Liability Dollarization and Exchange Rate Pass-Through to Domestic Prices

Junhyong Kim*
Annie Soyean Lee‡

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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 devaluation episode in Korea in 1997, we show that firms with higher foreign currency debt have indeed experienced balance sheet deterioration and faced lower growth rates of sales, net worths, and price-cost markups. We then empirically document that a sector populated by firms with higher foreign currency debt exposure prior to the crisis experienced a larger price increase. Building a heterogeneous firm model with financial constraints, we quantify the role of foreign currency liabilities in explaining the exchange rate pass-through to prices and find that 20% to 80% of the sectoral price changes during the crisis can be explained by the balance sheet effect of foreign currency debt alone. We emphasize the role of strategic complementarity in amplifying the sectoral price increase.

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

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

*Email: junkim3994@kdi.re.kr, Korea Development Institute.

†Email: annie.lee.econ@gmail.com, Johns Hopkins University.

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1 Introduction

The U.S. dollar hit a two-decade high in September 2022, having sharply appreciated by 16% since the beginning of the year.[1] Such sharp appreciation of the U.S. dollar concerned policymakers around the globe given the dollar's dominant role in international trade and finance. The pronounced increase of the dollar put even more pressure on the cost of living in many countries, including many emerging market countries, particularly those who rely on imported intermediate inputs in their production of goods and services.

On top of that, many emerging economies are alarmed by the rapid strengthening of the U.S. dollar, as their corporate sectors have high levels of dollar-denominated debt. The negative balance sheet effects of dollar debt upon the depreciation of emerging market currencies against the U.S. dollar could have a sizable impact on firms' activities, such as their net-worth, investment, and sales, which may, in turn, bring about significant macroeconomic consequences to emerging economies. While the negative balance sheet effect of foreign currency debt and its contractionary effect on the aggregate economy is widely studied both empirically and theoretically in the literature (Krugman (1999), Céspedes et al. (2004), Aguiar (2005), Kim et al. (2015), Bruno and Shin (2023) and Kalemli-Ozcan et al. (2016)), its very effect on prices–that is, domestic inflation– is pretty much neglected.

Given the prevalence of liability dollarization in emerging markets, we seek to answer two key questions in this paper. After a domestic currency depreciation, how do firms' price-setting decisions vary when they are more indebted in foreign currency? And, how much of the domestic producer inflation upon currency depreciation can be explained by much-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 but also via the deterioration of firms' balance sheets due to their exposure to foreign currency debt.

Before going into the details of how we tackle the proposed questions, we would like to highlight how the imported input channel, even under the assumption of a *complete* exchange rate pass-through of marginal cost shocks, falls short of generating the level of domestic producer price changes that we see in the data during large depreciation episodes.[2] In Table 1, for each country, we compute a marginal cost increase due to the higher imported input price during the crisis by multiplying changes in import price indices with the pre-crisis level of imported intermediate input share. Under the assumption of a complete exchange rate pass-through of higher marginal costs,

[1]The real broad effective exchange rate for the United States has increased by 16.7% in September 2022 since the start of the year.

[2]We also assume a production function with a constant return to scale.

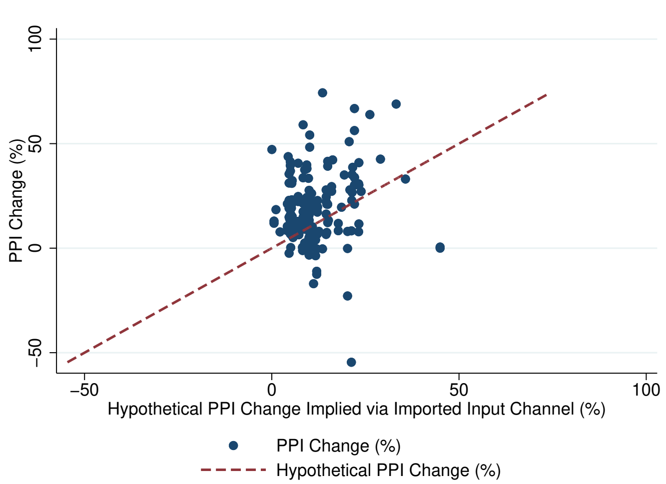
Table 1: PPI Changes vs. Hypothetical PPI Implied via Imported Input Channel

	Crisis Year	Import Price Index Changes (%)	Imported Input Share (%)	MC Changes Due to Import Price Changes (%)	PPI Changes (%)
Brazil	1999	64.08	6.0	3.84	33.00
Mexico	1994	165.39	13.2	21.87	47.11
Korea	1997	40.37	15.0	6.0555	16.46
Thailand	1997	20.09	22.0	4.43	17.86
Argentina	2002	169.87	6.1	10.39	122.22

Notes: All the price changes are percentage price changes from one year prior to the crisis to one year after. Marginal cost (MC) changes are computed by multiplying imported input price index changes by imported intermediate input share in the total inputs (both domestic and imported intermediate inputs and value-added from labor and capital) prior to the crisis, as we assume a production function with a constant return to scale. Due to data availability, we have used the imported input share of 1995 for Mexico, one year after the crisis. For Korea, we used the imported input share of 1995, two years prior to the crisis. The rest of countries' imported input shares are from one year prior to the crisis. Import price indices are from Burstein et al. (2005), and PPI changes are from the IMF International Financial Statistics (IFS). The imported input share is computed from the input-output table from the OECD Statistics. The country sample is identical to that of Burstein et al. (2005).

the domestic producer prices would change by the equivalent amounts.[3] However, in the data, we observe a much larger response in domestic producer prices.

Figure 1: PPI Changes vs. Hypothetical PPI Changes



Notes: A dot represents a narrowly defined manufacturing sector in our analysis. The y-axis is the sectoral PPI changes in 1996-98. The x-axis is the hypothetical PPI changes implied via the imported input channel, which we compute as the product of each imported input's price increase from 1996-98 and its share in the production. The dots above the 45-degree line are the sectors with higher realized PPI changes in 1996-1998 than what's implied from the imported input price changes, assuming a complete exchange rate pass-through of higher marginal costs.

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

Moreover, Figure 1 shows that during the Asian Financial Crisis in 1997 most of the narrowly defined manufacturing sectors in Korea, experienced a much more pronounced increase in domestic producer prices than what's expected – under the assumption of a complete exchange rate pass-through– from higher marginal costs due to higher imported input costs.[4] More than 70% of sectors have larger price increases than the hypothetical PPI changes implied by the imported input channel, even when assuming a 100% pass-through of higher imported input costs to prices.

In fact, what is even more intriguing is that the residual PPI changes that are unexplained by the imported input channel–i.e., the PPI changes minus the hypothetical PPI changes implied via the imported input channel –are strongly positively correlated with the pre-crisis level of foreign currency (FC) short-term debt to the total short-term debt ratio, as shown in Figure 2. In Figure 2, we define seven bins such that the first bin includes sectors with a zero FC share of short-term debt, and the rest are six equally-sized bins of the FC share of short-term debt. For instance, the second bin contains sectors with a FC share of short-term debt between 0 and 0.1. We then compute the mean of residual PPI changes over sectors in each bin. We see that those sectors with a higher foreign currency share of short-term debt on average have higher residual PPI changes, a portion of PPI changes unexplained by the imported input channel. This finding strongly supports the relevance and the significance of our channel in explaining domestic price dynamics. These empirical observations from back-of-the-envelope calculations–across countries and across sectors in Korea–suggest to us that there is a missing channel under-explored in the literature, and we argue that the balance sheet deterioration due to firms' foreign currency debt exposure upon a large depreciation can account for the much-pronounced increase in domestic producer prices after the depreciation of domestic currency.

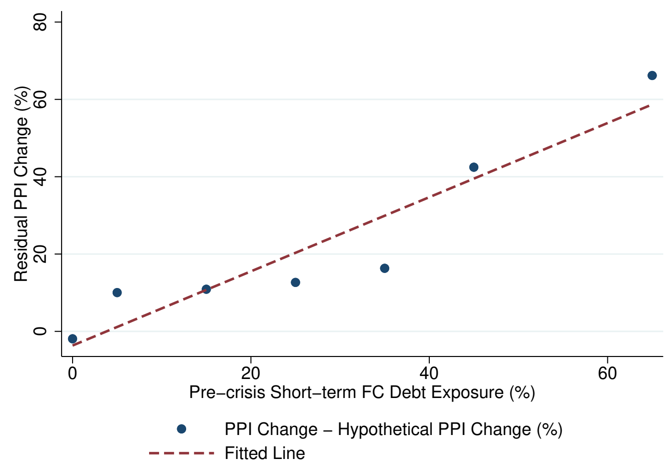
In this paper, exploiting a large unexpected devaluation episode in Korea during the Asian Financial Crisis in 1997, we explore the balance sheet effect of foreign currency borrowing on the domestic price dynamics. After the devaluation, the price of a dollar in Korean won increased from around 800 to 1695 won in December 1997, adopting a free-floating exchange rate regime, and the average PPI increased more than 1.2 fold, as depicted in Figure 3.[5] The currency crisis in Korea mostly caught market participants off guard.[6] On top of that, financial hedging against foreign

[4]Each sector has varying levels of marginal cost increase due to higher imported input prices as (i) each imported input price has increased by unequal magnitudes, and (ii) each sector uses a different amount of *each* imported input in its production. On top of that, each sector has a different share of total imported inputs in their total inputs used, which determines the marginal cost changes from the overall imported input price changes.

[5]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.

[6]During his visit to the Bank of Korea in September 1997, the BIS chair, Alfons Verplaetse, said: "Korea has strong fundamentals, unlike Latin American countries and Thailand; therefore, the probability of Korea facing a currency

Figure 2: Residual PPI Changes and Pre-crisis Short-term FC Debt Exposure



Notes: The residual PPI changes are the actual PPI changes in 1996-1998 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 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.

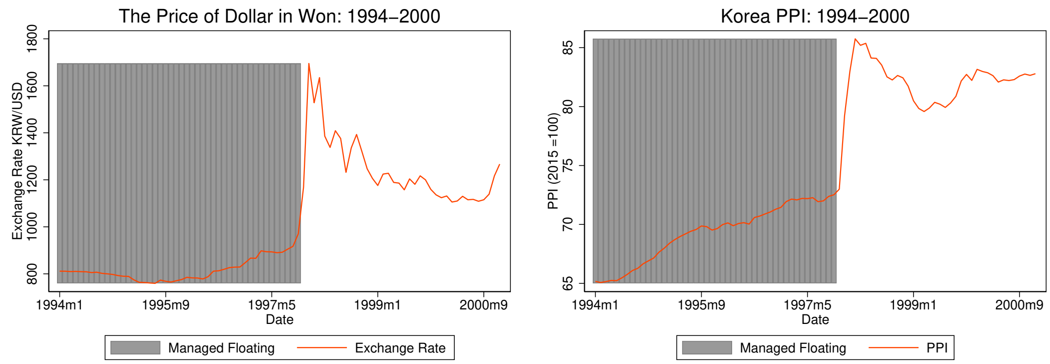
exchange risk was barely existing as the exchange to trade financial derivatives was established in 1999 in Korea after the Asian Financial Crisis. More than 97% of FX transactions in Korea before the devaluation were trading spot exchange rate contracts. Consequently, most of these loans were extended to firms without foreign exchange hedging. Firms' accumulation of *un-hedged short-term FC liabilities*, together with an unexpected large depreciation gives us a good quasi-natural experiment environment to identify the negative balance sheet effect on firms' price settings.

Identifying the negative balance sheet effect of dollar debt, we employ a unique dataset that merges the Korean firm-level balance sheet data with industry producer price indices. Most importantly, we construct the industry-level foreign currency debt exposure across manufacturing industries from firm-level balance sheet data. We employ the industry-level foreign currency debt exposure, computed by the weighted average of each firm's foreign currency share of short-term debt with its sales as weights. The Korean firm-level balance sheet data are conducive to our identification in that (1) the dataset contains information about the maturity and the currency composition of firms' debt; (2) it contains not only large listed firms but also small and medium-size firms, so it would not under-report the foreign currency exposure of industries populated by smaller firms; and (3) it contains a large set of other firm-level variables, such as firm-level exports and foreign currency liquid assets, which allows us to mitigate concerns about potential endogeneity bias.

With rich information on firm-level variables of our novel dataset, we first investigate whether

crisis is abysmal."

Figure 3: 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.

and to what extent firms with higher short-term foreign currency debt exposure have experienced the deterioration of their balance sheets. Our empirical results corroborate the negative balance sheet effects of foreign currency debt, documented in the existing literature; firms with higher short-term foreign currency debt exposure experienced lower growth of their net worth, which in turn, constrained their production, decreasing sales growth of those firms. The negative balance sheet effects on sales and net worth growth are smaller as the firm size is larger. We then examine how firms' estimated price-cost markups have changed during the devaluation period when they are more indebted in foreign currency. Firms with a higher foreign currency share of short-term debt faced lower markup growth. The deterioration of their balance sheet due to foreign currency debt exposure constrains firms' production, lowering their market share and their markups. The negative effect of short-term foreign currency debt on markups is smaller as the firm size is larger. Moreover, we find that the negative balance sheet effect of dollar liability on firm-level variables was non-existent before the devaluation, further confirming that the empirical results are not driven by some spurious relationships or pre-trends in firm-level variables across short-term foreign currency debt exposure. In sum, firms with short-term debt more tilted to foreign currency indeed have experienced a sharp decline in their net worth and sales, and the plunge in their market shares and, consequently, their price-cost markups.

Analyzing the industry-level price dynamics during the devaluation, we find that industries with higher short-term foreign currency debt exposure increased their prices from 1996 to 1998 more than those with lower short-term FC debt exposure. Specifically, one percentage point increase in industry-level foreign debt exposure leads to a 0.57 percentage point increase in price change. The sectoral price responses during a large depreciation episode are heterogeneous depending on their foreign currency exposure, which generates the relative price divergence. The industry-level price response is consistent with what we would expect from firm-level responses: when firms with more foreign currency debt face higher debt burden upon devaluation, constraining their production of goods, they lower their sales, increasing the price of goods sold.

These heterogenous 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 other firm-level variables such as firm size, *exports to sales ratio*, leverage ratio, domestic short-term debt to total debt ratio, and *foreign currency cash to total current assets ratio*. Broader sector fixed effects are also included to control for some industry-level demand shocks during this period and unobservable characteristics of industries. The positive and persistent effects of short-term FC debt exposure on sectoral producer prices upon a large drop in the value of Korean won are saliently shown when exploring the monthly price responses before and after September 1997. We clearly see that the effect of dollar liability on producer prices was non-existent before the devaluation, further confirming that the empirical results are not driven by the pre-devaluation trends in prices across sectors.

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 balance sheet channel in shaping the price dynamics across industries. We build a model where heterogeneous firms owned by entrepreneurs produce differentiated goods with the labor, 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 (i) the *industry-specific firm-level* distribution of foreign currency debt share and (ii) the *industry-specific* imported input share common across all firms in the same industry. Both of them are disciplined by their empirical counterparts. Each firm faces a financial constraint on how much debt they can issue, where the maximum amount that they can borrow is less than a fraction of the value of physical capital. In addition, each firm faces a working capital constraint on the amount of wages and foreign input costs. In our model, currency depreciation inflates the domestic value of foreign-denominated debt, increasing each firm's debt burden. Consequently, firms lower their liquid asset holdings and face tighter working capital constraints in the next period, which induces higher effective marginal costs. Furthermore, firms face tighter financial constraints reduce their investment, which lowers their labor productivity in the next period and leads to higher production costs. Both margins make firms that have borrowed substantially in foreign currency charge higher prices. These effects are more pronounced when the financial constraints are more binding.

With the calibrated model, we find that the balance sheet effect of foreign currency debt explains a substantial share of the sectoral price dynamics after the devaluation. First, we find that around 30% of the observed mean effect of the foreign currency debt share on the sectoral price change can be explained. Our estimated model can explain around 21% of the variation in price changes across industries. With the simulated firm-level data, we decompose the two distinct channels of exchange rate pass-through—the balance sheet channel and the imported input channel —at the firm level. We show that firms increase their prices and reduce their markups as they have higher foreign currency debt exposure, especially when they are financially constrained, consistent with the empirical relationships documented. We also highlight the role of both strategic complementarity and tighter financial constraints in explaining the price dynamics across firms after a large exchange rate depreciation.

A counterfactual exercise quantifies the role of the balance sheet channel in the price dynamics upon a depreciation shock. We find around 20% to 80% of the sectoral price changes after the devaluation can be explained by the balance sheet effect of foreign currency debt alone, conditional on borrowing in foreign currency. In fact, 36% to 74% of the balance sheet effect of foreign currency debt can be attributed to strategic complementarity in firms' price setting, i.e., general equilibrium effects from firms strategically responding to *other firms'* price increase due to *other firms'* foreign currency debt exposure. The quantitative importance of the balance sheet channel of foreign currency debt in explaining heterogenous sectoral price dynamics, which creates a relative price divergence, has an important implication for the optimal monetary policy, especially for emerging economies with dollarized liabilities.

The rest of the paper is organized as follows. The next section describes the related literature and how our work complements the previous research. Section 3 outlines our data and shows summary statistics of firm-level and aggregate industry-level data that we employ. This section also presents the results of our empirical analyses studying sectoral price dynamics and firm-level performance after the devaluation depending on the exposure to the foreign currency debt. Section 4 presents our heterogeneous firm model. Section 5 calibrates our model to study the qualitative and quantitative role of the balance sheet channel in shaping price dynamics across industries, and Section 6 studies the model mechanism using each individual firm's policy functions. Section 7 compares the patterns of the model-simulated data with its empirical counterparts. Section 8 quantifies the role of balance sheet effects of dollar debt in driving the 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.

In the literature, the degree of exchange rate pass-through to prices is extensively studied (see an extensive survey of this topic in Burstein and Gopinath (2014)). 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 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. Investigating the balance sheet effect of dollar debt upon a devaluation of domestic currency, this paper identifies an under-explored channel of how the exchange rate shock passes through to 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 during the devaluation episodes 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 provides an additional factor–the balance sheet channel of dollar 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).[7] 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.[8] Moreover, Kohn et al. (2020) and Bruno and Shin (2023) study the role of firms' foreign currency debt holdings and their exports. 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

[7] Casas et al. (2023) explore how the exchange rate affects exports and imports through the financial channel using the Colombian customs data.

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

debt exposure and price dynamics, this paper provides another important aggregate implication–price dynamics during a large devaluation episode.[9]

There are several papers that investigate the determination of the currency denomination of corporate borrowing in emerging economies. Salomao and Varela (2018) 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. (forthcoming), Hardy and Saffie (forthcoming) 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 from business operations. We take the distribution of foreign currency debt holdings prior to the devaluation 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

The Korean currency crisis of 1997 caught market participants by surprise, given the reassurances about the country's strong fundamentals by political leaders and policymakers in Korea and around the globe. Moreover, financial hedging against foreign exchange risk was nearly nonexistent at the time, as the exchange to trade financial derivatives was established only in 1999. The *unexpected* devaluation, combined with firms' accumulation of *unhedged* short-term foreign currency liabilities, provided a good quasi-natural experiment to identify the negative balance sheet effect on firms' activities.[10]

Exploiting a sharp and largely unexpected depreciation episode during the Asian Financial Crisis, we first show that firms indeed experienced balance sheet deterioration when more indebted in foreign currency short-term debt. We then empirically investigate how an industry populated by firms with higher foreign currency short-term debt exposure changes its price compared to other industries upon a large depreciation.

