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Essays on International Economics

A dissertation submitted in partial satisfaction of the requirements for the degree Doctor of Philosophy in Economics

by

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ABSTRACT OF THE DISSERTATION

Essays on International Economics

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In this dissertation, I present three essays on International Economics that investigate the impact of heterogeneity on the transmission of foreign shocks. The dissertation consists of three chapters. In Chapters 1 and 2, I collaborate with Brian Pustilnik to explore how firms' use of supply contracts can influence the propagation of commodity price shocks to aggregate variables. Specifically, I examine purchase obligations, which are contracts that entail fixed prices for the future delivery of goods. In Chapter 1, I rely a novel dataset to highlight two empirical findings. Firstly, I show that firms utilizing these contracts experience a substantial reduction in exposure to commodity price risk, with estimates suggesting a decrease of approximately 27% compared to non-users. Secondly, I observe that sector output and labor compensation exhibit a weaker negative correlation with commodity prices when firms engage in larger contracts. Moving on to Chapter 2, I evaluate the overall quantitative significance of these contracts by introducing and calibrating a tractable general equilibrium model. By constructing a counterfactual scenario where firms are unable to trade these contracts, I assess the contribution of purchase obligations in mitigating the aggregate transmission of commodity price shocks. The results demonstrate that when firms engage

in purchase obligations, the relative response of real consumption to a 10% commodity price shock is reduced by approximately 4%.

Chapter 3 shifts the focus to consumer heterogeneity and nominal rigidities. Specifically, I investigate the influence of consumer access to financial markets and price stickiness from the firm's perspective. These sources of heterogeneity can significantly alter the propagation of shocks and policy changes. The chapter provides a comprehensive survey of the current literature and explores the effects of policy changes using a stylized model. I examine the impact of nominal depreciation and wealth transfers. The findings reveal that currency depreciation has an expansionary effect, although the lack of access to financial markets may dampen its impact. On the other hand, wealth transfers reduce income inequality but could potentially trigger an economic recession when consumers benefiting from the transfer supply less labor.

The dissertation of Alvaro Nicolas Boitier is approved.

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To my parents

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Chapter 1

Risk-management of Commodity price Shocks using Purchase Obligations

1. Introduction

A long-standing research question in international economics concerns the aggregate consequences of commodity price shocks in countries that rely heavily on imported materials. In general, these price shocks are associated with economic hardship characterized by a reduction in employment and consumption (e.g., Blanchard and Gali (2009)). Due to lack of available data, this literature has overlooked the fact that the firms that demand these inputs use financial instruments to hedge against the volatility of their prices.[1] These risk-management policies could reduce the negative aggregate consequences of commodity price shocks.

In this Chapter, I use a novel dataset on purchase obligations for U.S. public manufacturing firms to discuss two empirical findings. Purchase obligations are supply contracts for future

[1] Recent finance papers only focus on individual firms or small sectors (e.g., Rampini et al. (2014)). For a review of commodity hedging in finance, see Carter et al. (2017).

purchases of goods that include fixed prices and quantities. Firms rely on these contracts to reduce their exposure to commodity price risk. Specifically, I show that these contracts allow them to reduce their exposure to commodity price risk. Following the empirical literature on hedging, I define exposure as the elasticity of firm value with respect to commodity prices.[2] I measure commodity prices by constructing a material input price index by sector (NAICS-3) using the Economic Census of 2012 and commodity prices from the BLS and World Bank. I use the terms "input prices" and "commodity prices" interchangeably, because these input price indexes only contains commodities.

I show empirically that firms that use purchase obligations have a lower exposure to these material input price shocks. The estimates suggest that companies that use purchase obligations have a relative lower exposure of 27% compared with non-users. The second empirical finding suggests that the use of these contracts can dampen the transmission of commodity price shocks to aggregate variables. I show that the correlation of input prices and sector aggregate variables, such as labor income and output, is lower when the sector aggregate value of purchase obligations is large.

Related Literature. Empirical studies in the finance literature have focused primarily on producers of commodities, such as oil, gas, and the gold industries (Tufano (1996); Haushalter (2000); Adam et al. (2017)) Recent papers have studied commodity users, but only for small sectors. Examples are Rampini et al. (2014) and Giambona and Wang (2020) for airlines and Mackay and Moeller (2007) for oil refineries. In this Chapter I extend the analysis and include all manufacturing sectors to study commodity shocks originating from a wide spectrum of commodities. [3]

Moreover, there is an incipient literature on purchase obligations using the same database.

[2]See Jorion (1990), for example.

[3]There is a vast literature regarding exchange rate hedging, for instance Alfaro et al. (2021), Allayannis and Ofek (2001) , Bartram (2008) , Bartram et al. (2010), Crabb (2002), Dekle and Ryoo (2007) and Géczy et al. (1997).

Almeida et al. (2017) leverage on the introduction of steel futures in 2008 to show that purchase obligations are hedging instruments, because companies switch to these commodity futures once they become available. The authors use the same purchase obligations dataset I use, but include all sectors in the United States. This Chapter considers only manufacturing industries because commodity price shocks are more important in these sectors than in services. On the other hand, Almeida et al. (2020) find empirical evidence showing that firms that hedge using purchase obligations can offset financial constraints and increase investment. I extend their work by an estimate of the contribution of purchase obligations as a hedging device for material input price risk.

Layout. The rest of the chapter is organized as follows. Section 2 explains the data used in the Chapter. Section 3 discusses the empirical findings. Section 4 concludes.

