ is a probability weighted average of the value function of continuing firms $v^c(.)$ and that of exiting firms $v^x(.)$.

$$v(k,d,a,z,\lambda,\kappa;X_I') = (1-\pi_d)v_c(k,d,a,z,\lambda,\kappa;X_I) + \pi_d v_x(k,d,a,z,\lambda,\kappa;X_I).$$

An exiting entrepreneur's problem is summarized as follows:

$$v_x(k,d,a,z,\lambda,\kappa;X_I) = \max_{c\geq 0,d',k',a',n,x,p} \frac{c^{1-\gamma}}{1-\gamma}$$

$$s.t.\quad (a)\ c = py - n - \xi^{\omega}x + (1-\delta)k + a - \Phi(k,0) - d\big((1-\lambda) + \lambda\frac{\xi}{\xi_{-1}}\big) + 1$$

$$(b)\ n + \xi^{\omega}x \leq \theta_a a,$$

Lastly, a new entrant's problem is summarized as follows:

$$\max_{d',k',a'} E_{z'}[v(k',d',a',z',\lambda,\kappa;X_I')]$$

$$s.t.\quad (a)\ k' + a' + \Phi(k_{ini},k') = k_{ini} + \frac{d'}{1+r}, \quad (b)\ \frac{d'}{1+r} \leq \theta_k k'$$

We define a recursive stationary industry equilibrium as (i) industry I's price P_I and output Y_I, (ii) a set of policy functions $\{d_c', k_c', a_c', c_c, n_c, x_c, y_c, p_c\}$ and value functions $v_c(k,d,a,z,\lambda,\kappa;X_I)$ for continuing firms, (iii) a set of policy functions $\{c_x, n_x, x_x, y_x, p_x\}$ and value functions $v_x(k,d,a,z,\lambda,\kappa;X_I)$

for exiting firms, (iv) a set of policy functions $\{d'_e, k'_e, a'_e\}$ for new entrants, and (v) a measure ψ_I on $(k, d, a, z, \lambda, \kappa)$ satisfying:

1. Policy and value functions solve the firm's optimization.
2. Industry output market clears.

$$\ln P_I = (1-\pi_d)\int \ln(p_c(k,d,a,z,\lambda,\kappa))d\psi_I(k,d,a,z,\lambda,\kappa) + \pi_d \int \ln(p_x(k,d,a,z,\lambda,\kappa))d\psi_I(k,d,a,z,\lambda,\kappa)$$

$$Y_I = \left((1-\pi_d)\int y_c(k,d,a,z,\lambda,\kappa)^{\sigma/\epsilon}d\psi_I(k,d,a,z,\lambda,\kappa) + \pi_d \int y_x(k,d,a,z,\lambda,\kappa)^{\sigma/\epsilon}d\psi_I(k,d,a,z,\lambda,\kappa)\right)^{\sigma/\epsilon}$$

3. Measure ψ_I is stationary and consistent with decision rules and exogenous processes.

Parameter Sensitivity Check

Table A21: Model Moment Sensitivity to A 1% Increase in Each Parameter Value

	Average $\frac{d}{k}$	Average $\frac{k}{y}$	Average $\frac{a}{k}$	Average ln(Markup)	IQR MKT Share	Average k_0 to Average k
θ_k	***1.16***	0.21	-0.14	0.00	-0.11	-0.28
θ_a	-0.01	0.01	***-0.79***	0.01	*-0.21*	-0.13
β	***-7.52***	***3.20***	-1.30	0.02	0.65	***-3.43***
ϵ	0.03	-0.02	0.03	0.02	***-0.31***	0.18
σ	0.00	0.39	-0.08	***-0.93***	***1.18***	-0.71
k_0	0.02	*0.14*	*-0.15*	0.00	-0.06	**0.93**

Notes: The table reports how a 1% increase in each parameter value changes the six model moments, holding other parameter values fixed. Std stands for standard deviation. The numerical simulation uses a 10% increase for θ_k, θ_a, β , and k_0, and a one-unit increase for ϵ and σ to generate a sufficiently meaningful absolute change in all the parameter values.

Table A21 reports information that helps assess the sources of identification in our calibration exercise. Specifically, it shows the local elasticity of the targeted moments with respect to the parameters chosen in our calibration, computed at the estimated parameter values. The resulting patterns are intuitive. First, a higher degree of the collateral constraint, θ_k, increases the amount of debt firms can borrow for a given level of the capital stock $\frac{d}{k}$. Second, an increase in the working capital constraint parameter θ_a allows firms to hire variable inputs with less liquid assets on hand, so the level of liquid assets relative to the scale of production $\frac{a}{k}$ declines. A higher discount factor β makes firms value future consumption more, which strengthens their incentive to invest; this is reflected in a higher capital to output ratio $\frac{k}{y}$ and higher net assets, so that $\frac{d}{k}$ decreases. An increase in k_0 naturally raises the ratio of the average capital of new firms to overall average capital. Finally, a higher super-elasticity ϵ implies lower dispersion in market shares, whereas higher elasticity of substitution σ is associated with lower average markups and larger dispersion in market shares.