[9]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 working paper by Ma and Schmidt-Eisenlohr (2023), contemporaneous work to our paper, explores a similar channel in the exchange rate pass-through to export prices with the country-level FC debt exposure and its aggregate export price index.

[10]Lyonnet et al. (2022) explore the role of financial hedging in shaping the invoicing currency choice of exporters.

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 of over 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.[11] The data are then compiled by the KIS.[12] As shown in Kim et al. (2015), the dataset coverage of firms is extensive, and firm-level data exhibit the patterns consistent with aggregate macroeconomic dynamics.[13]

As previously mentioned, 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.[14] One thing we would like to emphasize is that foreign currency debt does not include trade credit, such as foreign currency accounts payable for their imported inputs. The relationship we document later in this section is therefore not capturing a spurious correlation of 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. We employ the short-term and long-term foreign currency debt exposure as 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 – prior to a large depreciation in order to capture the degree of firms' balance sheet deterioration after an exchange rate shock. As we show in Sections 3.2 and 3.3, our results are robust to an alternative way of defining indebtedness in foreign currency debt.

In our KISVALUE dataset, each firm's industry is identified with a five-digit KSIC code (Korea Standard Industrial Classification). Since our main variable of interest is the producer price index (PPI) at the sector-level–a four-digit industry code that the Bank of Korea uses to classify each sector–we first map each KSIC code to the closest PPI industry classification.[15] Then, we aggregate all the firm-level variables at the sector level, where each sector is an industry defined by the Bank of Korea for its PPI classification. A *sector* in our empirical analysis corresponds to a four-digit industry defined by the Bank of Korea for its PPI.

We measure a sector's short-term foreign currency debt exposure as the weighted mean of each

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

[12] All the balance sheet information after 2000 are publicly available at http://dart.fss.or.kr/.

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

[14] Bonds are not included in the data.

[15] There is no matching code between KSIC codes and PPI industry classification; so, we manually map these two datasets. 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.

firm's short-term foreign currency debt to its total short-term debt ratio with their sales share in the sector as weights.[16] Hence, a sector with higher foreign currency exposure refers to a sector consisting of more firms that have a higher foreign currency share of short-term debt. Other industry-level variables aggregated from the firm-level data are defined similarly.

Table 2 presents the summary statistics of firm-level foreign currency debt exposure. It is noticeable that 52.1% of firms held foreign currency debt and 42.2% of firms held short-term foreign currency debt in 1996 because that indicates that it is not just a few large firms holding foreign currency debt. 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 was 15.6% in 1996. In 1996, looking at both the extensive and intensive margins of foreign currency debt issuance, a large fraction of firms borrowed in foreign currency, and a substantial fraction of the total debt was denominated in foreign currency, given that a firm issues its foreign currency debt. In Table 3, 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 strongly positively correlated with the foreign currency short-term 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 have a positive relationship with the foreign currency share of short-term debt, the size of correlation is much smaller. Nonetheless, we control for all these firm-level variables in the firm-level regressions and the weighted average of them in the sectoral-level regressions.

Table 2: Firm-level Summary Statistics: FC Debt Exposure

	1993	1994	1995	1996	1997	1998
Number of firms	1965	2319	2886	3319	3902	4269
Extensive Margin						
Fraction of firms with FC debt (%)	59.6	57.6	52.8	52.1	51.1	44.8
Fraction of firms with short-term FC debt (%)	52.0	47.7	42.7	42.2	40.0	35.7
Intensive Margin						
Mean FC share of short-term debt (%)	15.9	14.3	14.3	15.6	18.8	19.6
Mean FC share of long-term debt (%)	35.3	37.7	36.6	40.0	48.6	46.5
Stdev FC share of short-term debt (%)	19.4	18.8	19.6	20.4	20.8	22.5
Stdev FC share of long-term debt (%)	26.9	28.7	28.8	29.3	30.2	30.9
Mean short-term FC debt to total debt (%)	9.5	8.5	9.4	9.8	11.6	12.2
Mean long-term FC debt to total debt (%)	14.8	14.8	15.2	16.9	23.9	22.7
Stdev short-term FC debt to total debt (%)	13.0	12.3	14.8	14.7	14.8	16.1
Stdev long-term FC debt to total debt (%)	16.0	16.0	16.7	17.8	22.3	22.1

Notes: Short-term debt is the amount of debt with the remaining maturity less than one year, and long-term debt is the rest of the debt that is not short-term debt. Stdev stands for standard deviation.

[16] We use the log of real sales when computing firms' sales share to limit the effects of the outliers.

Table 3: Foreign currency debt and Other Firm-level Characteristics

	Mean	*Stdev*	*Corr with Short-term FC Debt Ratio*
Export Share (%)	8.26	20.87	0.12
Size	24.08	1.40	0.31
Leverage (%)	39.92	20.77	-0.06
Short-term Debt Ratio (%)	57.75	25.23	-0.01
FC Cash Ratio (%)	0.14	1.26	0.16

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 FC cash ratio (foreign currency cash to total current assets ratio).

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

Using information on firm-level variables of our novel dataset, we investigate whether and to what extent firms with higher foreign currency debt exposure have actually experienced the deterioration of their balance sheets during the crisis. We use the growth rates of net worth and sales to quantify the degree of balance sheet deterioration during the crisis period, as in Kim et al. (2015). In addition, we analyze how the negative balance sheet effect of foreign currency debt would be transmitted into firm-level price-cost markups during a large devaluation episode.

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

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

As explained above, y_j variables that we examine are: firm-level real net worth, real sales, and markups.[17] The dependent variable is the growth rate of y_j from 1996 to 1998. ST FC and LT FC are the firm-level foreign currency share of short-term debt and the foreign currency share of long-term debt, respectively. We investigate the marginal effects of short-term and long-term FC debt exposure separately, since FC debt that has longer maturities should be less of a concern for firms than FC debt that matures within a year. The latter immediately needs to be rolled over with new debt or paid back with a firm's asset. Price-cost markups are computed following De Loecker and Warzynski (2012).[18] We also interact FC debt variables with the firm size to see if the balance sheet effect would be smaller for large firms who are less financially constrained compared to small ones, following Kim et al. (2015). We control for other firm-level characteristics X_j – which are the *export to sales ratio*, the leverage ratio (total debt to total assets ratio), the short-term debt to total

[17] Nominal series are deflated with CPI to compute real series.

[18] We estimate the changes in markup as the changes in the ratio of total sales to the cost of sales. We find almost the same results with different measures of variables costs.

debt ratio, and the *foreign currency cash to total current assets ratio* –in order to deal with a potential endogeneity issue. Importantly, we control for both export to sales ratios and foreign currency share of liquid assets as both could be the determinants of the currency composition of debt, capturing natural hedges. We also include *broad sector fixed effects* to 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: Firm Performance and FC Debt: After Devaluation

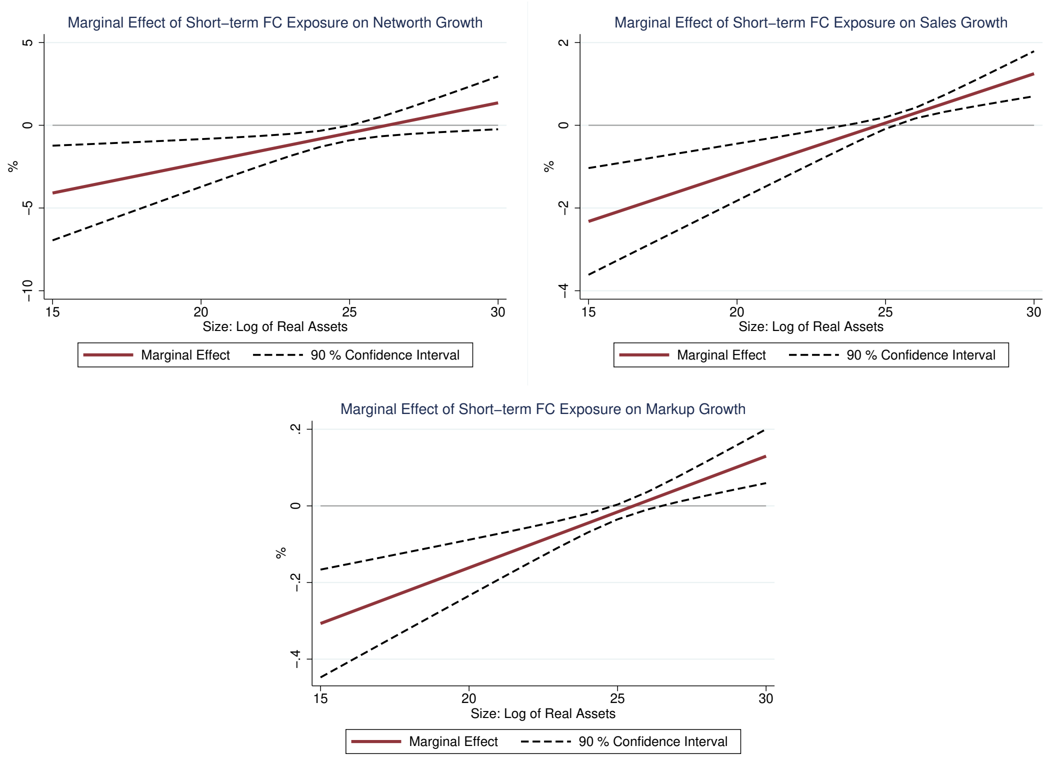
	(1) Net Worth Growth	(1) Sales Growth	(3) Markup Growth
ST FC	-9.5447**	-5.8952***	-0.7437***
	(4.2869)	(1.8463)	(0.2065)
LT FC	-2.3832	-1.2498	0.1319
	(3.4388)	(1.2450)	(0.1502)
Size	-0.1707***	-0.1656***	-0.0096***
	(0.0592)	(0.0172)	(0.0023)
ST FC x Size	0.3634**	0.2380***	0.0291***
	(0.1731)	(0.0720)	(0.0082)
LT FC x Size	0.1069	0.0605	-0.0050
	(0.1397)	(0.0496)	(0.0061)
Leverage Ratio	1.6953***	0.3283***	0.0151
	(0.2720)	(0.0712)	(0.0116)
Export to Sale Ratio	0.6269***	0.3365***	0.0422***
	(0.2398)	(0.0737)	(0.0089)
ST Debt Ratio	0.1088	-0.1836***	-0.0084
	(0.1684)	(0.0550)	(0.0077)
FC Cash Ratio	-0.4328	0.9980	0.2137**
	(1.4007)	(1.2785)	(0.1044)
Adjusted R^2	0.0502	0.1488	0.0429
N	3137	3137	3135

Notes: This table shows the results from firm-level regressions. The dependent variables are the growth rate of (1) real net worth, (2) real sales, and (3) markups from 1996 to 1998. The main regressors are the firm-level short-term foreign currency debt ratio (ST FC) and the cross product of firm size and ST FC in 1996. The size is measured as the log of real sales. To alleviate a potential endogeneity issue, we use the pre-crisis (1996) value of the regressors. Robust standard errors are calculated in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

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, showing the deterioration of their balance sheets during the crisis. The negative effect is mitigated as the firm size is larger since larger firms are less financially constrained. Specifically, a one percentage point rise in the short-term foreign currency ratio leads to a 0.80 percent reduction in net worth for a firm of average size. When firm size becomes smaller by one standard deviation, the negative effect gets larger by 0.49 percentage points. For the real sales, one percentage point increase in the short-term foreign currency ratio is associated with a 0.17 percent decrease in sales of an average-sized firm. This negative impact becomes more pronounced, increasing by 0.32 percentage points, when the firm size is reduced by one standard deviation.[19] This finding is consistent with the result of Kim et al. (2015).

Column (3) shows how each firm's markup growth has changed when more indebted in foreign currency short-term debt. The regression result shows that a deterioration of the balance sheet lowers firms' market share and their markups. Specifically, an one percentage point increase in short-term foreign currency debt exposure is associated with a 0.04 percent decrease in the price-cost markup for an average sized firm. If the firm size increases by one standard deviation, the negative impact on markup growth decreases by 0.04 percentage points.[20] Figure 4 shows a complete picture of how the marginal effects of short-term FC debt exposure on the growth of the firm-level variables vary across firm sizes.

Figure 4: Marginal Effects of Short-term FC Exposure on Firm-level Variables



Notes: The solid red lines depict the marginal effect of short-term FC exposure on firm-level variables depending on 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.

As a robustness check, we show that the results do not change qualitatively with a different definition of foreign currency debt exposure: short-term debt to total debt ratio and long-term debt

[19]The average and the standard deviation of firm sizes are 24.06 and 1.36, respectively.

[20]The results do not change when including the cross-product of other firm-level control variables with firm size, shown in Table A2 in the Appendix.

to total debt ratio, shown in Table A3 in the Appendix.[21] On top of these results, we also explore the effect of short-term foreign currency debt exposure on other firm-level variables: capital, labor productivity, labor cost, and total current asset holdings, summarized in Table A4 in the Appendix. We find that firms indebted in short-term foreign currency debt exposure have experienced lower growth rates of capital, labor productivity, labor costs and total current asset holdings, and the magnitude of the balance sheet effects on them is smaller as firm size is larger. The empirical results are aligned with our model mechanisms elaborated in details in Section 4.

To explore if the unobservable firm-level characteristics may have led to a spurious correlation between firms' short-term FC debt exposure and their performance, we run a similar set of regressions using the sample of the pre-devaluation period. If the results shown in Table 4 were driven by the unobserved characteristics attached to firms' short-term FC debt exposure that happen to be correlated with firms' performance, the relationship should also hold in the pre-devaluation period. Specifically, we estimate Equation 2, where the dependent variable is the growth rate of y_j from 1993 to 1995 and the regressors are 1993 values. y_j variables that we examine are: firm-level real net worth, real sales, and markups. As in regression 1, we control for firm-level characteristics X_j and include broad industry-level fixed effects.

$$\begin{aligned}\Delta y_{j,93-95} = \beta_0 &+ \beta_1 \text{ST FC}_{j,1993} + \beta_2 \text{LT FC}_{j,1993} + \beta_3 \text{Size}_{j,1993} \\ &+ \beta_4 \text{ST FC}_{j,1993} \cdot \text{Size}_{j,1993} + \beta_5 \text{LT FC}_{j,1993} \cdot \text{Size}_{j,1993} + \beta_6 \text{X}_{j,1993} + \epsilon_j \end{aligned} \tag{2}$$

The results are summarized in Table A5 in the Appendix. We clearly do not see different growth rates of real net worth, real sales, and markups for firms with different short-term FC debt exposure before the devaluation.

Lastly, we examine if firms with different degrees of foreign currency debt exposure in 1996 have exhibited systematically different growth rates of net worth, sales and markups before and after the devaluation. Specifically, we are interested in exploring if the two-year growth rates of firm-level variable $\Delta y_{j,t}$ (net worth, sales and markups) from year $t-2$ to year t, may or may not vary with their FC share of short-term debt as of 1996. Our baseline regression corresponds to $t = 1998$.

$$\Delta y_{j,t} = \beta_{0,t} + \beta_{1,t} \text{ST FC}_{j,1996} + \beta_{2,t} \text{Size}_{j,1996} + \beta_{3,t} \text{ST FC}_{j,1996} \cdot \text{Size}_{j,1996} + \epsilon_j \tag{3}$$

[21]Our firm-level dataset does not have information about the firm-level imported input share. We show that our results do not change qualitatively after controlling for some proxies of firm-level imported input share – the foreign currency share of account payables and the foreign currency account payables to cost of sales ratio. The results are available upon request.

Figure A1 in Appendix shows the estimated coefficients of $\beta_{1,t}$ on the left panel and $\beta_{3,t}$ on the right panel for $t = 1994, 1995, \ldots, 1999$. We see clearly that before the devaluation in 1997, firms do not exhibit different trends in the growth rates of net worth, sales and markups across their short-term foreign currency debt exposure of 1996. When the depreciation shock hits in November 1997, we see a drop in net worth and sales of firms indebted in foreign currency, and their mark-ups fall a year after. We see a immediate and persistent effect on the growth rates of sales and net worth, while we do not observe such patterns for the growth rates of markups. We suspect that the costly price adjustment could potentially help us to understand a slower adjustment of and shorter-lived effects on firms' prices and hence their markups.

In sum, during the large devaluation episode, firms with higher foreign currency debt exposure experienced a larger decline in its net worth, output and consequently, a larger drop in their market shares and price-cost markups.

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

Analyzing the negative balance sheet effect of FC debt 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 price from 1996 to 1998. The main regressors are sector-level short-term foreign currency debt to total short-term debt ratio (ST FC) and long-term foreign currency debt to total long-term debt ratio (LT FC) in 1996. Following the firm-level regression 1 in Section 3.2, we investigate the marginal effects of short-term and long-term FC debt exposure separately, since FC debt that has longer maturities should be less of a concern for firms than FC debt that matures within a year. The latter immediately needs to be rolled over with new debt or paid back with a firm's asset. To alleviate potential endogeneity concerns, we use the pre-crisis (1996) value of regressors.[22]

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 use the level of the product differentiation, the imported intermediate input share, and the price stickiness prior to the devaluation episode. We classify each industry selling homogeneous or differentiated goods, based on the method of Rauch (1999). When the dummy variable is equal to one, the sector is characterized as selling differentiated products. The imported input share for each sector is the share of imported intermediate inputs in the total amount of inputs, which include

[22]Ten industries with highest foreign currency share of short-term debt are reported in Table A6 in the Appendix. Summary statistics of industry-level controls are included in Table A7 in the Appendix.

all intermediate inputs and value added from labor and capital. We use the Input-Output table of 1995 due to the data availability. The degree of price stickiness for each industry is measured as the median frequency of price change documented by Nakamura and Steinsson (2008).[23] A higher value of this measure indicates that prices are *less* sticky within that industry. The weighted average values of firm-level characteristics are included as well–firm size (log of real sales), the exports to sales ratio, the leverage ratio (total debt to total assets ratio), the short-term debt to total debt ratio, and the foreign currency cash to total current assets ratio. We use a firm's size as its weight when computing the weighted averages of firm-level variables for each industry. We also include two-digit broader sector fixed effects to control for some industry-level shocks during this period and unobservable characteristics.

Table 5: Industry Price Dynamics and Short-term FC Debt Ratio After Devaluation

	(1)	(2)	(3)	(4)	(5)
ST FC	0.6950***	0.7109***	0.6722***	0.6565***	0.5685***
	(0.1607)	(0.1856)	(0.1783)	(0.2162)	(0.2038)
LT FC		-0.0295	-0.1302	-0.1899	-0.1846
		(0.1173)	(0.1245)	(0.1351)	(0.1365)
Size				0.0063	0.0024
				(0.0183)	(0.0181)
Export to Sale 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 Industry FE	No	No	Yes	Yes	Yes
Adjusted R^2	0.1400	0.1348	0.4245	0.4439	0.4513
N	156	156	156	156	156

Notes: This table shows the results from regression 4 with a different set of regressors. The dependent variable is the growth rates of sectoral prices 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. To alleviate a potential endogeneity issue, we use the pre-crisis (1996) value of the regressors. For the imported input share, we use the 1995 value due to the data availability. Robust standard errors are reported in parentheses.* p<0.1, ** p<0.05, *** p<0.01.