2. Data and Background

The main contribution is to describe how risk-management policies can have implications for the transmission of material input price shocks. I rely on a novel dataset on purchase obligations from U.S. public companies in the manufacturing sector. I also construct a sector input price index using the Bureau of Labor Statistics (BLS) and the 2012 Economic Census.[4]

Firms. I use COMPUSTAT for firm characteristics from public corporations in the U.S. manufacturing sector between 2003 and 2018.[5] I include purchase obligations for future periods from Securities and Exchange Commission (SEC) year filings. Companies are required to report their future obligations in their annual reports (10-Ks) under the Sarbanes-Oxley Act of 2002.[6][7] According to the SEC, a purchase obligation (PO) is a binding obligation for

[4]See Appendix 5.2 for more details.

[5]I do not include corporations with negative net income for all sample periods; profits from these companies might be unrelated to commodity price risk.

[6]For more details on the institutional background, see Lee (2018).

[7]Smaller reporting companies are not required to disclose their purchase obligations. I treat company-year

Figure 1.1: Example Purchase Obligations: Tabular Disclosure

(Dollar amounts in thousands)	Payment Due by Period						
Contractual Obligations	Total	2019	2020	2021	2022	2023	After 2023
Unsecured notes	$ 290,458	$ 173,578	$ —	$ —	$ —	$ —	$ 116,880
Capital lease obligations and other	6,245	1,182	—	5,063	—	—	—
Interest on debt and capital lease obligations	88,150	23,127	9,241	8,994	8,912	8,912	28,964
Operating leases	125,729	31,711	27,861	17,158	12,951	9,324	26,724
Notes payable (a)	15,288	15,288	—	—	—	—	—
Purchase obligations (b)	308,812	253,967	54,845	—	—	—	—
Postretirement benefits other than pensions (c)	251,798	15,344	15,927	16,238	16,446	16,557	171,286
Pensions (d)	148,250	45,000	40,000	25,000	20,000	15,000	3,250
Income taxes payable (e)	20,145	—	1,372	—	2,614	7,181	8,978
Other obligations (f)	33,158	10,509	1,340	2,165	972	520	17,652
Total contractual cash obligations	$ 1,288,033	$ 569,706	$ 150,586	$ 74,618	$ 61,895	$ 57,494	$ 373,734

(a) Financing obtained from financial institutions in the PRC to support the Company's operations there.
(b) Purchase commitments for capital expenditures, TBR truck tires and raw materials, principally natural rubber, made in the ordinary course of business.
(c) Represents benefit payments for postretirement benefits other than pension liabilities.
(d) Represents Company contributions to retirement trusts based on current assumptions.
(e) Represents income taxes payable related to the deemed repatriation tax on undistributed earnings of foreign subsidiaries under the Tax Act, as based on the Company's most recently filed tax returns, as well as anticipated state income tax obligations.
(f) Includes stock-based liabilities, warranty reserve, deferred compensation, nonqualified benefit plans and other non-current liabilities.

Notes. The figure shows an extract of the disclosure of purchase obligations for Cooper Tire & Rubber Company in their annual report for 2018 (emphasis added). See https://www.sec.gov/ix?doc=/Archives/edgar/data/0000024491/000002449119000012/a2018123110k.htm page 33.

the purchase of goods and services that requires future payments and has fixed or variable quantities and prices.[8] For instance, a tire manufacturer could sign a contract with a supplier for the purchase of natural rubber. I use a Python code to download the relevant information described in the financial section of each firm's annual report.[9] Figure 1.1 shows a sample for the Cooper Tire & Rubber Company for their 2018 annual report. I have information on the total value of PO for future periods. I focus on future contracts with a maturity of 1 year. Companies briefly describe the content of their POs in a footnote. I manually reviewed about 1% of the sample to verify that companies include raw materials in their PO.

Some firms also report, in the text of their annual reports, the reason for using purchase obligations. For example, The Hershey Company (a food manufacturing company) provides details in their 10-K for 2010. This is shown in Figure 1.2. I see that the main reason the company engages in these contracts is to reduce their exposure to input price risk.

observations as missing if a company does not report purchase obligations.

[8] See https://www.sec.gov/rules/final/33-8182.htm.

[9] I thank Cando-IT for code support. Website https://candoit.com.ar/?lang=en.

Figure 1.2: Example of Purchase Obligations: Cite Disclosure

Purchase Obligations

We enter into certain obligations for the purchase of raw materials. These obligations were primarily in the form of forward contracts for the purchase of raw materials from third-party brokers and dealers. These contracts minimize the effect of future price fluctuations by fixing the price of part or all of these purchase obligations. Total obligations for each year presented above consists of fixed price contracts for the purchase of commodities and unpriced contracts that were valued using market prices as of December 31, 2010.

Notes. Extract from The Hershey Company's 2010 annual report. See https://www.sec.gov/Archives/edgar/data/47111/000119312511039789/d10k.htm page 36.

The final product is a firm-level yearly dataset for all public manufacturing companies in the U.S between 2003 and 2018. Summary statistics are shown in Table 1.1. I observe about 935 companies per year in 21 industries within the manufacturing sector. A key empirical finding is that firms that engage in risk-management policies are larger.

I can see this by comparing average sales and employment between hedgers and non-hedgers in Table 1.1 (Panel B). This can also be seen in Figure 1.4a. I group observations in bin deciles according to the sector-year distribution of sales. I compute the mean and median value of a PO indicator to measure the likelihood of firms in that sales bin to use purchase obligations. I see that the probability of engaging in risk-management policies is increasing in firm size. Small firms rarely use purchase obligations, whereas most large firms use them consistently over time and across sectors.

Along the intensive margin, the results are similar. Figure 1.4b shows the distribution of the natural logarithm of purchase obligations value across observations within the same bin of sales. The dataset suggests that purchase obligations are increasing in firm size, which shows that large corporations have stronger incentives to trade these contracts.

The dataset includes rich sector heterogeneity, as shown in Figure 1.9. For each sector, I plot the distribution over time of the percentage of total purchase obligations over total material inputs demand. I use one-period-lagged PO values to capture a measure of sector hedging intensity. Median values of this distribution lie between 1% and 10% percent. The three sectors with more hedging intensity, according to this metric are Petroleum and coal

Table 1.1: Dataset Summary Statistics

Panel A	**General Statistics**		
Total Obs	Total Sectors	Total Years	Firms (approx)
14,036	21	15	935
Panel B	**PO vs non-PO**		
Variable	PO > 0	PO = 0	
Mean Employment	11,448	5,987	
Mean Sales (M$)	5,440	1,911	
Firms %	66%	34%	
Panel C	**For PO users**		
Variable	Mean	Median	Std. dev.
PO (M$)	348	35	1,629
PO/COGS	13.2%	9.3%	13.7%

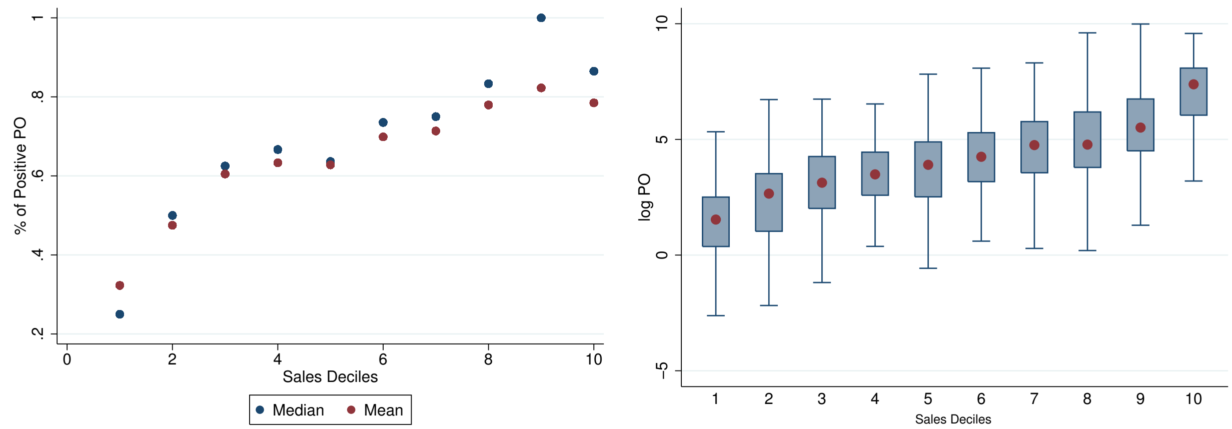
Notes. The table shows basic summary statistic for the dataset used in the Chapter.

products, Chemical products and Primary metals.

Limitations of the database include the inability to identify the share of the total value of purchase obligations that has fixed prices. For the empirics of the Chapter, I assume that the majority have fixed prices. Another assumption in line with this argument is to treat the adjustment of PO prices as if they were less than perfectly colinear with spot prices. For example, if PO prices include an adjustment lag, they will provide insurance against commodity price shocks.

Input price index. It is well known in economics that commodities are several times more volatile than other goods and services. I constructed a sector-year input price index to measure the evolution of the commodity prices used in manufacturing. Material price indexes are from the BLS or World Bank. Using the Economic Census of 2012, I construct material purchases shares of each NAICS-3 manufacturing sector. The input price index (IPI) is a Laspeyres index using material shares and material price indexes. Table 1.5 in the Appendix shows the most important material used in each sector (as share of total materials used).

Figure 1.3: Purchase Obligations and Firm size



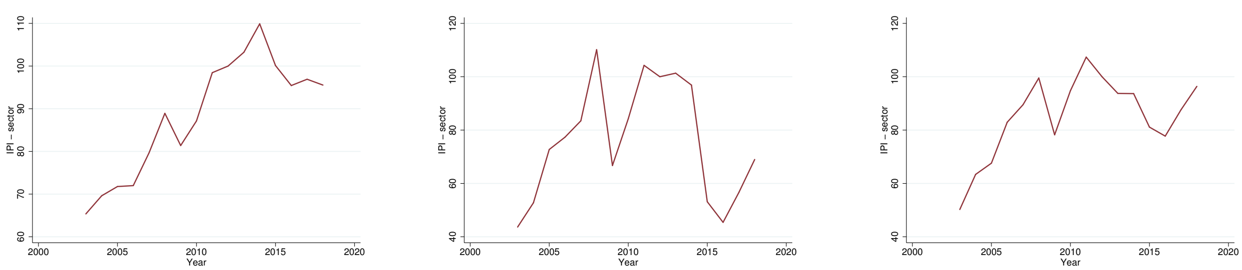
(a) PO - Extensive Margin

(b) PO - Intensive Margin

Notes. This figure show the distribution of purchase obligations across sales sales deciles. Panel (a) plots the mean and median of the purchase obligation indicator within bin. Panel (b) shows the distribution of the log PO across bin sales.

For instance, requirements include 9% cattle (Food Manufacturing, NAICS 311), 41% crude petroleum (Petroleum and Coal, NAICS 324), and 14% steel (Primary Metals, NAICS 331). Figure 1.5 plots the evolution of the input price index for three representative industries. The plot shows large fluctuations of commodity prices. The estimated standard deviation of this period is 12%. This is common for all industries in the sample. I plot all sectors in Figure 1.10 in the Appendix.

Figure 1.5: Input Price Index by sector



(a) Food Manufacturing

(b) Petroleum and coal products

(c) Primary metals

Notes. This figure shows the evolution of the input price index for a selected group of industries. It is constructed using material shares from the Economic Census 2012 for manufacturing sectors and commodity price indexes from the BLS and World Bank. Base year 2012.

3. Empirical Findings

In this section I discuss two empirical findings. Purchase obligations are risk-management tools that allow firms to reduce their exposure to input price risk. I first show that firms that use these instruments have significantly lower exposure. The second finding suggests that these firm policies could dampen the aggregate transmission of input price shocks. I show that the correlation of input prices and sector aggregate variables is lower when firms trade more purchase obligations.