Table 5 summarizes the regression estimates of Equation 4. Column 1 summarizes the result

[23]For more details on mapping and calculations, please refer to the Appendix.

with only the FC share of short-term debt. When an industry has higher short-term foreign currency debt exposure, its price goes up more after a large devaluation. Specifically, when the short-term foreign currency debt exposure goes up by one percentage point, the change in price is 0.70 percentage points higher. As we control for other industry-level characteristics, the estimate goes down to 0.57; it still has a significant impact on price changes even after controlling other factors documented in the literature. An industry with higher imported intermediate input share experiences a higher change in its domestic producer price. In addition, a sector with a lower average degree of price stickiness is associated with a higher change in its domestic price. The level of the product differentiation does not have a significant impact on the price dynamics during the crisis after controlling for broad industry fixed effects and the weighted average of firm-level characteristics.

The industry-level price response varying across short-term foreign currency debt exposure is consistent with what we would expect from firm-level responses: when firms with more foreign currency debt face higher debt burden upon devaluation, constraining their production of goods, firms lower their sales, increasing the price of goods sold. Importantly, we have documented that there is a heterogeneity in mark-up responses across firm size upon devaluation; large firms, in fact, *increase* their markups shown in Figure 4. In Section 4, we argue that strategic complementarity in price setting could explain the heterogeneity in firms' markup responses, and show that it amplifies the aggregate price response. In essence, smaller firms, with low strategic complementarity in their pricing, face tighter financial constraints when borrowing heavily in foreign currency; they pass-through most of their higher marginal costs to prices upon a large devaluation. However, larger firms indebted in foreign currency are unlikely to face tighter financial constraints due to their large holdings of liquid and illiquid assets. Larger firms, however, exhibit strong strategic complementarity in their pricing and, therefore, may increase their markups and prices in response to higher prices charged by other firms, amplifying the sectoral price increase. The importance of strategic complementarity will be further explored through our structural model in Section 4.

For robustness checks, we have conducted four additional exercises. First, we control for the changes in the number of firms in each industry, which may have some implications on the industrial price dynamics during the crisis. The results are shown in Table A8 in the Appendix. The main results are robust to controlling for changes in the level of competition which may occur when firms exit during the crisis. Second, we use a subsample of firms with zero exports and re-estimate regression 4 with newly constructed industry-level regressors. Table A9 in the Appendix summarizes the results, where we see that the estimated effect of foreign currency debt exposure on sectoral prices is still positive and quantitatively large. Third, we also have explored if the results may change with a different definition of foreign currency debt exposure: short-term debt to total debt ratio and long-term debt to total debt ratio. The results do not change shown in Table A10 in the Appendix. Lastly, we use a subsample of industries that have at least four firms and re-estimate regression 4. Shown in Table A11 in the Appendix, the results do not change much quantitatively, where the effect of short-term foreign currency debt exposure is estimated 0.5 and significant at 5% level.[24]

We then show that our results are not driven by some spurious correlation between a foreign currency share of short-term debt and the industry-level price changes.

First, to address the issue of unobserved industry-level characteristics which are not captured by the above variables, we compare the results in the pre-crisis period with those in the crisis period. If the results were driven by the unobserved industry-level characteristics that happen to be correlated with foreign currency debt exposure and sectoral inflation, the relationship between the foreign currency debt holdings and price changes would hold in both periods. Specifically, we run the following regression 5 and compare the results with the main regression 4:

$$\Delta p_{I,1993-95} = \beta_0 + \beta_1 \text{ST FC}_{I,1993} + \beta_2 \text{LT FC}_{I,1993} + \beta_3 \text{X}_{I,1993} + \epsilon_I \tag{5}$$

, where the dependent variable is the growth rate of sector I's domestic producer price from 1993 to 1995 and the regressors are 1993 values. We also control for industry-level characteristics and the weighted average of firm-level characteristics, as in regression 4. Table A12 in the Appendix shows the regression results in the pre-crisis period. In contrast to the estimates in Table 5, there is no evidence of negative balance sheet effects on sectoral price changes. The size of the coefficient estimates on short-term foreign currency debt ratio falls by more than half or becomes negative, and the estimates are not statistically different from zero. Furthermore, the regression based on the pre-crisis period in Table A12 in the Appendix shows a much smaller R^2 compared to the baseline regression in Table 5. For instance, a regression with only FC share of short-term debt during the crisis period has a R-square of 14%, whereas in the non-crisis period it falls to 0.15%. This empirical observation implies that the explanatory power of pre-crisis industry-level foreign currency debt exposure comes only during periods with depreciation shocks, and the identified negative balance sheet effects are not capturing some spurious relationship.

Second, we document how industries with different levels of FC share of short-term debt in 1996 have not shown different two-year price changes before and after the devaluation. Specifically, we analyze how the two-year growth rates of sectoral prices in year t, $\Delta p_{I,t}$ may or may not vary with their FC share of short-term debt as of 1996. Our baseline regression corresponds to $t = 1998$.

$$\Delta p_{I,t} = \beta_{0,t} + \beta_{1,t} \text{ST FC}_{I,1996} + \epsilon_I. \tag{6}$$

[24] We also have experimented with higher cutoffs for a number of firms in each industry. The results do not change when using a subsample of industries with more than five firms and those with more than ten firms. The results are available upon request.

Figure A2 in the Appendix shows that the coefficients $\beta_{1,t}$ from regression 6 are not different from zero; i.e., industries that have varying levels of FC share of short-term debt in 1996 do not exhibit different growth rates of their domestic producer prices before and after the crisis. In other words, industries with both high and low FC shares of short-term debt showed fairly similar price dynamics before and after the crisis. This finding reinforces our argument that the larger price increase was not due to unobserved characteristics of industries that have a higher share of their short-term debt in foreign currency in 1996.[25]

Furthermore, we explore the dynamic and higher frequency responses of monthly sectoral PPI, 18 months before and after the large devaluation. We estimate Equation 7, following Jordà (2005):

$$\frac{p_{I,1997\text{m}9+h} - p_{I,1997\text{m}9}}{p_{I,1997\text{m}9}} = \beta_h + \beta_{1,h}\text{ST FC}_{I,96} + \beta_{2,h}\text{LT FC}_{I,96} + \beta_{3,h}\text{X}_{I,96} + \epsilon_{I,h}, \tag{7}$$

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 FC debt exposure, long-term FC debt exposure and the imported input share. We see that industries have shown persistently higher levels of monthly PPIs for around a year when they are more indebted in foreign currency short-term debt; however, we see no differential responses of monthly PPIs for those sectors borrowing more in foreign currency long-term debt. Importantly, we see that coefficients are not significantly different from zero at 10 % significance level before December 1997 when Korea finally floated the exchange rate. We also observe positive dynamic effects of imported input share on sectoral monthly PPIs, lasting for around ten months. The results are robust to using quarterly PPIs, shown in Figure A4 in the Appendix.

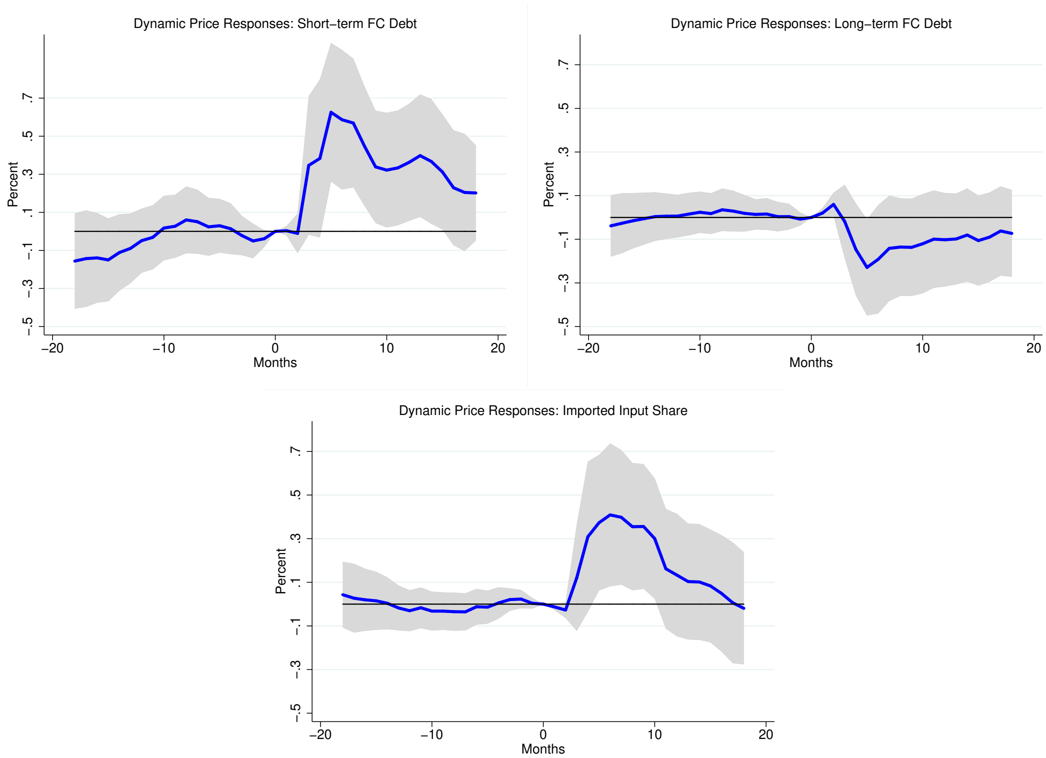
Lastly, we also have looked at the exchange rate pass-through to sectoral prices in more recent periods from 2000–2019. We estimate the panel regression of Equation 8:

$$\begin{aligned} \Delta p_{I,t} = \beta_I + \beta_t + \beta_1 \text{ ST FC}_{I,t-1} + \beta_2\text{LT FC}_{I,t-1} \\ + \beta_3\Delta e_t \times \text{ST FC}_{I,t-1} + \beta_4\Delta e_t \times \text{LT FC}_{I,t-1} + \beta_5\text{X}_{I,t-1} + \epsilon_{I,t}. \end{aligned} \tag{8}$$

The dependent variable is the annual growth rate of sector I's domestic producer price. The exchange rate is defined as the Korean won price of U.S. dollar, and therefore, an increase in the exchange rate is depreciation of Korean won against the U.S. dollar. We are interested in how the exchange rate shock passes through to domestic producer prices through the balance sheet channel.

[25] The results in Tables 5 and A12 and in Figure A2 are robust to dropping industries whose price changes are in the top 1% and the bottom 1%. The results after dropping outliers are presented in Tables A13 and A14 and in Figure A3 in the Appendix, respectively.

Figure 5: Monthly PPI Before and After the Devaluation 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 monthly sectoral PPIs, estimated in regression 7. The area represents the 90% confidence intervals with robust standard errors.

The coefficient estimates of our interest are β_3 and β_4. We include both year fixed effects and sector fixed effects. The standard errors are clustered at the sectoral-level. We find that the estimates are qualitatively and quantitatively aligned with what we have found during the Asian Financial Crisis, where β_3 is estimated to be at 0.42 and 0.56 without and with the interaction term of $\Delta e_t \times \mathrm{X}_{i,t-1}$, respectively. The results are reported in Table A15 in the Appendix. In a nutshell, the panel regression results reaffirm that the balance sheet effect of dollar debt is playing an important role in the determination of the degree of exchange rate pass-through to domestic prices.[26]

In sum, from the empirical analyses, we find that during the large devaluation episode, firms with higher foreign currency debt exposure indeed experienced a larger balance sheet deterioration and a larger drop in price-cost 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 build up a structural model, where a large foreign

[26] We re-estimate the panel regression with two subsample periods: periods of KRW appreciation against USD and periods of KRW depreciation against USD. Our estimation results shown in Table A16 in the Appendix corroborate that it is the depreciation of the domestic currency that balloons firms' foreign currency debt burden, which constrains their production, increasing their prices.

currency debt exposure together with a large depreciation leads to an increase in firms' effective marginal costs. We would like to quantify how important the balance sheet effect of dollar debt is in channeling the exchange rate shock to domestic producer prices.

4 Model

In this section, we build a heterogeneous firm model to rationalize our empirical findings and quantify the balance sheet effects on industry price dynamics during the crisis. 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 devaluation.

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 level of foreign currency debt ratio, exogenously given in our model. 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 they can issue debt, as determined by a fraction of capital. Second, when firms produce output, they face a working capital constraint that requires non-interest-bearing assets for the wage bill and imported input payment, as seen in Uribe and Yue (2006). We will assume that the economy is in the stationary equilibrium before an unexpected real exchange rate depreciation. Our focus is on the transition dynamics 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:[27]

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

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

[27] We assume that $\bar{Y} = 1$ without loss of generality.

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:[28]

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

4.2 Firms' Technology

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.[29] We assume that each firm faces a Kimball demand structure, which is characterized by two parameters, σ and ϵ, as we describe in the previous subsection.[30] Firms produce differentiated goods with the production technology $y_t = z_t k_t^{\alpha} x_t^{\kappa} n_t^{1-\alpha-\kappa}$, hiring labor n_t, imported input x_t and physical capital k_t. 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). In our model, we assume that firms import intermediate inputs but do not export their products. We focus on domestic firms and domestic price dynamics.[31]

Each entrepreneur owns a firm and maximizes their expected sum of discounted utility from final goods consumption with relative risk aversion, γ:

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{c_t^{1-\gamma}}{1-\gamma}$$

An entrepreneur is endowed with a unit of labor and supplies that labor inelastically at a competitive wage. Each entrepreneur accumulates physical capital, which is subject to convex adjustment cost $\Phi(k_t, k_{t+1})$, by investing i_t amount of final goods capital. Physical capital in the model has two modes: production and collateral.

In the beginning of the period, entrepreneurs learn this period's productivity z_t and the exchange

[28]Detailed information on the functional form of Kimball demand can be found in the Appendix.

[29]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.

[30]We normalize the aggregate price, aggregate output and aggregate wage to one.

[31]An extension of the model to include firms' exporting decisions both at the extensive and the intensive margins itself is an interesting venue to explore. In fact, Kim et al. (2024) have found that (i) exporters also suffer from the balance sheet deterioration due to their dollar debt after the devaluation in Korea in 1997, and (ii) financially constrained exporters lower their domestic sales *even more* than domestic firms. The possibility of reallocating sales from domestic to international markets by constrained exporters could make our balance sheet channel even stronger as domestic sales fall even more for financially constrained exporters.

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. Then, they hire labor 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, pay back old debt and issue new debt d_{t+1}, and choose the next period's level of capital k_{t+1} and working capital a_{t+1}.

A 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. In the beginning of the following period, 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 the one-time unexpected exchange rate depreciation, the currency composition of debt cannot be determined in the model, justifying our assumption on the exogeneity of the foreign currency debt share.

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

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

It is important to note that the exchange rate does not *directly* affect the constraint. That is, the borrowing constraint is not getting mechanically tighter upon the depreciation of domestic currency. We would like to explore firms' pricing decisions when facing higher debt burden due to their foreign currency debt exposure, while abstracting away from the financial constraint itself getting directly affected by the exchange rate and the foreign currency debt exposure. Nonetheless, with such extensions, our mechanism will be stronger.

In addition, each entrepreneur faces a working capital constraint. Specifically, in order to finance their wage bill payment $w_t n_t$ and imported 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-trough to import prices, and ω equal to one implies a complete exchange rate pass-through to import prices. Hence, the amount of wages and imported inputs that each entrepreneur can pay is limited by the amount of the non-interest bearing asset a_t:

$$w_t n_t + \xi_t^\omega x_t \leq \theta_a a_t.$$

Each industry has a different firm-level distribution of foreign currency debt exposure λ and a different imported input share κ. The average foreign currency debt ratio for industry I is determined by the distribution of λ_m across firms in industry I. We approximate the distribution by assuming a finite number of values that λ can take, $\{\lambda_m : m = 1, 2, \ldots, n\}$, with the industry-specific probability mass function of $\{\pi_m^I : m = 1, 2, \ldots, n\}$. We calibrate λ_m and π_m^I to match the data counterparts, which will be explained in more details in the calibration section. In the model, the average foreign currency debt ratio of an industry I will be defined as: $\bar{\lambda}_I = \sum_m \lambda_m \pi_m^I$. Since firm-level imported input data are not available, we assume that all firms in a industry share a common value of industry-level imported input share κ_I.

We analyze how much the variation in $\bar{\lambda}_I$ and κ_I that we observe from the data can explain the dispersion in price changes across sectors after a large unexpected depreciation. Furthermore, we decompose the observed sectoral price changes into the balance sheet channel and the imported input channel to highlight the role of foreign currency debt exposure in the determination of the exchange rate pass-through to sectoral prices.

4.3 Recursive Formulation and Equilibrium

The aggregate state X is defined as

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

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 wage. Then, an entrepreneur's problem is summarized as follows:

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

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

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

where

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

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 $\{d', k', a', c, n, x, y, p\}$ and value functions $v(k, d, a, z, \lambda, \kappa)$, and (iii) a measure ψ_I on $(k, d, a, z, \lambda, \kappa)$ satisfying:

1. Policy and value functions solve the firm's problem.

2. Industry output market clears.

$$\ln P_I = \int \ln(p(k,d,a,z,\lambda,\kappa))d\psi_I(k,d,a,z,\lambda,\kappa)$$

$$Y_I = \Big(\int y(k,d,a,z,\lambda,\kappa)^{\sigma/\epsilon}d\psi_I(k,d,a,z,\lambda,\kappa)\Big)^{\sigma/\epsilon}$$

3. Measure ψ_I is consistent and stationary.

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 unexpected depreciation of the real exchange rate, where industries are characterized by different foreign debt exposure and different imported input share.

5 Calibration

Table 6 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. Most importantly, we set λ_m and π_m^I to match the cross-sectional distribution of foreign currency debt ratio across firms for 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 calibrate the $\{\pi_m^I : m = 1, 2, \ldots, 21\}$ to approximate the distribution. We use the sales weighted probability mass function when calibrating π_m^I. $\bar{\lambda}_I = \sum_m \lambda_m \pi_m^I$ 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 see if there are 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 with the weight as a firm's sales revenue. We find that their correlation is close to one.

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 0.07, respectively. We discretize the process following Tauchen (1986). Due to the data availability, with the monthly observations of three-year government bond yields and the realized inflation rates in 1996, we compute the real interest rate by subtracting the mean of the realized year-over-year inflation rates from the mean of three-year government annualized bond yields. We hold the real interest rate constant to focus on the effect of the quantity of foreign currency debt rather than the price of debt. Nonetheless, our mechanism through financial constraints will be stronger if we allowed the interest rate to go up together with a large depreciation of domestic currency. We set the value of capital adjustment cost ϕ as 0.9569, following Gilchrist and Sim (2007) who use the same Korean firm-level data (KIS) as we used. We use the data from the Korean Input-Output table in 1995 to calculate each industry's imported input share κ_I in the total inputs used and the value added by each industry. With growth rates of the average import price in Korea and the KRW/USD exchange rate during the 1997 large devaluation episode, we set the degree of exchange rate pass-through to import prices ω as 0.353.