3.1 Risk-management Empirical Findings

I estimate how the use of purchase obligations can reduce firm exposure to input price risk. I follow the empirical literature in finance pioneered by Adler and Dumas (1984) and Jorion (1990). The approach is to compute the elasticity of firm value with respect to the underlying risk. In the benchmark setting, I proxy for changes in firm value using stock returns. For the underlying risk, I use the measure of sector input price index computed using BLS and Census data.

I follow a log specification to estimate the elasticity using the dataset. The reduced-form equation will be:

$$\log\left(1 + R_{i,s,t}\right) = \alpha + \beta_1 \Delta IPI_{s,t} + \beta_2 \Delta IPI_{s,t} * \mathbb{I}_{PO_{i,t-1}>0} + \epsilon_{i,t} \tag{1.1}$$

I define $R_{i,s,t}$ as the ex-dividend stock return of company i in sector s at time t and $\Delta IPI_{s,t}$ the change input price index (base 2012) of sector s between t and $t-1$. The key component of the regression is adding an indicator that takes the value of 1 if the company reported having positive purchase obligations in the previous year ($\mathbb{I}_{PO_{i,t-1}>0}$). The results are shown in Table 1.2. The first parameter, β_1, captures the semi-elasticity of returns (R) with respect to sectorial input prices (IPI) for non-PO users. The second parameter, β_2, is the most relevant because it captures the difference in semi-elasticity between companies that used purchase obligations in the past versus non-users.

Table 1.2: Input price elasticity estimation

	(1) log Returns	(2) log Returns	(3) log Returns
Change Sector IPI	-0.0138***	-0.0151***	-0.0148***
	(0.00168)	(0.00172)	(0.00184)
Change Sector IPI × lag Ind PO	0.00530**	0.00556**	0.00410+
	(0.00192)	(0.00195)	(0.00212)
Constant	0.0143**	0.0156***	0.0177***
	(0.00468)	(0.00461)	(0.00110)
Observations	13237	13237	13074
R^2	0.016	0.021	0.161
FE	None	NAICS 3	Firm

Notes. This table reports the estimation of input price elasticity using stock returns as a measure of change in firm value. The estimated equation is 1.1. Additional controls include fixed effects. Standard errors are clustered at the firm level and included in parenthesis. $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 1.3: Percentage of input-price shock hedged - log Returns

Model	Point Estimate	S.E.	Conf. Int. L.B.	Conf. Int. U.B.
OLS	38.3	18.11	20.19	56.41
FE Sector	36.91	16.73	20.19	53.64
FE Firm	27.76	17.48	10.28	45.24

Notes. This table reports a summary of the log returns estimations. I report the share hedged as the (negative) ratio of the estimated coefficients and confidence intervals computed using the delta method.

Using the third column, in which I include firm fixed effects, I find that that a 10% increase in input prices is associated with a decrease in returns of about 14.8% for firms that do not use purchase obligations. For companies that have supply contracts this number is only 10.7%. This stems from the fact that β_2 captures the differential effect.

This reduction is substantial: by computing the ratio of the coefficients, I obtain the percentage of the input price shock that hedgers can offset.[10] I also provide confidence intervals computed using the delta method.[11] Coefficients are shown in Table 1.3 using the coefficients for each log returns regression. The preferred estimates are the coefficients estimated using the firm fixed effects specification. Based on these estimates, PO firms have a differential exposure to input price changes of 27%. These numbers suggest that these supply contracts are an excellent tool to hedge against unexpected price changes in material costs.

3.2 Robustness

I conduct a series of robustness checks to provide further evidence supporting my hypothesis. First, I use other measures of firm value to estimate the differential exposure to input price risk. Second, I estimate different coefficients along the distribution of the dollar value of

[10] Specifically, $-\frac{\beta_2}{\beta_1}$.

[11] The delta method uses the Central Limit Theorem to compute the asymptotic distribution of a function of a random variable with known asymptotic distribution. See Hogg et al. (2012) chapter 5.

purchase obligations. Finally, I allow differential coefficients for increases or decreases of input prices.

Other measures of firm value. I introduce other measures of firm value: net income (NI), earnings before taxes ($EBIT$), and earnings before taxes and depreciation ($EBITDA$). I normalize by total assets and estimate the reduced form:

$$\Delta\left(\frac{V_{i,t}}{AT_{i,t}}\right) = \alpha + \beta_1 \Delta IPI_{s,t} + \beta_2 \Delta IPI_{s,t} * \mathbb{I}_{PO_{i,t-1}>0} + \epsilon_{i,t} \tag{1.2}$$

The results are shown in Table 1.6. Fixed effects are included in Table 1.7. The main hypothesis remains consistent for these other firm value measures: Firms that use purchase obligations have lower exposure to input price risk. I plot the implied input price elasticity in Figure 1.11 using the delta method. For NI, $EBIT$, and $EBITDA$, I normalize by the median ratio of firm value to total assets. All plots show that firms that use purchase obligations have a lower input price elasticity.

Controlling for hedging intensity. I use the dollar amount of purchase obligations to estimate heterogeneous coefficients across firms. I measure the intensity of hedging by computing the ratio of PO value chosen in the previous period and cost of goods sold ($COGS$). I repeat the estimation strategy using other measures of firm value, but include this new hedging intensity variable. The reduced form is:

$$X_{i,t} = \alpha + \beta_1 \Delta IPI_{s,t} + \beta_2 \Delta IPI_{s,t} \frac{PO_{i,t-1}}{COGS_{i,t}} + \epsilon_{i,t} \tag{1.3}$$

For $X : \log(1+R)$, $\Delta\, NI/AT$, $\Delta\, EBIT/AT$ or $\Delta\, EBITDA/AT$. The results are shown in Tables 1.9, 1.10, 1.11 and 1.12. These estimates are still consistent with a positive exposure differential for firms using purchase obligations.

To highlight the intuition, I plot the implied elasticity of firm value to input price for several values of the distribution of PO/COGS. Delta method standard errors are included as confidence bands. The plots, which are presented in Figure 1.12, show that purchase obligations are correlated with lower exposure to input price risk, but only if the firm has large contracts: Only firms above the median of the PO/COGS have lower exposure to input price risk.

Ups and downs. I test whether there are heterogeneous effects from increases or decreases of input prices. If firms have a large share of their input prices fixed due to purchase obligations, a decrease in the price should yield more benefit for corporations that do not use these contracts. These firms will have the flexibility to take advantage of the reduction in input prices. I estimate the following reduced form:

$$\begin{aligned} \log(1+R_{i,t}) = \alpha + \beta_1\, \Delta IPI_{st} + \beta_2\, \Delta IPI_{st} \times \mathbb{I}_{PO_{i,t-1}} \\ + \beta_3\, \Delta IPI^{+}_{st} + \beta_4\, \Delta IPI^{+}_{st} \times \mathbb{I}_{PO_{i,t-1}} + \epsilon_{it} \end{aligned} \tag{1.4}$$

To measure differential effects from ups or downs in input prices, I construct $\Delta IPI^{+}_{st} = \Delta IPI_{st} * \mathbb{I}_{\Delta IPI_{st}>0}$. Therefore, β_1, captures the correlation between firm value and input prices only for reductions and non-PO. On the other hand, $\beta_1 + \beta_3$ show the correlation for price increases. Finally, the key coefficients in this reduced form are β_2 and $\beta_2 + \beta_4$, which capture the differential effect for PO firms.

I include these results in Table 1.13. Basically, these results show that the use of purchase obligations substantially benefits firms for positive input price shocks. These estimates suggest that a decrease in input prices does not significantly benefit non-PO firms over PO firms.

3.3 Discussion on Endogeneity

The causal inference of the interaction parameter is guaranteed if there is no correlation between unobservables and the purchase obligations. The main problem is that firm size might be a confounding factor, as I saw above. I see this by estimating a linear probability model of the PO indicator on several standard hedging determinants (e.g., Almeida et al.

(2017)). Results are shown in Table 1.8. There is a positive correlation between purchase obligations and firm financial characteristics that will overestimate the hedging contribution.

I address this endogeneity concern by repeating the estimation of the input price elasticity using the ratio of PO/COGS and controlling for firm characteristics. Larger firms might have a lower input price elasticity than smaller firms. The estimated equation is:

$$\log(1 + R_{i,s,t,}) = \alpha + \beta_1 \Delta IPI + \beta_2 \Delta IPI \times \frac{PO_{i,t-1}}{COGS_{i,t}} + \sum_l \beta_l \Delta IPI \times Control^l_{i,t-1} + \epsilon_{i,t} \tag{1.5}$$

I include controls that proxy for the firm's financial soundness and size, for example Working Capital/Total Assets, Retained Earnings/ Total Assets and log assets. The results are show in Table 1.4. The most important variable to control for the correlation between size and PO is total assets.

These results show that larger firms are less exposed, regardless of their amount of purchase obligations, as seen in the estimated coefficient for the interaction of commodity prices and total assets. However, controlling for the commodity price risk exposure due to size, I still find a positive contribution of purchase obligations, as the interaction between commodity prices and PO/COGS is positive. The results are still consistent with my hypothesis: firms with a positive amount of purchase obligations have lower exposure to commodity price risk.

I study the implications of these results by computing the input price elasticity for different values of firm characteristics. For all calculations I use the estimated coefficients from Table 1.4 and different values of PO/COGS. I show summary statistics of the variables used in the estimation and analysis in Table 1.14 and the results in Table 1.15. I report a summarized version of the results in Figure 1.7, by computing the ratio of estimated elasticities between PO and non-PO firms, for different ratios PO/COGS and firms characteristics. This statistic represents the relative exposure between PO and non-PO firms.

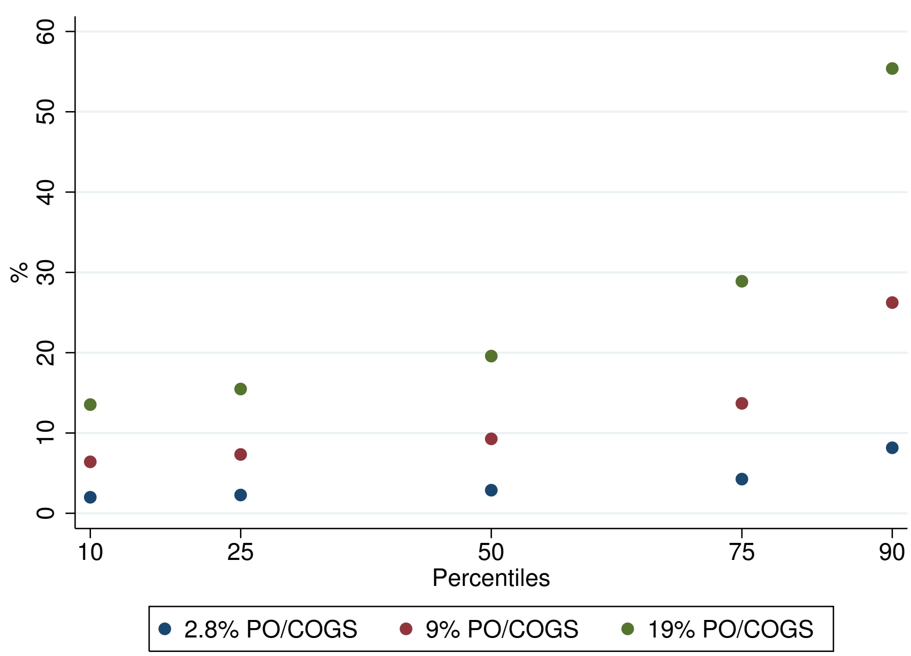
Table 1.4: Input-price elasticity estimation - controlling with assets