For the calibrated parameters–i.e., the discount factor β, the fraction of capital used as collateral θ_k, and the fraction of working capital constraints θ_a–we find the parameters that minimize the distance between the model and data moments. The model moments are computed in the representative stationary industry equilibrium where there is no exchange rate shock. Thus, the value of λ does not play a role in computing the stationary equilibrium. We also assume that in the representative equilibrium, the imported input share is 15%, which is the average level of κ_I across industries. The targeted moments are the cross-sectional mean and the standard deviation of debt to sales ratios, and the cross-sectional mean of cash to sales ratios in 1996; 0.595, 0.21, and 0.412, respectively, in the data.

Table 6: List of Parameter Values

Predetermined			
Parameter	**Value**	**Description**	**Data Source**
γ	2.0	Relative risk aversion	Standard
δ	0.1	Depreciation rate of physical capital	Standard
ν	2.0	Elasticity of substitution across sectors	Standard
σ	5.0	Elasticity of substitution within a sector	Gopinath and Itskhoki (2010)
ϵ	6.0	Super elasticity of demand	Gopinath and Itskhoki (2010)
ϕ	0.9569	Physical capital adjustment cost	Gilchrist and Sim (2007)
ω	0.353	Degree of exchange rate pass-through to import price	Estimated from Korean data
r	0.08	Interest rate	Bank of Korea
ρ_z	0.9106	AR coefficient of z	Estimated following Ackerberg et al. (2006)
σ_z	0.0986	STD of z	Estimated following Ackerberg et al. (2006)
λ_m	$\in$ $[0, 0.975]$	Distribution of FC debt share	Estimated from KIS data
π_m^I	$\in$ $[0, 1]$	Distribution of FC debt share	Estimated from KIS data
κ_I	$\in$ $[0, 1]$	Industry-level imported input share	Estimated from Korean Input-Output table in 1995
Calibrated			
Parameter	**Value**	**Description**	**Targeted Moments**
β	0.9090	Time discount factor	Mean of Debt to Sales Ratio (0.708)
θ_k	0.7444	Fraction of capital as a collateral	Std of Debt to Sales Ratio (0.291)
θ_a	1.2431	Fraction of working capital	Mean of Cash to Sales ratio (0.471)

For the exchange rate, we compute the Korean won price of dollar percentage growth rate from 1996Q4 to 1998Q4. Following the actual dynamics of the exchange rate after the Asian Financial Crisis, 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 an one-time unexpected shock to the exchange rate *returns* but assume zero expected returns afterwards.[32] Hence, there will be

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

no deviation from the UIP 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 the balance sheet effects of foreign currency debt exposure. Specifically, we assume that a firm's debt burden increases while the price of imported input remains constant following a large depreciation, i.e., $\omega = 0$. All other parameters are set to our calibrated values summarized in Table 6. We start with a firm's optimal pricing decision from the model,

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

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

Following a large depreciation, firms face higher debt burden, affecting firms' pricing decisions through two channels: (i) investment adjustment and (ii) working capital constraint. First, firms lower their investment and become less productive in the next period, increasing the physical marginal cost of production $mc_{j,t}$. Second, firms lower their liquid savings and face a tighter working capital constraint in the next period, resulting in a higher value of the Lagrangian multiplier $\eta_{2,j,t}$, which has an upward pressure on the price.

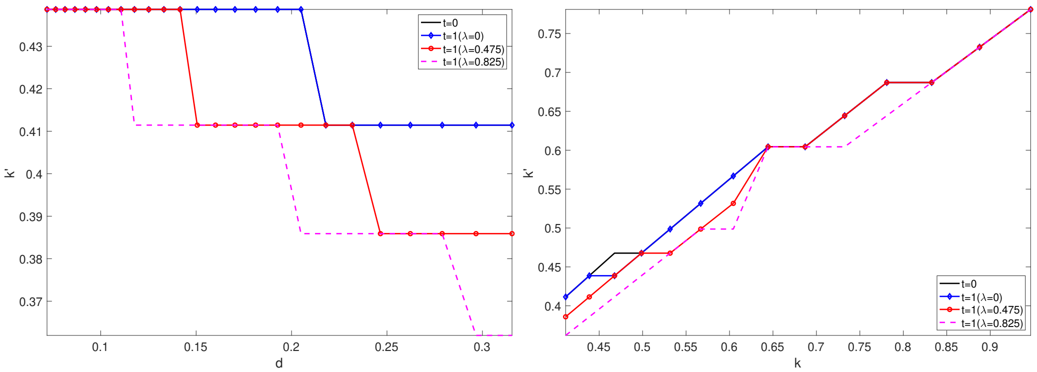
Our analysis investigates these two margins, investment decisions and working capital constraints, under the steady state and on the transition path to analyze the negative balance sheet effects. Specifically, we plot policy functions against the debt level or the capital stock because firms with a higher debt burden or lower capital stock (equivalent to lower collateral assets) would face more severe balance sheet deterioration. Policy functions with different foreign currency debt exposure are also considered to capture heterogeneous balance sheet effects due to their foreign currency debt exposure upon a large depreciation. When illustrating the mechanism, we look at an industry with a non-degenerate cross-sectional distribution of foreign currency debt ratio across firms. We fix idiosyncratic productivity z at the median level.[33]

Figure 6 shows the policy functions of k' against k and d.[34] In the left panel, we find that when a firm's debt burden is too high, the borrowing constraint starts binding, which lowers the next

[33]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 are meaningfully operating for policy function illustration.

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

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.

period's capital stock. Hence, higher debt burden is associated with lower investment. The right panel shows that next period's capital stock becomes larger when a firm holds more initial capital stock. This result illustrates that the borrowing constraint is less binding for firms with larger capital, so they tend to hold more of the next period's capital stock. Furthermore, Figure 6 shows the effect of a large depreciation on firm-level capital stock. For any given amount of foreign currency debt, firms need to pay more in units of domestic goods due to the depreciation. This higher debt burden lowers a firm's investment. When a firm's reliance on foreign currency debt is large prior to the crisis, its increase in debt burden is more pronounced, lowering its investment further. A fall in capital for those firms indebted in foreign currency upon devaluation is empirically corroborated, and the results are reported in Table A4 in the Appendix.[35]

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,

$$\beta E_{z'|z}[(c')^{-\gamma}(1+r)\big((1-\lambda)+\lambda\frac{\xi'}{\xi}\big)] + \eta_1 = \beta E_{z'|z}[(c')^{-\gamma} + \theta_a \eta_2'] \tag{9}$$

, where η_1 and η_2 are the Lagrangian multipliers on the collateral constraint, $\frac{1}{1+r}d' \leq \theta_k k'$, and the working capital constraint, $wn + \xi^{\omega} x \leq \theta_a a$, respectively. Equation 9 shows that even for the non-binding collateral constraint case $\eta_1 = 0$, any positive value of expected net interest rate r implies that the working-capital constraint always binds, i.e., $E_{z'|z}[\eta_2'] > 0$.[36] More importantly, when the collateral constraint becomes tighter, i.e., $\eta_1 > 0$ increases, it has a direct effect on the Lagrangian

[35] In both panels, the policy functions of firms with zero FC holdings in the steady state and when the exchange rate shock hits coincide with each other.

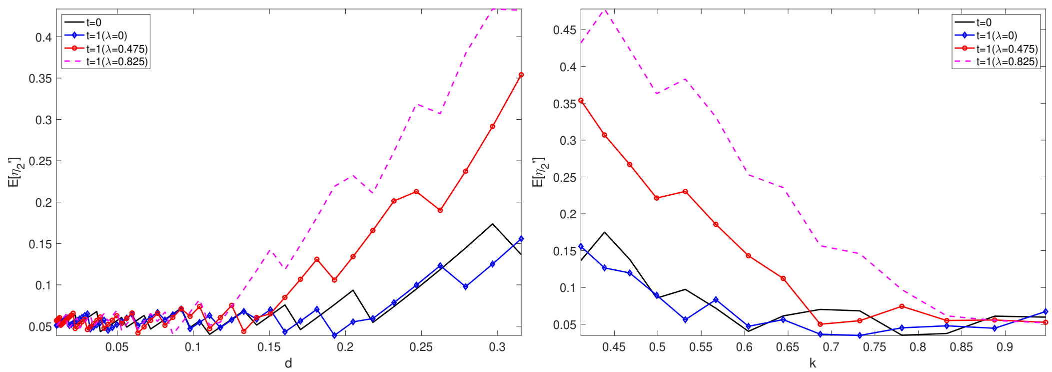
[36] Agents expect that the exchange rate to be held constant all the time.

multiplier, $E_{z'|z}[\eta_2']$, on working capital constraint. Because the firm's optimal pricing decision is

$$p' = \mu' \times mc' \times (1 + \eta_2'),$$

tighter collateral constraint (higher η_1) 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).

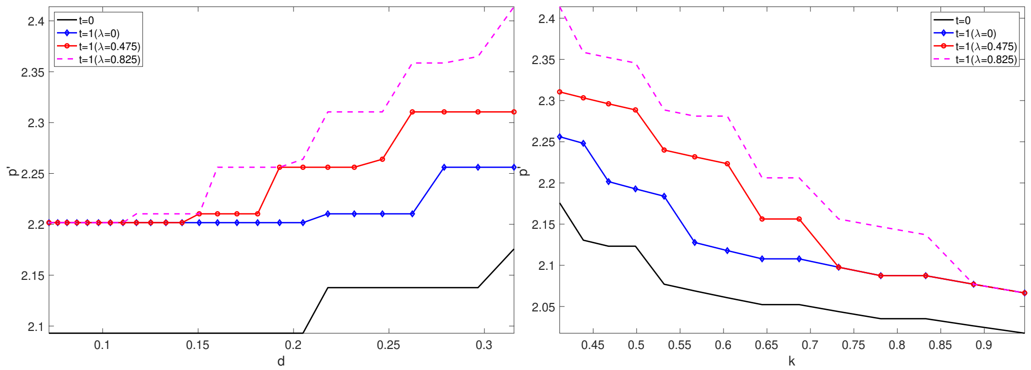


Notes: The solid black lines are the policy functions in the stationary equilibrium. The blue diamond lines, red circle lines, and dashed magenta lines are the policy functions for firms with 0, 0.475, and 0.825 of foreign currency debt ratio, respectively.

Figure 7 plots the Lagrangian multiplier: $E_{z'|z}[\eta_2']$. In the left panel, we find that on average firm's working capital constraint becomes tighter in the next period when its debt burden is high or capital is low this period. Furthermore, when a firm's reliance on foreign currency debt is larger prior to the exchange rate shock, the working capital constraint becomes even tighter, which leads to higher costs of production. Figure A5 in the Appendix shows the policy functions of liquid assets against d and k, corroborating that firms choose to hold less liquid savings when indebtedness is high and much so if in foreign currency. We also see a much larger negative balance sheet effect on liquid asset holdings for firms with low capital stock.

Then, we explore how this period's debt d and capital stock k affects the prices p' and the markups μ' in the next period, the ultimate objects of our interest. Figure 8 illustrates how firms change their prices upon a large devaluation. The left panel shows the pricing decision in the next period as a function of this period's debt level. When the debt burden becomes larger, firms face tighter financial constraints and tend to charge higher prices in the subsequent period. Furthermore, firms that have higher foreign currency debt holdings increase their prices even more after a large depreciation. This result echoes the findings in Figures 6 and 7 that higher debt burden this period translates into a lower level of capital stock and tighter working capital constraints in the next period. If a firm invests less in this period, they become less productive in the next period, increasing their costs of production. Furthermore, a tighter working capital constraint implies a higher cost of

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



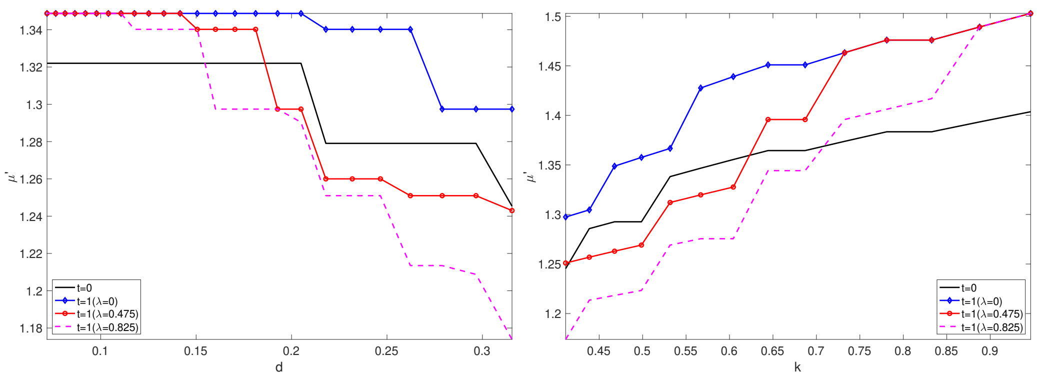
Notes: The solid black lines are the price policy functions in the stationary equilibrium. Blue diamond lines, red circle lines, and dashed magenta lines are policy functions for firms with 0, 0.475, and 0.825 of foreign currency debt ratio, respectively.

production. Both channels lead to higher prices. The right panel in Figure 8 shows the pricing decision as a function of initial capital stock. Consistent with the findings in Figures 6 and 7, when firms hold more capital stock this period, firms tend to charge lower prices in the next period. Moreover, firms with more foreign currency debt, increase their prices more after the devaluation.

In addition to the negative balance sheet effect, we find that strategic complementarity plays an important role in determining firm-level pricing decisions in both panels. Even if firms are not directly affected by the devaluation when holding zero foreign currency debt (the blue diamond lines in both panels), they will set the price higher than what they have at the steady state (the solid black lines in both panels). This result arises from strategic complementarity due to the Kimball preference, which makes firms raise their price because their competitors increase their prices. Therefore, in our model, firms increase their prices not only because of the direct effect from their balance sheet deterioration but also due to the strategic complementarity of their competitors' charging higher prices.

Lastly, we investigate how firm-level markup changes upon a large depreciation. In both panels in Figure 9, firms with higher debt or lower capital this period charge lower markups in the next period. Firms face tighter financial constraints when having more debt or lower capital, decreasing their investment and liquid asset holdings. Both increase the costs of production in the subsequent period, constraining their production and lowering their market share and markups. Furthermore, we show that firms with higher foreign currency debt exposure charge even lower markups after the devaluation. Firms, indebted in foreign currency debt, lower their investment and become less productive in the next period. Moreover, they also lower their liquid savings and face tighter working capital constraints in the following period. Both channels constrain the production of firms, making firms less competitive in their industry; so, they charge smaller markups compared to those with lower foreign currency debt exposure.

Figure 9: μ' against (i) d (Left) and (ii) k (Right).



Notes: The solid black lines in both graphs show the markup policy functions under steady state. 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.

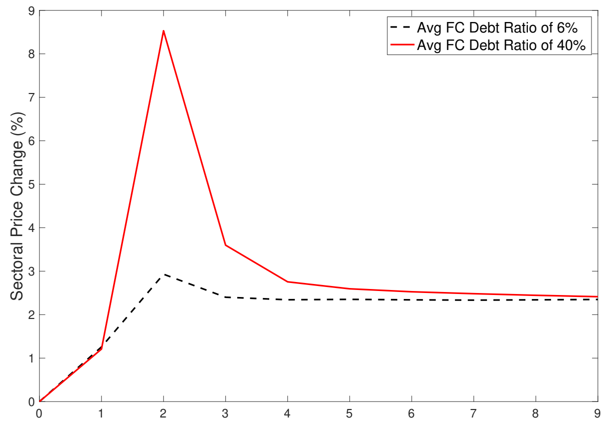
On top of that, firms with zero foreign currency debt, ceteris paribus, increase their markups upon a large devaluation. That is, policy functions of markups for firms with zero foreign currency debt exposure have shifted up (from the solid black lines to the blue diamond lines) as they are unaffected 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 devaluation, while others charge lower; that is, the red and the magenta lines cross the black lines. Specifically, firms with lower debt or higher capital charge higher markups in the next period than what they would have charged in the stationary equilibrium. These firms are not affected by a large depreciation, relatively better off than their competitors; therefore, they increase their market shares and markups and charge higher prices. These model predictions are closely aligned with the empirical observations in Table 4, where firms with higher foreign currency short-term debt exposure decrease their markups, with the effect being smaller for larger firms. Additionally, we empirically confirm that firms with zero foreign currency short-term debt increase their markups, as shown in Table A17 in the Appendix.

7 Quantitative Analysis

7.1 Model Simulations of Industry Price Dynamics

This section summarizes the results from the model simulations of 156 industries with the parameter values calibrated. We first investigate the transition path of each industry price upon a large unexpected depreciation in period 1. Figure 10 depicts the transition path of the industry prices for two sectors with the same imported input share of 10%, but with different average shares of foreign currency debt to total debt, $\bar{\lambda}_I$: 40% and 6%. After a large depreciation of the domestic currency, those industries experienced price increases by around 9% and 3% two years later relative to pre-crisis levels. As an industry has a higher exposure to foreign currency debt, it increases its price more after the exchange rate depreciates unexpectedly.

Figure 10: Impulse Response Functions of Sectoral Prices



Notes: The red solid line and blue dashed-line show the price responses of industries with average FC-loan shares of 4 and 40 percent, respectively. Both industries have the same imported input share of 10%. An unexpected large depreciation happens at period 1.

Industry-level transition paths are the consequence of the negative balance sheet effects and the strategic complementarity between firms in the same industry as illustrated with the policy functions in the previous section. Firms with a high level of foreign currency exposure face a larger debt burden upon a large unexpected depreciation; hence, they reduce investment more and face tighter working capital constraints, which leads to a more pronounced price increase. The effect is stronger when firms are more financially constrained due to lower initial capital or higher initial debt before the crisis. On top of that, the Kimball demand structure allows firms to strategically interact with each other, which amplifies the price responses of firms to the balance sheet deterioration. In our model, smaller firms with lower capital (therefore, on average, lower sales) experience a larger increase in marginal costs due to financial constraints. With this negative correlation of firm size and increase in marginal costs, the within industry strategic complementarity in pricing leads to a higher increase in the industry price (Amiti et al. (2018)).

We regress PPI changes on both $\bar{\lambda}_I$ and imported input share κ_I in the total inputs. As can be seen in Table 7, the coefficient estimate on sectoral foreign currency debt ratio is 0.1637, and the data counterpart is 0.5685. The model explains around 30% of the mean effect of the short-term foreign currency debt on the price changes across industries. The model reproduces the un-targeted empirical estimate of the sectoral price changes on the imported input share.

Given that the model underestimates the impact of foreign currency debt on sectoral price changes, the quantitative significance of dollar debt on the sectoral inflation in Section 8 can be thought of as a lower bound. Moreover, the quantitative fit could improve if we model the borrow-

Table 7: Marginal Effect of Short-term FC Debt Ratio on Sectoral Price Changes

	Data	Model
ST FC	0.5685	0.1637
	(0.2038)	
Imported Input Share	0.2830	0.2223
	(0.1656)	
R^2	0.4316	0.9800
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.

ing cost as a function of firms' net worth as in Céspedes et al. (2004) or the exchange rate as in Drenik and Perez (2021). With such extensions, the depreciation of domestic currency increases firms' borrowing costs as it increases their debt burden and lowers net worths, which, in turn, raises firms' borrowing costs; or as it mechanically comes with a higher interest rate. This feature would further aggravate firms' financial standing and their production of goods. In this paper, we currently focus more of a direct consequence of the exchange rate depreciation on firms' net worth when indebted in dollars whilst holding the interest rate constant.

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 15.5% and 3.2%, respectively. Our simple model– with two variations across industries regarding foreign currency exposure and imported input share–can explain 21% of the observed variation in price changes during the Asian Financial Crisis. We would like to emphasize that all these numbers were not targeted in our calibration, and hence its quantitative size shows how well our model captures the sectoral price dynamics during the crisis and also the cross-sectional variation in price changes across industries with varying degrees of exposure to the foreign currency debt and imported input share.

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 qualitatively compare with the data patterns. With the simulated data, we investigate the role of foreign currency debt and financial constraints in shaping the price dynamics upon the depreciation shock. We run the below regression specifications:

$$
\begin{aligned}
&\Delta y_j = \beta_0 + \beta_1 \text{ST FC}_j + \beta_2 ImportedInputShare_I + \beta_3 \Delta P_I + \epsilon_j, \\
&\Delta y_j = \beta_0 + \beta_1 \text{ST FC}_j + \beta_2 ImportedInputShare_I + \beta_3 \Delta P_I \\
&+ \beta_4 1_{\text{Unconstrained},j} + \beta_5 \text{ST FC}_j \times 1_{\text{Unconstrained},j} + \epsilon_j, \\
&\Delta y_j = \beta_0 + \beta_1 \text{ST FC}_j + \beta_2 ImportedInputShare_I + \beta_3 \Delta P_I \\
&+ \beta_4 \log(k_j) + \beta_5 \text{ST FC}_j \times \log(k_j) + \alpha \log(X_j) + \gamma \text{ST FC}_j \times \log(X_j) + \epsilon_j.
\end{aligned}
\tag{10}
$$

ST FC is the short-term foreign currency debt ratio of firm j in industry I, which is λ in our model, and we interact the short-term foreign currency debt ratio with two measures of financial constraints. As we observe if firms are financially constrained or not in the model, we first interact with the indicator function, $1_{\text{Unconstrained},j}$, to indicate whether a firm j is financially constrained ($1_{\text{Unconstrained},j} = 0$) or not ($1_{\text{Unconstrained},j} = 1$) when making their borrowing decisions after the shock hits. We also use log of capital stock chosen before the exchange rate shock hits as a proxy for the degree of financial constraint, as it corresponds to the amount of collateral that a firm can pledge for its borrowing.[37] The conditional correlation between the two measures is 0.33, implying that firms with larger capital are indeed less financially constrained.[38] For both measures, a lower value of each measure implies that firms are more financially constrained. We would like to elicit the role of the financial constraint in amplifying the negative effect of high foreign currency debt ratio on a firm's balance sheet after a large depreciation of domestic currency. β_1 and β_5 are the coefficients of our interest.[39]The imported input share in total inputs is included to take out the direct effect of the exchange rate shock on the costs of imported inputs used for their production. We also include the sectoral price changes to capture firms' price response to other firms' prices, highlighting the role of strategic complementarity.

Tables 8 and 9 summarize the estimation results of regression 10 with dependent variables of price and markup changes. In Table 8, firms with higher foreign currency debt exposure increase their prices more, and, on top of that, financially constrained firms increase their prices more compared to unconstrained firms with the same level of foreign currency debt exposure. The result illustrates that financial friction amplifies the negative balance sheet effects of high foreign currency debt exposure. Even with the same amount of short-term foreign currency debt exposure, firms with higher capital stock are not financially constrained as much as firms with lower capital stock, so their production is not as constrained as smaller firms upon the exchange rate depreciation.

[37]Moreover, we use the amount of capital instead of sales as a measure of financial constraint so that we can directly link our results to the policy functions in Section 6. The results are, however, robust to using sales instead of the amount of capital.

[38]The correlation is computed after controlling for other firm-level variables X_j: log of debt d_j, liquid assets a_j and the productivity z_j before the shock hits.

[39]We control for other firm-level variables and their interactions with short-term foreign currency debt ratio when we use an imperfect proxy for the degree of financial constraints, log of capital stock.

Table 8: Firm-level Regressions: Price Changes

	Price Changes		
	(1)	(2)	(3)
ST FC$_j$	0.0532	0.0583	0.1190
Imported Input Share$_I$	0.0647	0.0691	0.0754
ΔP_I	0.7043	0.6997	0.6954
$1_{\text{Unconstrained},j}$ × ST FC$_j$		-0.0415	
$log(k_j)$ × ST FC$_j$			-0.0136

Notes: The dependent variables are the growth rate of firm-level prices. ST FC$_j$ corresponds to the firm-level foreign currency debt ratio. The imported input share is the ratio of imported inputs to total inputs in the model. The regressions are based on the model simulated firm-level data. For Column (3), we control for other firm-level variables X_j: log of debt d_j, liquid assets a_j and the productivity z_j and their interaction with short-term foreign currency debt ratio before the shock hits. The regressions are based on the model simulated firm-level data.

Table 9: Firm-level Regressions: Markup Changes

	Markup Changes		
	(1)	(2)	(3)
ST FC$_j$	-0.0774	-0.0852	-0.1728
Imported Input Share$_I$	-0.0940	-0.1013	-0.1025
ΔP_I	0.4395	0.4469	0.4468
$1_{\text{Unconstrained},j}$ × ST FC$_j$		0.0628	
$log(k_j)$ × ST FC$_j$			0.0315

Notes: The dependent variables are the growth rate of price-cost markups. ST FC$_j$ corresponds to the firm-level foreign currency debt ratio. The imported input share is the ratio of imported inputs to total inputs in the model. The regressions are based on the model simulated firm-level data. For Column (3), we control for other firm-level variables X_j: log of debt d_j, liquid assets a_j and the productivity z_j and their interaction with short-term foreign currency debt ratio before the shock hits. The regressions are based on the model simulated firm-level data.

Consequently, the increase in price is much more muted for unconstrained firms. We also observe that a firm in an industry with higher imported input share increases its price more. Lastly, we see that a firm with zero foreign currency debt and zero imported input share also increases its price when the industry price goes up, exhibiting a strong strategic complementarity.

In Table 9, we find that firms with higher foreign currency debt exposure lower their price-cost markups more. Moreover, financially unconstrained firms reduce their price-cost markups by lesser degrees compared to financially constrained firms for a given level of foreign currency debt exposure. Similarly, even with the same amount of short-term foreign currency debt exposure, firms with higher capital stock are less financially constrained than firms with lower capital stock, so firms with higher capital lower their markups less than firms with lower capital. The results are consistent with what we see from the firm-level regressions in Section 3. A firm with zero foreign currency debt and zero imported input share increases both their markups and their prices due to strategic complementarity when their competitors in the same industry increase their prices. This firm-level analysis using simulated data highlights the role of both the balance sheet channel of foreign currency debt and the strategic complementarity in the price setting play in explaining sectoral price dynamics upon a large depreciation.

8 Counterfactuals: Quantifying Balance Sheet Effects

While the firm-level regression with simulated data highlights how firms facing the same level of imported input share and the average industry price changes experience *significantly higher* 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 after taking into account firms' strategic interactions with other firms in the industry. Each sector faces a different firm-level distribution of foreign currency debt and imported input share, and both channels put upward pressure on sectoral prices, 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 upon a depreciation shock. That is, we assume ω =0.

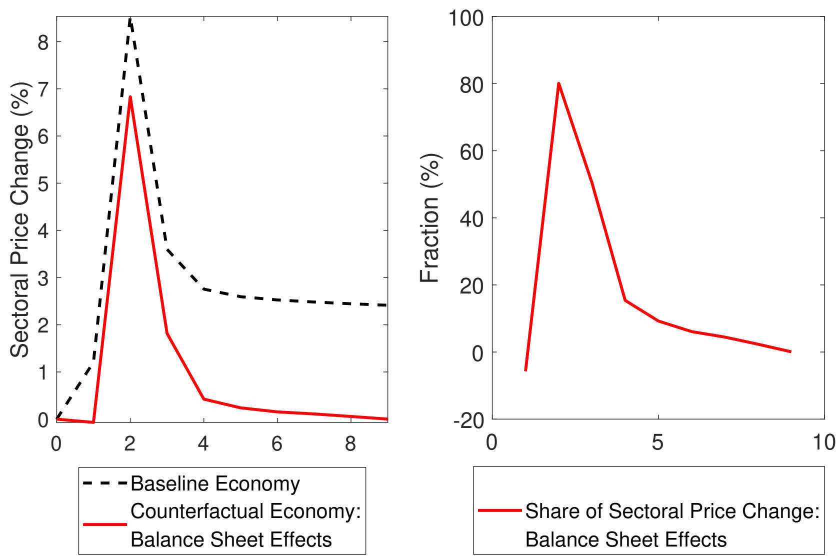
Figure 11 depicts the transition paths of an industry with an average foreign currency debt share of 40% in the baseline model and in the counterfactual economy, where the depreciation shock does not affect the imported input prices. We see that the industry price level increases by 9% in the baseline model, where 80% of the price response can be attributed to the deterioration of the balance sheet.

We then compute the the average sectoral price changes across foreign currency debt ratios in the baseline model and in the counterfactual economy, shutting down the effect of exchange rate shock on imported input prices. We group sectors with foreign currency debt ratios in $(0\%, 5\%)$, $[5\%, 15\%)$, $\ldots$, $[45\%, 55\%)$, $[55\%, 70\%)$. Figure 12 shows that the balance sheet effect of foreign currency debt alone explains around 20% to 80 % of sectoral price changes observed in the baseline model. For an average industry with positive foreign currency short-term debt, 50% of sectoral price changes can be attributed to the balance sheet effect of foreign currency debt.

Using the simulated firm-level price data, analogous to Figure 12, we look at the fraction of firm-level price changes that can be attributed to the balance sheet effects of foreign currency debt.[40] We compute, across foreign currency debt ratio deciles, the average firm-level price changes in the baseline economy, and the average firm-level price changes in the counterfactual economy. Shown in Figure A6 in the Appendix, 25% to 65% of firm-level price changes can be attributed to the balance sheet channel of foreign currency debt. The numbers are pretty much aligned with what we have seen with sectoral level price changes in the baseline model and in the counterfactual exercise, depicted in Figure 12.

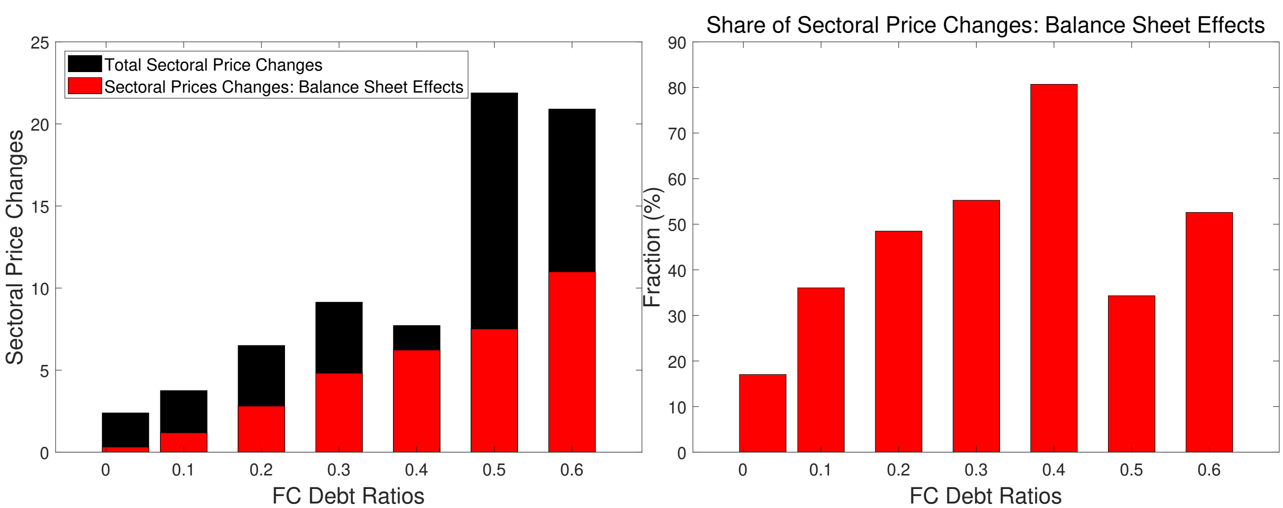
[40] In all the computations in Section 8, we only include firms with positive foreign currency debt, but the quantitative results for the lowest deciles do not vary much even when we include those with zero foreign currency debt.

Figure 11: Impulse Response Functions of Industry Prices



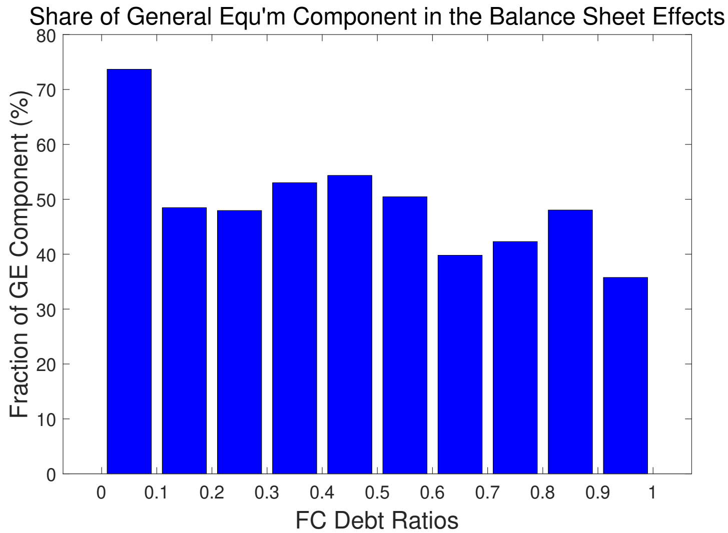
Notes: In the left panel, the solid red line and the dashed black line show the average price responses of an industry with average FC-loan share of 40% upon an unexpected large depreciation at period 1. The dashed black line shows the the price response in the baseline economy where both higher imported input prices and the balance sheet effect of foreign currency debt put upward pressure on the sectoral price level, while the solid red line captures only the balance sheet effect of foreign currency debt on the sectoral price level. The fraction of the sectoral price change explained by the balance sheet effect for this industry is presented in the right panel.

Figure 12: Counterfactual Exercise
The Quantitative Size of the Balance Sheet Channel of FC Debt at the Sectoral-level



Notes: The figure uses the two sets of 156 sectoral price changes: one computed in the baseline model and the other computed in the counterfactual model with ω=0, shutting down the effect of exchange rate shock on imported input prices. 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)/(i) across sectoral foreign currency debt ratios.

Figure 13: Share of General Equilibrium Effects in the Balance Sheet Effects of FC Debt



Notes: The figure uses the model simulated firm-level price data. The figure shows the ratio of average general equilibrium effects to average firm-level price changes in the counterfactual economy for each foreign currency debt ratio deciles. For each foreign currency debt ratio deciles, the average general equilibrium effects are computed by subtracting the average predicted firm-level price changes via firms' foreign currency debt ratios from average firm-level price changes in the counterfactual economy.

To highlight the role of strategic complementarity in firms' price setting, we then further 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 general equilibrium effects arising from firms strategically responding to *other firms' price changes* due to *other firms'* foreign currency debt exposure. Across foreign currency debt ratio deciles, we compute the average *predicted* firm-level price changes via their own foreign currency debt exposure from regression 10: $\Delta y_j = \beta_0 + \beta_1 \text{ST FC}_j + \beta_2 ImportedInputShare_I + \beta_3 \Delta P_I + \epsilon_j$, i.e., $\hat{\beta}_1 \text{ST FC}_j$. It captures the *direct* effect of firms' holding foreign currency debt on their own pricing decisions. Then, we calculate the *general equilibrium* component of the balance sheet effect of foreign currency debt on firm-level price changes. For each of foreign currency debt ratio decile, we take out the average direct effect of their own foreign currency debt exposure from the average firm-level price changes in the counterfactual economy.

Figure A7 in the Appendix shows that 6% to 36% of firm-level price changes that we see in the baseline model can be attributed to their own foreign currency exposure, while 18% to 32% of those can be attributed to firms' strategically responding to other firms' price changes owing to other firms' indebtedness in foreign currency debt. The relative size of the direct vs. indirect effect of foreign currency debt is shown in Figure 13. 36% to 74% of the balance sheet effect of foreign currency debt can be attributed to 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 such as a larger price increase when an industry is on average holding a higher foreign currency debt ratio. Moreover, from firm-level simulations, we confirm that the model can explain the observed firm-level behavior after a large devaluation well. We have shown that firms significantly increase their prices as they have higher foreign currency debt exposure, especially when they are financially constrained. The counterfactual exercise affirms the quantitatively sizable role of the balance sheet channel in explaining sectoral price dynamics and shows the significance of firms' strategic complementarity in their price setting.

9 Conclusion

With a unique firm-level and aggregated industry-level dataset, our empirical findings suggest that the balance sheet channel of dollar debt–whose role is understudied in the exchange rate pass-through literature–plays an important role in explaining how the exchange rate affects domestic prices, especially for emerging economies with dollarized liabilities. During a large devaluation in Korea, we first find that firms indeed suffer from lower sales and net worth growths when they held a high level of foreign currency debt before the crisis. The negative balance sheet effect is mitigated as the firm size is larger since larger firms are less financially constrained. Moreover, our firm-level analysis shows that their markups have *declined* more when indebted in foreign currency deb, especially for smaller firms.

We then find that industries populated by firms with higher foreign currency debt exposure have increased their prices more upon a large devaluation. The industry-level price responses are consistent with what we find from the firm-level analyses. When firms with more foreign currency debt exposure face higher debt burden upon the devaluation, constraining their production of goods, firms lower their sales, increasing the price of goods sold. The very negative balance sheet effect is stronger for smaller firms. On top of that, larger firms, who do not face disruptions in their production, strategically respond to higher prices set by other constrained firms by increasing their markups and prices. The sectoral producer inflation is amplified by the strategic complementarity in firms' price setting.