	(1)	(2)	(3)
	log Returns	log Returns	log Returns
Change Sector IPI	-0.0111^{***}	-0.0182^{***}	-0.0262^{***}
	(0.00109)	(0.00310)	(0.00451)
Change Sector IPI × lag PO/COGS	0.0169^{*}	0.0155^{*}	0.0132^{+}
	(0.00681)	(0.00664)	(0.00678)
Change Sector IPI × lag log Assets		0.00103^{**}	0.00149^{**}
		(0.000383)	(0.000468)
lag log AT		0.0208^{***}	0.0213^{***}
		(0.00256)	(0.00263)
lag PO / COGS		-0.0456	-0.0458
		(0.0382)	(0.0387)
Constant	0.0175^{***}	-0.116^{***}	-0.117^{***}
	(0.00465)	(0.0195)	(0.0199)
Other Controls	No	No	Yes
Observations	12989	12983	12639
R^2	0.014	0.021	0.022

Notes. This table reports the estimation of input-price elasticity allowing for different coefficients according to the hedging intensity and including additional firm controls. The estimated equation is 1.5. Additional controls include: Working Capital / Total Assets; Retained Earnings/ Total Assets; EBIT / Total Assets; Market Value of Equity / Book value of Liabilities; Sales / Total Assets. Standard errors are clustered at the firm level and included in parenthesis. $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Figure 1.7 shows several important conclusions. First, firms having positive PO are less exposed to commodity price shocks. For example, comparing two median firms where the PO firms has a 9% PO/COGS ratio, the exposure differential is about 10%. Second, the exposure differential is increasing in PO intensity and size. For instance, following the previous example, increasing the ratio PO/COGS to 19% I see that the exposure differential changes to about 20%. Moreover, computing the same statistic for firms at the top of the distribution (90% percentile), I find that PO firms are 27% less exposed when having a PO/COGS ratio of 9%. This statistic increases to 55% when using a ratio PO/COGS of 19%

Figure 1.7: Input Price Elasticity Estimation

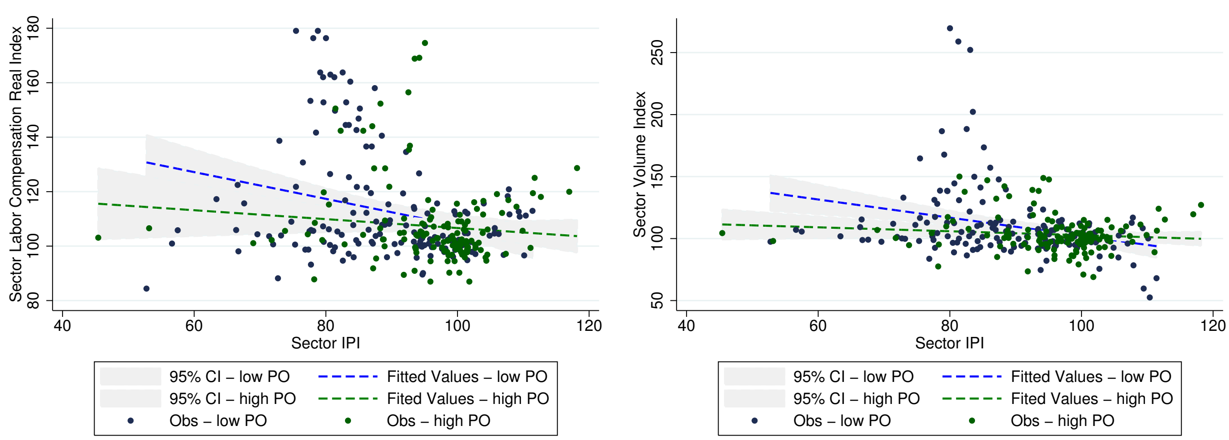


Notes. This figure reports estimates of the input-price relative elasticity between PO and non-PO firms for different firm characteristics, following results from Table 1.4 (column 3). The x-axis corresponds to the percentiles of the size distribution according to the covariates used in the estimation. The y-axis corresponds to the percentage difference between PO and non-PO elasticity, for different PO/COGS ratios. Each color reports the relative elasticity comparing non-PO firms with PO-firms having the displayed PO/COGS ratio.

3.4 Aggregate Empirical Findings

This section provides evidence that firms' risk-management policies could have consequences for the transmission of commodity price shocks to aggregate variables. In Figure 1.8, I plot the Labor Compensation and Output Volume Index from the Bureau of Economic Analysis (BEA) as a function of the input price index for all sector-year observations in the sample. Both variables are measured as indexes with base in 2012. For Labor Compensation, I divide by the yearly Consumer Price Index from the BLS to measure real labor compensation. I split the sample according to the previous year's total purchase obligations of the sector, using the median value within sectors as the cutoff. Finally, I show the regression line for each group. Consistent with previous studies (e.g., Blanchard and Gali (2009)) I found a negative correlation between labor compensation and input prices. However, these elasticities seem to be smaller when firms in the sector have a total purchase obligation value over the median. This suggests that these risk-management policies could dampen the transmission of input price shocks to aggregate variables.

Figure 1.8: Sector Variables and Input Prices



(a) Sector Labor Compensation

(b) Sector Volume Index

Notes. This figure shows the correlation between input prices and sector aggregate variables for different values of purchase obligations. Panel (a) shows sector labor compensation divided by CPI and Panel (b) shows sector volume. Both measures are expressed as indexes normalized to 2012.