Based on these empirical findings, we build a quantitative heterogeneous firm model to study an industry equilibrium and its transition path upon an unexpected exchange rate depreciation. We analyze the qualitative and quantitative implications of the financial frictions in explaining the average changes in the sectoral prices and its dispersion. With the industry-specific firm-level distribution of foreign currency debt and the industry-specific imported input share, the model can explain around 30% of the mean effect of the foreign currency debt ratio on the price changes and 21% of the variation in price changes across industries. With the firm-level simulated data from the estimated model, we decompose the two distinct channels of exchange rate pass-through–balance sheet channel and imported input channel–at the firm level and show that both are significant contributors to the firm-level price dynamics during the crisis. We also highlight the role of strategic complementarity in the price setting and the financial frictions in explaining sectoral price dynamics after a large depreciation of domestic currency. The counterfactual exercise highlights the quantitative size of the balance sheet channel in explaining the price dynamics after a depreciation shock. We find that 20 – 80% of sectoral price changes and 25 – 65% of firm-level price changes can be attributed to the balance sheet channel of foreign currency debt. Around 36 to 74% of these balance sheet effects of foreign currency debt can be attributed to firms responding to other firms' price changes.

Our empirical analysis and our quantitative analysis through a heterogenous firm model reveal that it is important, albeit overlooked, to incorporate the balance sheet effect when analyzing how the exchange rate affects domestic prices, especially for emerging economies with dollarized liability. Our findings have important policy implications on shaping the optimal monetary policy and currency choice in external borrowings. We believe that it is an important normative question to ask, but we will leave it for future research.

References

Ackerberg, D., Caves, K., and Frazer, G. (2006). Structural identification of production functions.

Affendy, A. M., Yee, L. S., and Madono, S. (2010). Commodity-industry classification proxy: A correspondence table between sitc revision 2 and isic revision 3. *Memeo*.

Aguiar, M. (2005). Investment, devaluation, and foreign currency exposure: The case of mexico. *Journal of Development Economics*, 78:95–113.

Alfaro, L., García-Santana, M., and Moral-Benito, E. (2021). On the direct and indirect real effects of credit supply shocks. *Journal of Financial Economics*, 139(3):895–921.

Amiti, M., Itskhoki, O., and Konings, J. (2018). International shocks, variable markups, and domestic prices. *Review of Economic Studies*.

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

Amiti, M. and Weinstein, D. E. (2018). How much do idiosyncratic bank shocks affect investment? evidence from matched bank-firm loan data. *Journal of Political Economy*, 126(2):525–587.

Bruno, V. and Shin, H. S. (2017). Global dollar credit and carry trades: a firm-level analysis. *Review of Financial Studies*, 30(3):703–749.

Bruno, V. and Shin, H. S. (2023). Dollar and exports. *Review of Financial Studies*, 36(8):2963–2996.

Burstein, A., Eichenbaum, M., and Rebelo, S. (2005). Large devaluations and the real exchange rate. *Journal of Political Economy*, 113(4):742–784.

Burstein, A. and Gopinath, G. (2014). International prices and exchange rates. *Handbook of International Economics*, 4:391–451.

Casas, C., Meleshchuk, S., and Timmer, Y. (2023). The dominant currency financing channel of external adjustment.

Céspedes, L. F., Chang, R., and Velasco, A. (2004). Balance sheets and exchange rate policy. *American Economic Review*, 94(4):1183–1193.

Christiano, L. J., Eichenbaum, M. S., and Trabandt, M. (2015). Understanding the great recession. *American Economic Journal: Macroeconomics*, 7(1):110–67.

Colacito, R., Qian, Y., and Stathopoulos, A. (2022). Global sales, international currencies and the currency denomination of debt. *International Currencies and the Currency Denomination of Debt (February 1, 2022)*.

Corsetti, G., Crowley, M., and Han, L. (2022). Invoicing and the dynamics of pricing-to-market: Evidence from uk export prices around the brexit referendum. *Journal of International Economics*, 135:103570.

Crucini, M. J. and Telmer, C. I. (2020). Microeconomic sources of real exchange rate variation. *Review of Economic Dynamics*, 38:22–40.

De Loecker, J. and Warzynski, F. (2012). Markups and firm-level export status. *American Economic Review*, 102(6):2437–71.

Del Negro, M., Giannoni, M. P., and Schorfheide, F. (2015). Inflation in the great recession and new keynesian models. *American Economic Journal: Macroeconomics*, 7(1):168–96.

Devereux, M. B. and Engel, C. (2002). Exchange rate pass-through, exchange rate volatility, and exchange rate disconnect. *Journal of Monetary Economics*, 49(5):913–940.

Drenik, A. and Perez, D. J. (2021). Domestic price dollarization in emerging economies. *Journal of Monetary Economics*, 122:38–55.

Engel, C. (1993). Real exchange rates and relative prices: An empirical investigation. *Journal of Monetary Economics*, 32(1):35–50.

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

Engel, C. (2006). Equivalence results for optimal pass-through, optimal indexing to exchange rates, and optimal choice of currency for export pricing. *Journal of the European Economic Association*, 4(6):1249–1260.

Gilchrist, S., Schoenle, R., Sim, J., and Zakrajšek, E. (2017). Inflation dynamics during the financial crisis. *American Economic Review*, 107(3):785–823.

Gilchrist, S. and Sim, J. W. (2007). Investment during the korean financial crisis: a structural econometric analysis. Technical report, National Bureau of Economic Research.

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

Goldberg, L. S. and Tille, C. (2008). Vehicle currency use in international trade. *Journal of International Economics*, 76(2):177–192.

Goldberg, L. S. and Tille, C. (2016). Micro, macro, and strategic forces in international trade invoicing: Synthesis and novel patterns. *Journal of International Economics*, 102:173–187.

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

Gopinath, G. and Itskhoki, O. (2010). Frequency of price adjustment and pass-through. *Quarterly Journal of Economics*, 125(2):675–727.

Gopinath, G., Itskhoki, O., and Rigobon, R. (2010). Currency choice and exchange rate pass-through. *American Economic Review*, 100(1):304–336.

Gutierrez, B., Ivashina, V., and Salomao, J. (2023). Why is dollar debt cheaper? evidence from peru. *Journal of Financial Economics*, 148(3):245–272.

Hardy, B. and Saffie, F. (forthcoming). From carry trades to trade credit: Financial intermediation by nonfinancial corporations.

Huang, Y., Panizza, U., and Portes, R. (forthcoming). Corporate foreign bond issuance and interfirm loans in china.

Jordà, Ò. (2005). Estimation and inference of impulse responses by local projections. *American Economic Review*, 95(1):161–182.

Kalemli-Ozcan, S., Kamil, H., and Villegas-Sanchez, C. (2016). What hinders investment in the aftermath of financial crises: Insolvent firms or illiquid banks? *Review of Economics and Statistics*, 98(4):756–769.

Kedia, S. and Mozumdar, A. (2003). Foreign currency–denominated debt: An empirical examination. *Journal of Business*, 76(4):521–546.

Kim, J., Lee, A. S., and Lee, S. (2024). Corporate dollar debt and global trades.

Kim, R. (2021). The effect of the credit crunch on output price dynamics: The corporate inventory and liquidity management channel. *Quarterly Journal of Economics*, 136(1):563–619.

Kim, Y. J., Tesar, L. L., and Zhang, J. (2015). The impact of foreign liabilities on small firms: Firm-level evidence from the korean crisis. *Journal of International Economics*, 97(2):209–230.

Kimball, M. S. (1995). The quantitative analytics of the basic neomonetarist model. *Journal of Money, Credit and Banking*, 27(4):1241.

Kohn, D., Leibovici, F., and Szkup, M. (2020). Financial frictions and export dynamics in large devaluations. *Journal of International Economics*, 122:103257.

Krugman, P. (1999). Balance sheets, the transfer problem, and financial crises. In *International finance and financial crises*, pages 31–55. Springer.

Lee, A. S. and Wu, S. P. Y. (forthcoming). Carry trade and precautionary saving of foreign currency debt: Evidence from korean firms. *Review of Economics and Statistics*.

Lyonnet, V., Martin, J., and Mejean, I. (2022). Invoicing currency and financial hedging. *Journal of Money, Credit and Banking*, 54(8):2411–2444.

Ma, S. and Schmidt-Eisenlohr, T. (2023). The financial channel of the exchange rate and global trade.

Mukhin, D. (2022). An equilibrium model of the international price system. *American Economic Review*, 112(2):650–688.

Nakamura, E. and Steinsson, J. (2008). Five facts about prices: A reevaluation of menu cost models. *Quarterly Journal of Economics*, 123(4):1415–1464.

Rauch, J. E. (1999). Networks versus markets in international trade. *Journal of International Economics*, 48(1):7–35.

Salomao, J. and Varela, L. (2018). Exchange rate exposure and firm dynamics.

Tauchen, G. (1986). Finite state markov-chain approximations to univariate and vector autoregressions. *Economics Letters*, 20(2):177–181.

Uribe, M. and Yue, V. Z. (2006). Country spreads and emerging countries: Who drives whom? *Journal of International Economics*, 69(1):6–36.

Yang, J. and Kwon, O. (2023). Imports, exports, and the currency composition of corporate debt.

Online Appendix

Data Source

The below 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 (PPI)	Bank of Korea (1991 – 2000)	Base year of 2015
Consumer Price Index (CPI)	Bank of Korea (1991 – 2000)	Base year of 2015
Rauch Classification	Rauch (1999)	4-digit SITC Rev. 2 commodities
Imported Input Share	Bank of Korea	Input-Output (IO) table
Price Stickiness	Nakamura and Steinsson (2008)	Median frequency of price change in Table 12
Imported Input Price Indices	Bank of Korea	Import Price Indices

Data Cleaning

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

- missing or negative value of sales, total assets, total liability, and net worth
- not included in manufacturing sector $(KSIC \in [10, 34])$
- short-term foreign currency debt exposure larger than 1
- long-term foreign currency debt exposure larger than 1
- export to sales ratio larger than 1
- foreign currency cash to total current assets ratio larger than 1

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 and or below the bottom 1 percent of the distribution. We didn't 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 and or below the bottom 1 percent of the distribution. These results are included 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[41] 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 levels, Rauch (1999) defines whether it is a differentiated product or not. Following Affendy et al. (2010), we map each 4–digit SITC code to a ISIC Rev.3 code. This 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 now 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.[42] 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, now we have one PPI industry classification is mapped to none or one or a few 4–digit SITC Rev.2 codes.

[41] We use the log of real sales when computing firms' sales share to limit the effects of the outliers.
[42] This is a 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 numbers, where the weights are the commodities' trade shares in 1996.[43] 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 Input-Ouput (IO) table in 1995 from the Bank of Korea. We map each PPI industry classification to one or two closest items in the IO table; i.e., one PPI industry classification is now mapped to one or more items in the IO table.[44] For each item j in the IO table, we can compute the share of imported intermediate inputs in the total amount of inputs (all intermediate inputs and value-added from labor and capital) used for the production of 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 for 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.[45] 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.

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

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

[43]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.

[44]The number of items in the IO table are much smaller, i.e. the classification is much broader, so we map each PPI industry classification to one or more IO items rather than the other way around. Some PPI industries are, therefore, matched with the same IO item(s).

[45]Note that item j can be in sector S and S' at the same time.

the price stickiness is measured in Table 12 of Nakamura and Steinsson (2008).[46]

Additional Tables and Figures for Sections 3 and 6

Table A2: Firm Performance: Estimates with Additional Controls

	(1) Net Worth Growth	(2) Sales Growth	(3) Markup Growth
ST FC	-8.7242*	-4.3365**	-0.7757***
	(4.6277)	(1.7812)	(0.2097)
LT FC	-0.1046	-0.0989	0.1211
	(3.4772)	(1.2777)	(0.1593)
Size	0.0370	-0.1253***	-0.0098*
	(0.1415)	(0.0435)	(0.0056)
ST FC x Size	0.3320*	0.1771**	0.0303***
	(0.1873)	(0.0696)	(0.0083)
LT FC x Size	0.0109	0.0128	-0.0046
	(0.1415)	(0.0511)	(0.0065)
Leverage Ratio	13.1064*	8.7033***	-0.2491
	(7.5494)	(1.7785)	(0.2227)
Export to Sale Ratio	-7.7715	0.4043	-0.1332
	(5.2220)	(1.5827)	(0.2523)
ST Debt Ratio	0.9711	-4.3091***	0.1844
	(3.4852)	(1.1957)	(0.1485)
FC Cash Ratio	38.4897	-21.2779	-0.1175
	(33.9071)	(15.1306)	(1.4714)
Leverage Ratio x Size	-0.4769	-0.3495***	0.0110
	(0.3156)	(0.0725)	(0.0092)
Export to Sale Ratio x Size	0.3416	-0.0024	0.0071
	(0.2142)	(0.0627)	(0.0103)
ST Debt Ratio x Size	-0.0354	0.1732***	-0.0081
	(0.1458)	(0.0490)	(0.0062)
FC Cash Ratio x Size	-1.5865	0.8785	0.0136
	(1.3668)	(0.6189)	(0.0607)
Adjusted R^2	0.0540	0.1734	0.0434
N	3137	3137	3135

Notes: This table shows the results from firm-level regressions. The dependent variables are the growth rate of (1) real net worth, (2) real sales, and (3) markups from 1996 to 1998. The main regressors are firm-level short-term foreign currency debt ratio (ST FC) and the cross product of firm size and ST FC in 1996. The size is measured as the log of real sales. To alleviate a potential endogeneity issue, we use the pre-crisis (1996) value of regressors. Robust standard errors are reported in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

[46] 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.

Table A3: Firm Performance and FC Debt: Different Definitions of Currency Composition

	(1) Net Worth Growth	(12) Sales Growth	(3) Markup Growth
ST FC	-21.9625***	-11.9181***	-0.9225***
	(5.2742)	(2.4475)	(0.3060)
LT FC	-1.6368	-0.4541	0.0838
	(5.8041)	(2.9081)	(0.3108)
Size	-0.1662***	-0.1540***	-0.0097***
	(0.0582)	(0.0166)	(0.0022)
ST FC x Size	0.8270***	0.4820***	0.0361***
	(0.2070)	(0.0955)	(0.0121)
LT FC x Size	0.0887	0.0365	-0.0032
	(0.2379)	(0.1160)	(0.0126)
Leverage Ratio	1.6176***	0.3259***	0.0156
	(0.2602)	(0.0715)	(0.0116)
Export to Sale Ratio	0.6441***	0.3015***	0.0436***
	(0.2354)	(0.0630)	(0.0090)
Domestic ST Ratio	0.3012*	-0.1129**	-0.0048
	(0.1785)	(0.0549)	(0.0081)
FC Cash Ratio	-0.8312	1.5143	0.2615**
	(1.3010)	(1.5018)	(0.1179)
Adjusted R^2	0.0521	0.1489	0.0419
N	3122	3122	3120

Notes: This table shows the results from firm-level regressions. The dependent variables are the growth rate of (1) real net worth, (2) real sales, and (3) markups from 1996 to 1998. We compute the foreign currency exposure for short-term and long-term debt as the ratio of foreign currency short-term or long-term debt to *total debt*. The main regressors are the firm-level short-term foreign currency debt ratio (ST FC) and the cross product of firm size and ST FC in 1996. The size is measured as the log of real sales. To alleviate a potential endogeneity issue, we use the pre-crisis (1996) value of the regressors. Robust standard errors are calculated in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table A4: Firm Performance and FC Debt: Estimates of Other Dependent Firm-level Variables

	(1) Capital Growth	(2) Labor Productivity Growth	(3) Labor Cost Growth	(4) Total Current Assets Growth
ST FC	-6.8785**	-5.0145**	-5.1204***	-7.0549***
	(3.2908)	(2.0269)	(1.1846)	(2.6712)
LT FC	-0.2167	-0.2146	-0.4887	1.4621
	(1.9374)	(1.2766)	(1.0091)	(2.1451)
Size	-0.0580**	-0.0875***	-0.1098***	-0.1027***
	(0.0281)	(0.0181)	(0.0134)	(0.0191)
ST FC x Size	0.2681**	0.1980**	0.2018***	0.2750***
	(0.1296)	(0.0789)	(0.0468)	(0.1061)
LT FC x Size	0.0110	0.0188	0.0226	-0.0487
	(0.0776)	(0.0507)	(0.0401)	(0.0863)
Leverage Ratio	-0.1682*	0.4032***	-0.0010	0.0548
	(0.1016)	(0.0938)	(0.0474)	(0.0997)
Export to Sale Ratio	-0.1160	0.3001***	0.2206***	0.3495***
	(0.0866)	(0.0810)	(0.0587)	(0.0949)
ST Debt Ratio	-0.3329***	-0.0289	-0.1712***	-0.2901***
	(0.1069)	(0.0676)	(0.0475)	(0.0705)
FC Cash Ratio	1.2075	0.6663	2.1621**	-2.4079***
	(1.9843)	(1.6507)	(1.1024)	(0.6931)
Adjusted R^2	0.0196	0.0603	0.1278	0.0542
N	2725	3015	2181	3130

Notes: This table shows the results from firm-level regressions. The dependent variables are the growth rate of (1) capital, (2) labor productivity, (3) labor cost, and (4) total current assets from 1996 to 1998. We measure the labor productivity as sales to employment ratio and labor cost as personnel expenses. The main regressors are firm-level short-term foreign currency debt ratio (ST FC) and the cross product of firm size and ST FC in 1996. The size is measured as the log of real sales. To alleviate a potential endogeneity issue, we use the pre-crisis (1996) value of regressors. Robust standard errors are reported in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table A5: Firm Performance and FC Debt: Placebo Test Before Devaluation

	(1) Net Worth Growth	(2) Sales Growth	(3) Markup Growth
ST FC	1.0404	-1.7186	0.0737
	(2.2741)	(1.4186)	(0.2314)
LT FC	0.2087	-3.9180***	-0.0084
	(1.9175)	(1.1576)	(0.1431)
Size	0.0615*	-0.1205***	0.0022
	(0.0354)	(0.0183)	(0.0024)
ST FC x Size	-0.0485	0.0727	-0.0025
	(0.0910)	(0.0558)	(0.0092)
LT FC x Size	-0.0096	0.1614***	0.0006
	(0.0770)	(0.0469)	(0.0058)
Leverage Ratio	0.7746***	0.3498***	0.0549***
	(0.2080)	(0.0742)	(0.0118)
Export to Sale Ratio	0.0570	-0.1137***	-0.0153**
	(0.1362)	(0.0433)	(0.0074)
Domestic ST Ratio	-0.0756	-0.1513***	0.0011
	(0.1247)	(0.0536)	(0.0092)
FC Cash Ratio	0.2753	-0.0342	-0.1964***
	(0.4077)	(0.2065)	(0.0428)
Adjusted R^2	0.0087	0.1209	0.0229
N	1883	1883	1883

Notes: This table shows the results from firm-level regressions. The dependent variables are the growth rate of (1) real net worth, (2) real sales, and (3) markups from 1993 to 1995. The main regressors are the firm-level short-term foreign currency debt ratio (ST FC) and the cross product of firm size and ST FC in 1993. The size is measured as the log of real sales. Robust standard errors are calculated in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table A6: 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

Notes: The table shows top 10 industries with higher FC share of short-term debt ratio in 1996. Columns 1 and 2 show the foreign currency share of short-term debt ratio and long-term debt ratio, respectively.

Table A7: Summary Statistics of Industry-level Control Variables

	(1) *Mean*	*(2)* *Stdev*
Import Share (%)	17.62	11.91
Rauch dummy	0.82	0.38
Price Stickiness	7.70	6.67

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 A8: Industry Price Dynamics and Short-term FC Debt Ratio:
Accounting for Change in Number of Firms

	(1)	(2)	(3)
ST FC	0.5685***	0.6437***	0.5531***
	(0.2038)	(0.2173)	(0.2060)
LT FC	-0.1846	-0.1920	-0.1830
	(0.1365)	(0.1346)	(0.1363)
Log Change of # of Firms		1.0001**	1.0207*
		(0.4832)	(0.5382)
Rauch Dummy	0.0075		-0.0020
	(0.0447)		(0.0465)
Imported Input Share	0.2830*		0.2728
	(0.1656)		(0.1675)
Degree of Price Stickiness	0.0317*		0.0327*
	(0.0168)		(0.0167)
Size	0.0024	0.0066	0.0023
	(0.0181)	(0.0184)	(0.0183)
Export to Sale Ratio	-0.0469	-0.0169	-0.0413
	(0.1543)	(0.1562)	(0.1526)
Leverage Ratio	0.3351**	0.3365**	0.3076*
	(0.1589)	(0.1494)	(0.1645)
Domestic ST Ratio	0.1255	0.0929	0.1443
	(0.1253)	(0.1176)	(0.1253)
FC Cash Ratio	-0.2252	0.4050	-0.1171
	(3.1429)	(3.1391)	(3.2099)
Broad Industry FE	Yes	Yes	Yes
Adjusted R^2	0.4513	0.4440	0.4515
N	156	156	156

Notes: This table shows the results from regression 4 with a different set of regressors. The dependent variable is the growth rates of sectoral prices 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. To alleviate a potential endogeneity issue, we use the pre-crisis (1996) value of the regressors. For the imported input share, we use the 1995 value due to data availability. The number of firms for each industry is collected from the Korean Statistical Information Service (KOSIS). Robust standard errors are reported in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table A9: Industry Price Dynamics and Short-term FC Debt Ratio:
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)
Domestic ST 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)
Broad Industry FE	Yes	Yes	Yes
Adjusted R^2	0.4157	0.4373	0.4365
N	155	155	155

Notes: This table shows the results from regression 4 with a subsample of domestic firms whose exports are zero. The dependent variable is the growth rates of sectoral prices 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. To alleviate a potential endogeneity issue, we use the pre-crisis (1996) value of the regressors. For the imported input share, we use the 1995 value due to data availability. Robust standard errors are reported in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table A10: Industry Price Dynamics and Short-term FC Debt Ratio:
Different Definitions of Currency Composition

	(1)	(2)	(3)	(4)	(5)
ST FC	0.8978***	0.9008***	0.7497***	0.7598***	0.6780***
	(0.1951)	(0.2025)	(0.1597)	(0.2293)	(0.2099)
LT FC		-0.0319	-0.0943	-0.4331	-0.4063
		(0.2922)	(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)
Broad Industry FE	No	No	Yes	Yes	Yes
Adjusted R^2	0.1411	0.1356	0.4131	0.4452	0.4457
N	156	156	156	156	156

Notes: This table shows the results from regression 4 with a different definition of foreign currency exposure. We compute the foreign currency exposure for foreign currency short-term and long-term debt as the ratio of short-term or long-term debt to *total* debt. The dependent variable is the growth rates of sectoral prices 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. To alleviate a potential endogeneity issue, we use the pre-crisis (1996) value of the regressors. For the imported input share, we use the 1995 value due to data availability. The number of firms for each industry is collected from the Korean Statistical Information Service (KOSIS). Robust standard errors are reported in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table A11: Industry Price Dynamics and Short-term FC Debt Ratio: Subsample of Industries

	(1)	(2)	(3)	(4)	(5)
ST FC	0.6005***	0.6502***	0.4862**	0.5779**	0.4956**
	(0.1904)	(0.2136)	(0.2008)	(0.2529)	(0.2477)
LT FC		-0.0760	-0.2039	-0.2048	-0.1616
		(0.1264)	(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)
Broad Industry FE	No	No	Yes	Yes	Yes
Adjusted R^2	0.0888	0.0843	0.4160	0.4360	0.4479
N	136	136	136	136	136

Notes: This table shows the results from regression 4 with a subsample of sectors that have at least four firms. The dependent variable is the growth rates of sectoral prices 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. To alleviate a potential endogeneity issue, we use the pre-crisis (1996) value of the regressors. For the imported input share, we use the 1995 value due to data availability. Robust standard errors are reported in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table A12: Placebo Test, Industry Price Dynamics Before Devaluation and Short-term FC Debt Ratio

	(1)	(2)	(3)	(4)	(5)
ST FC	0.1228	0.0967	-0.0480	-0.2587	-0.2671
	(0.1325)	(0.1130)	(0.1552)	(0.2197)	(0.2176)
LT FC		0.0403	-0.0217	-0.0250	-0.0130
		(0.0690)	(0.0979)	(0.0958)	(0.0953)
Size				0.0316	0.0287
				(0.0269)	(0.0254)
Export to Sale Ratio				0.1479	0.1477
				(0.1167)	(0.1180)
Leverage Ratio				0.2299	0.2329
				(0.1606)	(0.1582)
ST Debt Ratio				-0.1488	-0.1400
				(0.1847)	(0.1761)
FC Cash Ratio				-1.3659	-1.3601
				(1.3813)	(1.3956)
Rauch Dummy					0.0109
					(0.0519)
Imported Input Share					0.1285
					(0.1104)
Degree of Price Stickiness					-0.0276**
					(0.0126)
Broad Industry FE	No	No	Yes	Yes	Yes
Adjusted R^2	0.0015	-0.0036	0.2476	0.2818	0.2760
N	151	151	151	151	151

Notes: This table shows the results from regression 5 with different sets of regressors. The dependent variable is the growth rates of sectoral prices from 1993 to 1995. The main regressors are sector-level short-term foreign currency debt exposure (ST FC) and long-term foreign currency debt exposure (LT FC) in 1993. To alleviate a potential endogeneity issue, we use the 1993 value of the regressors. Robust standard errors are reported in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table A13: Industry Price Dynamics and Short-term FC Debt Ratio (Crisis Period): 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)
Domestic ST 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)
Broad Industry FE	Yes	Yes	Yes
Adjusted R^2	0.3519	0.3750	0.3899
N	154	154	154

Notes: This table shows the results from regression 4 with a different set of regressors. The dependent variable is the growth rates of sectoral prices 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. To alleviate a potential endogeneity issue, we use the pre-crisis (1996) value of the regressors. For the imported input share, we use the 1995 value due to the data availability. Robust standard errors are reported in parentheses. We exclude industries whose price changes are in the top 1% and the bottom 1% of the distribution. * p<0.1, ** p<0.05, *** p<0.01.

Table A14: Industry Price Dynamics and Short-term FC Debt Ratio (Pre-crisis Period): After Dropping Outliers

	(1)	(2)	(3)
ST FC	0.0121	-0.0621	-0.0739
	(0.1453)	(0.1552)	(0.1570)
LT FC	0.0322	0.0248	0.0364
	(0.0769)	(0.0786)	(0.0788)
Size		0.0116	0.0122
		(0.0113)	(0.0123)
Export to Sale Ratio		0.0976	0.1082
		(0.0972)	(0.1001)
Leverage Ratio		0.0981	0.1059
		(0.0963)	(0.0944)
Domestic ST Ratio		-0.0216	-0.0321
		(0.0763)	(0.0772)
FC Cash Ratio		-0.6957	-0.6485
		(0.9885)	(0.9287)
Rauch Dummy			0.0450
			(0.0407)
Imported Input Share			0.0576
			(0.0936)
Degree of Price Stickiness			-0.0261***
			(0.0080)
Broad Industry FE	Yes	Yes	Yes
Adjusted R^2	0.2924	0.2848	0.2917
N	149	149	149

Notes: This table shows the results from regression 5 with different sets of regressors. The dependent variable is the growth rates of sectoral prices from 1993 to 1995. The main regressors are sector-level short-term foreign currency debt exposure (ST FC) and long-term foreign currency debt exposure (LT FC) in 1993. To alleviate a potential endogeneity issue, we use the 1993 value of regressors. Robust standard errors are reported in parentheses. We exclude industries whose price changes are in the top 1% and the bottom 1% of the distribution. * p<0.1, ** p<0.05, *** p<0.01.

Table A15: Panel Regression: 2000-2019

	(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)
Domestic ST 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)
Industry FE	Yes	Yes
Time FE	Yes	Yes
Adjusted R^2	0.2363	0.2451
N	3498	3300

Notes: This table shows the results from panel regression 8. The dependent variable is the annual growth rate of sectoral producer prices. The main regressors are the interaction of change in the exchange rate (dFX) and sectoral short-term foreign currency debt ratio (ST FC) and long-term foreign currency debt ratio (LT FC). To alleviate a potential endogeneity issue, we use the one year lagged value of the regressors. Robust standard errors are reported in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Table A16: Panel Regression: 2000-2019, 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)
Domestic ST 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)
Industry FE	Yes	Yes
Year FE	Yes	Yes
Adjusted R^2	0.2184	0.2719
N	1636	1662

Notes: This table shows the results from panel regression 8 when we divide sample periods into two sub-periods; the estimation results with periods of KRW appreciation against USD and KRW depreciation against USD are reported in Columns 1 and 2, respectively. The dependent variable is the annual growth rate of sectoral producer prices. The main regressors are the interaction of change in the exchange rate (dFX) and sectoral short-term foreign currency debt ratio (ST FC) and long-term foreign currency debt ratio (LT FC). To alleviate a potential endogeneity issue, we use the one year lagged value of the regressors. Robust standard errors are reported in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

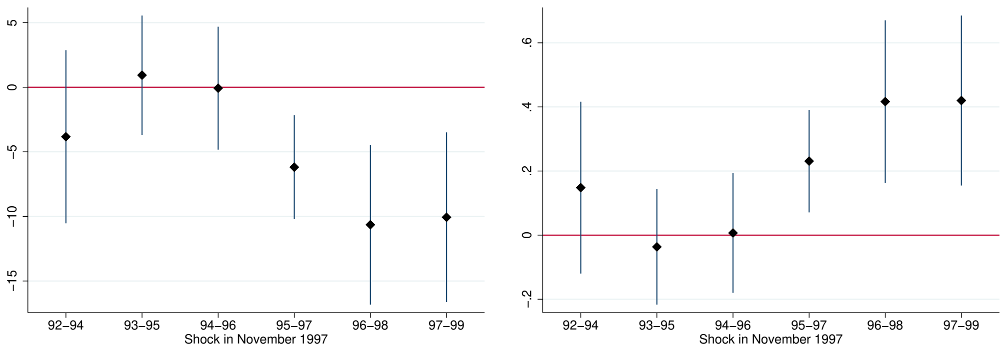
Table A17: Markup Growth Rates for Firms with Zero FC Debt

	Markup Growth Rates
$D_{\text{ST FC=0}}$	0.0092*
	(0.0055)
LT FC	0.0143*
	(0.0086)
Size	-0.0091***
	(0.0023)
Leverage Ratio	0.0211
	(0.0138)
Export to Sale Ratio	0.0385***
	(0.0094)
Domestic ST Ratio	-0.0086
	(0.0086)
FC Cash Ratio	0.2323**
	(0.1109)
Adjusted R^2	0.0396
N	3167

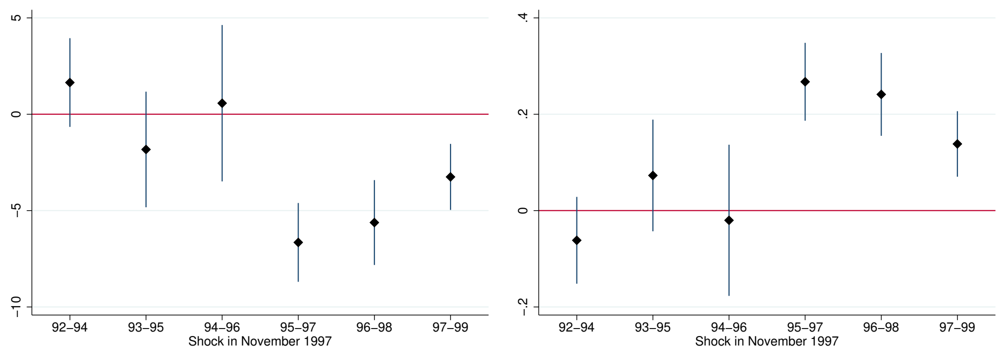
Notes: This table shows the results from firm-level regressions. The dependent variable is the growth rate of estimated markups from 1996 to 1998. $D_{\text{ST FC=0}}$ is the dummy variable that is equal to one when firms' short-term FC debt in 1996 is zero and zero otherwise. We use the pre-crisis (1996) value of regressors. Robust standard errors are reported in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

Figure A1: Treatment vs. Control Groups: Firm-level Variables in Pre- and Post-Devaluation

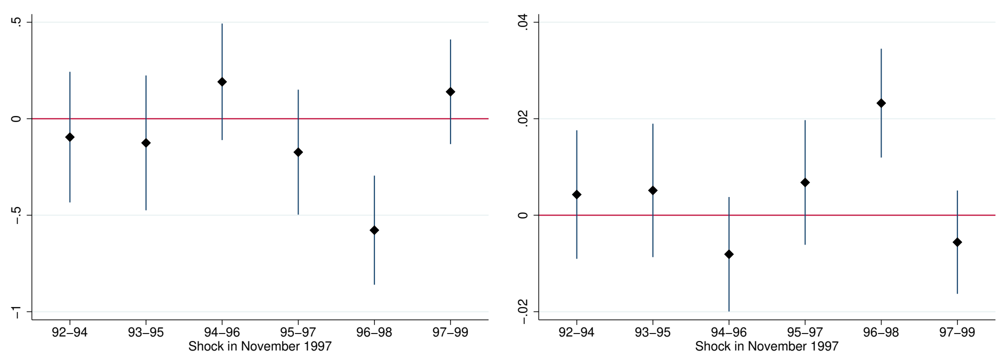
Firm-level Net Worth Growth



Firm-level Sales Growth

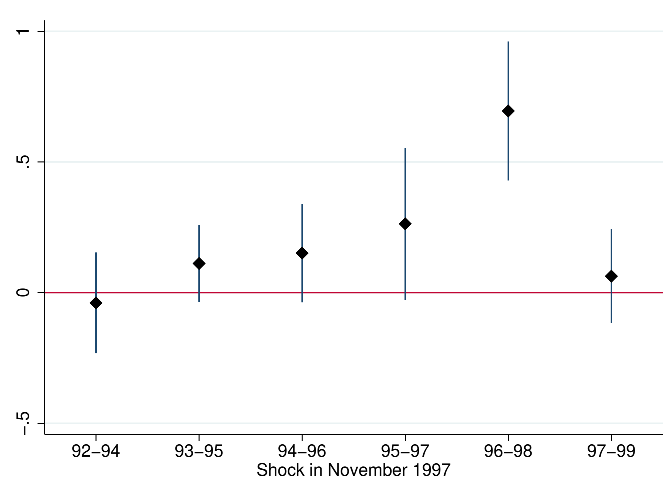


Firm-level Mark-Up Growth



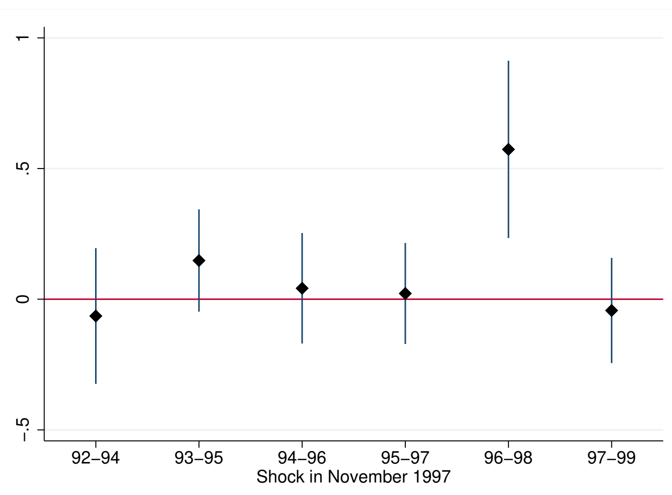
Notes: The left panel shows the estimated coefficients of $\beta_{1,t}$, and the right panel plots those of $\beta_{3,t}$ for $t = 1994, 1995, \ldots, 1999$ from the regressions: $\Delta y_{j,t} = \beta_{0,t} + \beta_{1,t}\text{ST FC}_{j,1996} + \beta_{2,t}\text{Size}_{j,1996} + \beta_{3,t}\text{ST FC}_{j,1996} \cdot \text{Size}_{j,1996} + \epsilon_j$. The first, second and third rows show the estimates on net worth growth, sales growth, and mark-up growth, respectively. The bar represents 90% confidence intervals computed with robust standard errors.

Figure A2: Treatment vs. Control Groups: Sectoral Prices in Pre- and Post-Devaluation



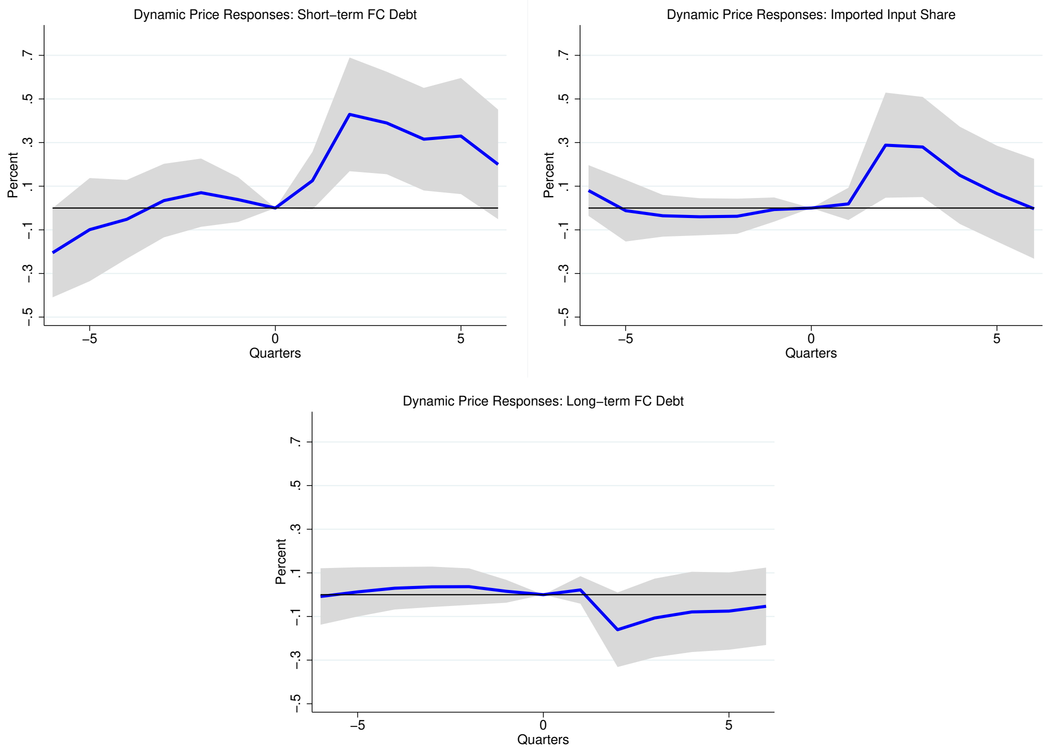
Notes: The figure plots $\beta_{1,t}$ from the regressions of$\Delta p_{I,t} = \beta_{0,t} + \beta_{1,t}\text{ST FC}_{I,1996} + \epsilon_I$, where t equal to 1998 represents our baseline regression. The bar represents 90 % confidence intervals computed with robust standard errors.