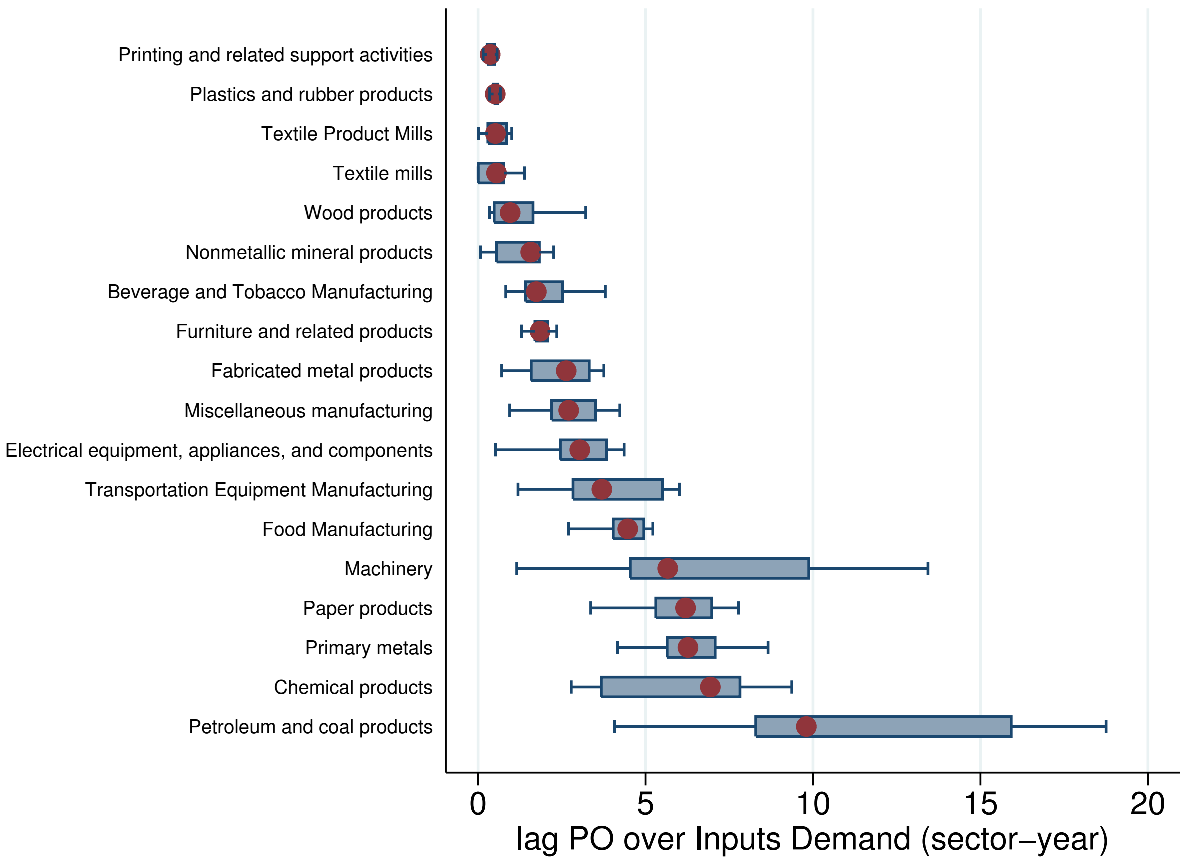
4. Conclusion

In this Chapter I studied empirically how firms in the manufacturing sector in the U.S. can use purchase obligations to reduce their exposure to commodity price risk. These results show that firms in this industries can drastically improve their financial outcomes over their competitors. In particular my results show that on average, firms can reduce their exposure to commodity price between 10% to 27%. This suggests that company managers should keep in mind hedging commodity prices using purchase obligations. The next Chapter will analyze the macroeconomic implication of commodity hedging.

5. Appendix

5.1 Additional Tables and Figures

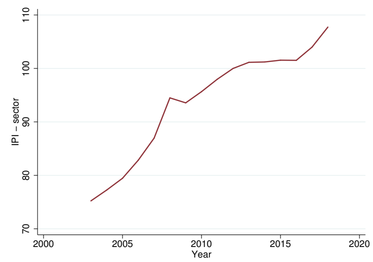
Figure 1.9: PO–Sector Intensity



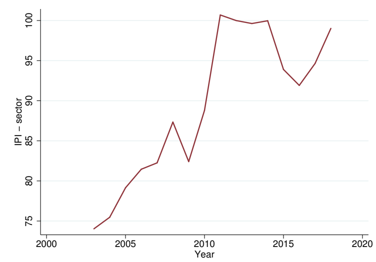
Notes. The figure shows the distribution over time of the share (%) of total sector purchase obligations (lag) over total sector material inputs demand. Red dots represent the median across time.