Figure A3: Treatment vs. Control Groups: Pre- and Post-crisis After Dropping Outliers



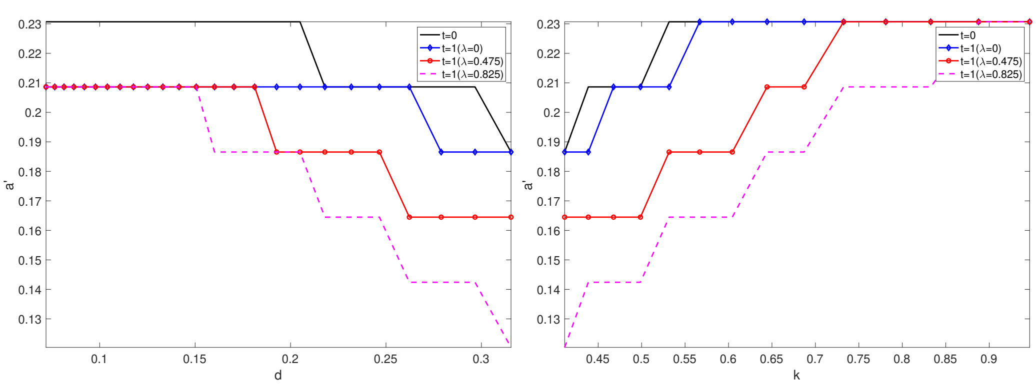
Notes: The figure plots $\beta_{1,t}$ from the regressions of$\Delta p_{I,t} = \beta_{0,t} + \beta_{1,t}\text{ST FC}_{I,1996} + \epsilon_I$, where t equal to 1998 represents our baseline regression. The bar represents 90% confidence intervals computed with robust standard errors. We exclude industries whose price changes are in the top 1% and the bottom 1% of the distribution.

Figure A4: Quarterly PPI Changes



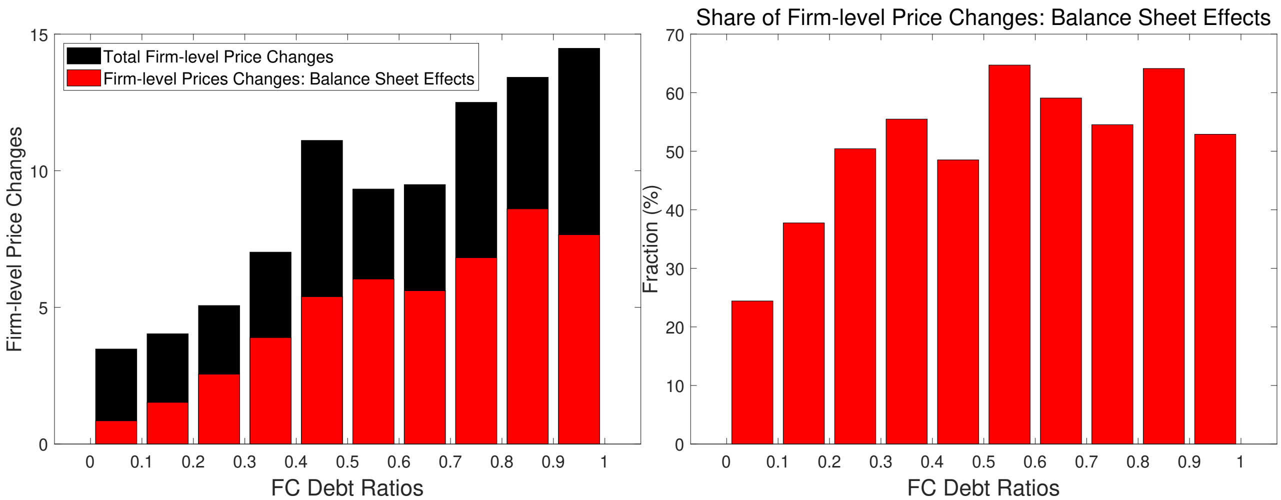
Notes: The figure plots the dynamic effects β_h of short-term FC debt exposure, long-term FC debt exposure and the imported input share on quarterly sectoral PPIs: $\frac{p_{I,1997Q3+h}-p_{I,1997Q3}}{p_{I,1997Q3}} = \beta_h + \beta_{1,h}\text{ST FC}_{I,96} + \beta_{2,h}\text{LT FC}_{I,96} + \beta_{3,h}\text{X}_{I,96} + \epsilon_{I,h}$. The area represents the 95% confidence intervals with robust standard errors.

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



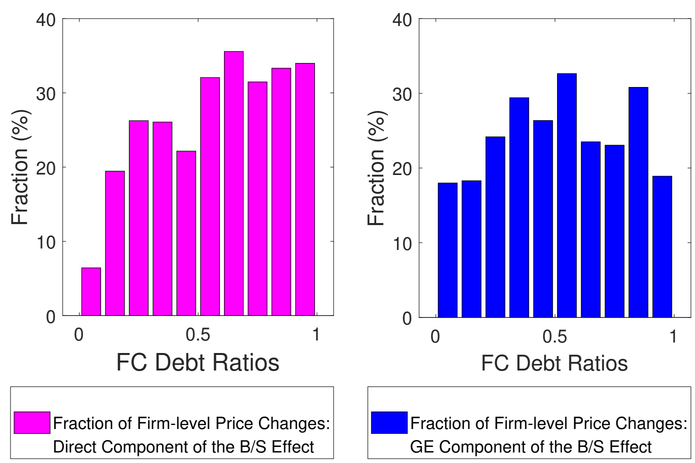
Notes: The solid black lines are the policy functions in the stationary equilibrium. The blue diamond lines, red circle lines, and dashed magenta lines are the policy functions for firms with 0, 0.475, and 0.825 of foreign currency debt ratio, respectively.

Figure A6: Counterfactual Exercise
The Quantitative Size of the Balance Sheet Channel of FC Debt at the Firm-level



Notes: The figure uses the model simulated firm-level price data. We first compute (i) the average firm-level price changes in the baseline model and (ii) that in the counterfactual exercise across firm-level foreign currency debt ratio deciles. The figure shows the ratio of (ii)/(i) across foreign currency debt ratio deciles.

Figure A7: The Quantitative Size of the Balance Sheet Channel of FC Debt
Direct Effects vs. General Equilibrium Effects of Foreign Currency Debt



Notes: The figure uses the model simulated firm-level price data. Across foreign currency debt ratio deciles, we compute the average *predicted* firm-level price changes via their own foreign currency debt exposure from regression 10: $\Delta y_j = \beta_0 + \beta_1 \text{ST FC}_j + \beta_2 ImportedInputShare_I + \beta_3 \Delta P_I + \epsilon_j$, i.e., $\hat{\beta}_1 \text{ST FC}_j$, and they are shown on the left in pink. The figure on the right shows average firm-level price changes in the counterfactual economy for each foreign currency debt ratio deciles minus the average predicted firm-level price changes for each foreign currency debt ratio deciles.

Productivity Shock Estimation

Estimation

Following Ackerberg et al. (2006), we assume the below value added production function:

$$y_{it} = \beta_k k_{it} + \beta_\ell \ell_{it} + \omega_{it} + \epsilon_{it}$$

, where ω_{it} evolves according to a first order Markov process. Additionally, we assume that labor is "less variable" (chosen slightly before) than raw materials

$$m_{it} = f_t(\omega_{it}, k_{it}, \ell_{it})$$

Then, we invert this function for ω_{it} and substitute it into the value added production:

$$y_{it} = \beta_k k_{it} + \beta_\ell \ell_{it} + f_t^{-1}(m_{it}, k_{it}, \ell_{it}) + \epsilon_{it}$$

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

$$\Phi_{it} = \beta_k k_{it} + \beta_\ell \ell_{it} + f_t^{-1}(m_{it}, k_{it}, \ell_{it})$$

We approximate $f_t^{-1}(m_{it}, k_{it}, \ell_{it})$ with a second-order polynomial function of $m_{it}, k_{it}, \ell_{it}$. Given the first-order Markov assumption on ω_{it}, we have

$$\omega_{it} = \mathbb{E}[\omega_{it}|I_{i,t-1}] = \mathbb{E}[\omega_{it}|\omega_{i,t-1}] + \xi_{it}$$

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

We then use the two moment conditions for the identification of β_k and β_ℓ:

$$\mathbb{E}[\xi_{it}|k_{it}] = 0$$

$$\mathbb{E}[\xi_{it}|\ell_{i,t-1}] = 0$$

Then, we back out the productivity shocks as:

$$\hat{\omega}_{it} = \hat{\Phi}_{it} - \hat{\beta}_k k_{it} - \hat{\beta}_\ell \ell_{it}$$

Data

Table A18 summarizes a detailed description of the data used to estimate the productivity shocks to firms.

Table A18: Variables Used for Estimation: 1991-1996

		Data Used	Variable Descriptions	KIS Variable Code/Sources
Value Added (y_{it})	$y_{it} = ln((SALE_{it} - RCOST_{it}) * 100/CPI_t)$	$SALE_{it}$ $RCOST_{it}$ CPI_t	Sales Raw Material Costs Consumer Price Index	21000 151000 Bank of Korea
Capital (k_{it})	$k_{it} = ln(K_{it})$ $\tilde{K}_{it} = TTAS_{it} - LAND_{it} - LEASE_{it}$ $I_{it} = (\tilde{K}_{it} - \tilde{K}_{it-1})/P_k$, and $K_{i0} = \tilde{K}_{i0}$ and $K_{it} = K_{it-1} + I_{it}$ if $t > 1$	$TTAS_{it}$ $LAND_{it}$ $LEASE_{it}$ P_k	Total Tangible Assets Land Lease Assets Price of Capital	113200 113110 113310 Bank of Korea
Labor (l_{it})	$\ell_{it} = ln(EMP_{it})$	EMP_{it}	Number of Employees	105000
Raw Material Costs (m_{it})	$m_{it} = ln(RCOST_{it} * 100/CPI_t)$	$RCOST_{it}$ CPI_t	Raw Material Costs Consumer Price Index	151000 Bank of Korea

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 would like to capture the strategic complementarity between firms' pricing decisions and see how the model predictions are aligned with what we have seen from the data. Moreover, we can talk about variable markups due to the Kimball aggregator, which would not be possible using the nested CES demand structure. Following Gopinath and Itskhoki

(2010), we do the first-order approximation of the industry price level.[47]

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

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

Computation - Stationary Industry Equilibrium

Market Environment – Partial Equilibrium

- In the industry equilibrium, we normalize aggregate consumption as $Y_t = \bar{Y}$ and aggregate price as P_t=1 (both are given parameters).

- We assume the CES aggregator for aggregate consumption

$$\bar{Y} = \left(\sum_i Y_i^{\frac{\nu-1}{\nu}}\right)^{\frac{\nu}{\nu-1}}, \quad \nu > 1$$

  , where Y_i is demand for sector i's composite goods.

- Given $\bar{Y}$ and $P_t = 1$, we can derive the demand for Y_i as

$$Y_i = P_i^{-\nu}\bar{Y}$$

For a given industry, we first calculate the two stationary industry equilibria with $\xi = 1$ and $\xi = 2.1$. Then, we shock the economy with a one-time unexpected depreciation of the exchange rate; i.e., an unexpected change of ξ from 1 to 2.1, and calculate the transition price dynamics.

Step 1.

First, we guess the industry price P^0. Then, given the industry price P^0, and consumption Y^0, we solve the following firm's problem.

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

$$s.t. \ (i) \ c + k' - (1-\delta)k + \Phi(k,k') + a' + d\big(\lambda + (1-\lambda)\frac{\xi}{\xi_{-1}}\big) = \pi(a,k,z;\kappa,\xi) + \frac{d'}{1+r} + w + a$$

$$(ii) \ \frac{1}{1+r}d' \leq \theta_k k'$$

, where

$$\Phi(k,k') = \frac{\phi}{2}\left(\frac{k' - (1-\delta)k}{k}\right)^2 k$$

$$\text{and} \quad \pi(a,k,z;\kappa,\xi) = \max_{n,x} \ p(y)y - wn - \xi^{\omega}x$$

$$s.t.\ i)\ y = zk^{\alpha}x^{\kappa}n^{1-\alpha-\kappa}$$

$$ii)\ p(y) = exp\Big(\frac{1}{\epsilon}\Big(1 - \big(\frac{y}{Y^0}\big)^{\epsilon/\sigma}\Big)\Big)P^0, \quad iii)\ wx + \xi^{\omega}x \leq \theta_a a$$

Then, we get a set of policy functions,

$$k'(k,d,a,z;\kappa,\xi,P^0),\ d'(k,d,a,z;\kappa,\xi,P^0),\ a'(k,d,a,z;\kappa,\xi,P^0),\ p(k,d,a,z;\kappa,\xi,P^0).$$

To solve the firm's dynamic problem, we use the Howard policy iteration method.

Step 2.

Given the firm's optimal policy functions,

$$k'(k,d,a,z;\kappa,\xi,P^0),\ d'(k,d,a,z;\kappa,\xi,P^0),\ a'(k,d,a,z;\kappa,\xi,P^0)$$

and the law of motion for idiosyncratic productivity shocks z, we find a stationary distribution

$$\psi(k,d,a,z;\kappa,\xi,P^0).$$

Step 3.

Using

$$p(k,d,a,z;\kappa,\xi,P^0)\ and\ \psi(k,d,a,z;\kappa,\xi,P^0)$$

, we find

$$\tilde{P} = exp\Big(\int ln\Big(p(k,d,a,z;\kappa,\xi,P^0)\Big)d\psi(k,d,a,z;\kappa,\xi,P^0)\Big)$$

Then, we compare $\tilde{P}$ and P^0. If they are close enough, we are done. Otherwise, we update the new guess for the industry price as

$$P^1 = x\tilde{P} + (1-x)P^0 \quad \text{for some } x\ \in (0,1)$$

and then restart the loop from Step 1.

Computation - Transition Dynamics

We assume that in period 0, the economy is in a stationary equilibrium where all firms believe there is no change in future aggregate variables, including the exchange rate. However, in period 1, there is an one-time unexpected shock to the exchange rate ξ in the economy. At that point, firms observe a complete path of future exchange rates from period 1. It is assumed that the exchange rates stay constant at the new level (the period 1 level) so that there is no deviation from UIP. Specifically, we assume that the evolution of the exchange rate is characterized by a sequence $\{\xi_t\}_{t=0}^{\infty}$ such that $\xi_0 = 1$ and $\xi_t = 2.1, \text{ for } t \geq 1$.

Step 1.

First, we guess a period $\bar{T}$ such that the economy is in a stationary equilibrium from period $T > \bar{T}$ onwards.

Step 2.

Then, we guess the sequence of industry-level prices $\bar{P}^0 = \{P_t^0\}_{t=0}^{\bar{T}}$ and corresponding output $\bar{Y}^0 = \{Y_t^0\}_{t=0}^{\bar{T}}$.

Step 3.

Given the sequences of $\{\xi_t\}_{t=0}^{\infty}$, $\{P_t^0\}_{t=0}^{\bar{T}}$, and $\{Y_t^0\}_{t=0}^{\bar{T}}$, we solve for a sequence of the firm's optimal problem. Specifically, we set $v_{\bar{T}+1}(d, k, a, z; \lambda, \kappa, \xi = 2.1) = v(d, k, a, z; \kappa, \xi = 2.1)$, where $v(d, k, a, z; \kappa, \xi = 2.1)$ is the value function we obtain from a stationary equilibrium when $\xi = 2.1$. Then, from $t = \bar{T}$ to $t = 1$, we solve the following firm's problem sequentially

$$v_t(d, k, a, z; \lambda, \kappa, \xi_t, \xi_{t-1}) = \max_{c \geq 0, d', k', a'} \frac{c^{1-\gamma}}{1-\gamma} + \beta E_{z'|z}[v_{t+1}(d', k', a', z'; \lambda, \kappa, \xi_{t+1}, \xi_t)]$$

$$s.t.\ (i)\ c + k' - (1-\delta)k + \Phi(k, k') + a' + d\big(\lambda + (1-\lambda)\frac{\xi_t}{\xi_{t-1}}\big) = \pi(a, k, z; \kappa, \xi_t) + \frac{d'}{1+r} + w + a$$

$$(ii)\ \frac{1}{1+r} d' \leq \theta_k k'$$

, where

$$\Phi(k, k') = \frac{\phi}{2}\Big(\frac{k' - (1-\delta)k}{k}\Big)^2 k$$

$$\text{and} \quad \pi(a,k,z;\kappa,\xi_t) = \max_{n,x}\ p(y)y - wn - \xi_t^{\omega} x$$

$$s.t.\ i)\ y = zk^{\alpha}x^{\kappa}n^{1-\alpha-\kappa}$$

$$ii)\ p(y) = exp\Big(\frac{1}{\epsilon}\Big(1-(\frac{y}{Y_t^0})^{\epsilon/\sigma}\Big)\Big)P_t^0, \quad (iii)\ wn + \xi_t^{\omega}x \leq \theta_a a$$

We then have

$$k_t(k,d,a,z;\lambda,\kappa,\xi_t,\xi_{t-1},\bar{P}^0),\ d_t(k,d,a,z;\lambda,\kappa,\xi_t,\xi_{t-1},\bar{P}^0),\ p_t(k,d,a,z;\lambda,\kappa,\xi_t,\xi_{t-1},\bar{P}^0),\ t=1,...,\bar{T}$$

.

Step 4.

With policy functions and the stationary distribution at $t=1$ in hand, we compute a sequence of distributions starting from $t=2$

$$\psi_t(k,d,a,z;\lambda,\kappa,\xi_t,\xi_{t-1},\bar{P}^0),\ t=2,...,\bar{T}$$

and the sequence of industry prices from $t=1$ as

$$\tilde{P}_t = exp\Big(\int ln\Big(p_t(k,d,a,z;\lambda,\kappa,\xi_t,\xi_{t-1},\bar{P}^0)\Big)d\psi_t(k,d,a,z;\lambda,\kappa,\xi_t,\xi_{t-1},\bar{P}^0)\Big)$$

Step 5.

Then, we compare the original guess $\bar{P}^0$ and the new sequence $\tilde{P} = \{\tilde{P}_t\}_{t=1}^{\bar{T}}$. If they are close enough, we move to Step 6. Otherwise, we update our new guess for the industry price as

$$\bar{P}^1 = x\tilde{P} + (1-x)\bar{P}^0 \quad \text{for some } x\ \in (0,1)$$

, and then restart the loop from Step 2.

Step 6.

If the difference between the aggregate price at $\bar{T}-1$ and $\bar{T}$ is small enough, then we are done. Otherwise, we return to Step 1 and reset $\bar{T}$.