Figure 1.10: Input Price Index by Sector

(a) Food Manufacturing

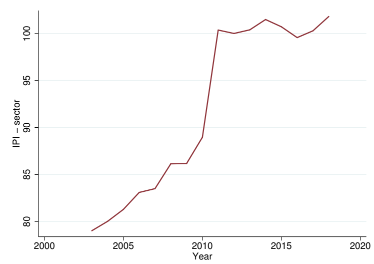


(b) Beverage and Tobacco Manufacturing



(c) Textile mills

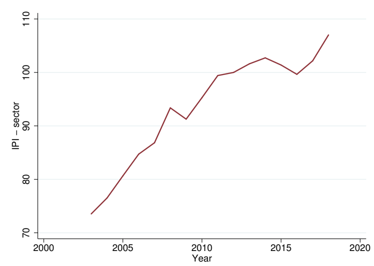
(d) Textile Product Mills



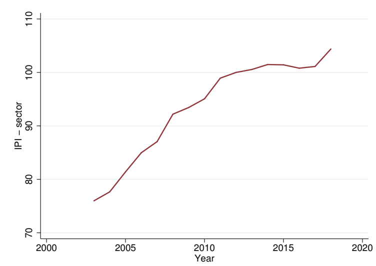
(e) Apparel Manufacturing

(f) Leather and Allied Product Manufacturing

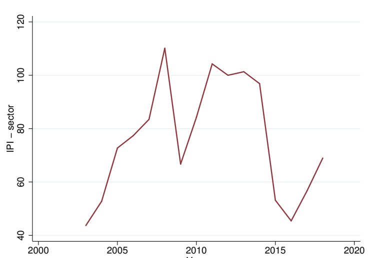
(g) Wood products



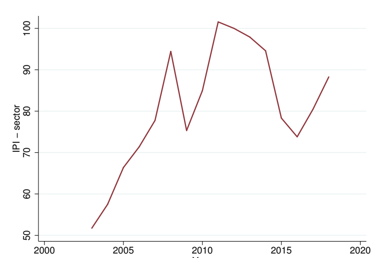
(h) Paper products



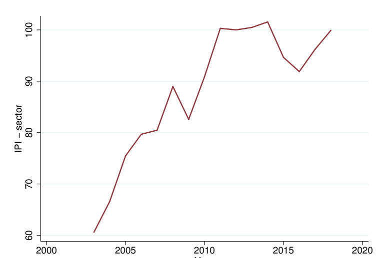
(i) Printing and related support activities



(j) Petroleum and coal products

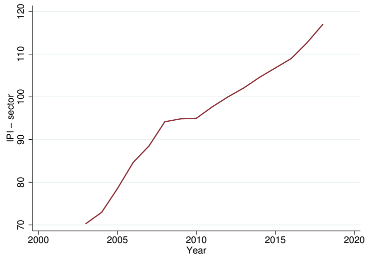


(k) Chemical products

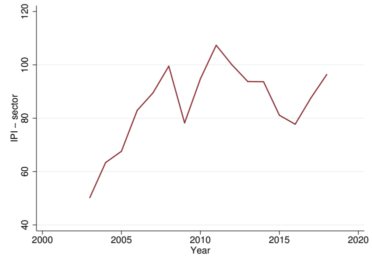


(l) Plastics and rubber products

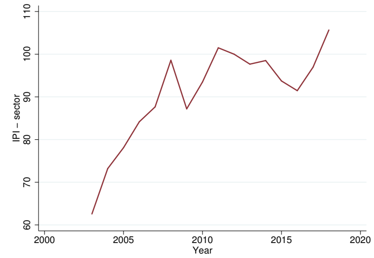
Notes. This figure shows the evolution of the input price index. It is constructed using material shares from the Economic Census 2012 for manufacturing sectors and commodity price indexes from the BLS and World Bank. Base year 2012.



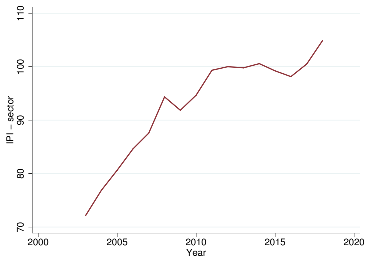
(m) Nonmetallic mineral products



(n) Primary metals

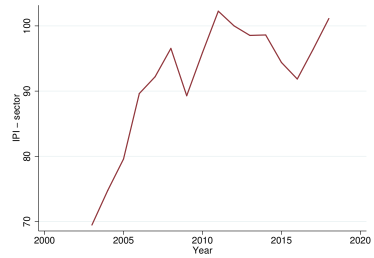


(o) Fabricated metal products

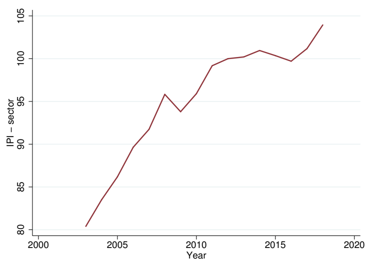


(p) Machinery

(q) Computer and electronic products

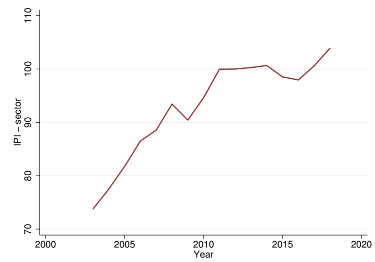


(r) Electrical equipment, appliances, and components



(s) Transportation Equipment Manufacturing

(t) Furniture and related products



(u) Miscellaneous manufacturing

Table 1.5: IPI–Material Shares

Sector (NAICS-3)	Sector Name	Share Material Used (%)	Material Description
311	Food Manufacturing	9.31	Cattle slaughtered
312	Beverage and Tobacco Manufacturing	15.7	Other concentrated liquid beverage bases
313	Textile mills	11.8	Raw cotton fibers
314	Textile Product Mills	19.44	Nylon filament yarn
315	Apparel Manufacturing	37.63	Broadwoven fabrics
316	Leather and Allied Product Manufacturing	47.35	Hides, skins, and pelts
321	Wood products	19.47	Softwood logs and bolts
322	Paper products	47.78	Paper and paperboard
323	Printing and related support activities	17.76	Coated paper
324	Petroleum and coal products	47.58	Foreign crude petroleum
325	Chemical products	10.18	Agricultural products
326	Plastics and rubber products	45.67	Plastics resins
327	Nonmetallic mineral products	16.89	Portland and blended cements
331	Primary metals	14.05	All other steel shapes and forms
332	Fabricated metal products	7.45	Steel sheet and strip
333	Machinery	7.97	Iron and steel castings
334	Computer and electronic products	12.87	Semiconductors
335	Electrical equipment, appliances, and components	6.51	Electronic-type components
336	Transportation Equipment Manufacturing	8.61	Gasoline engines and parts
337	Furniture and related products	6.9	Other woven upholstery fabrics
339	Miscellaneous manufacturing	19.79	Surgical and orthopedic supplies

Notes. This table shows the share of total materials costs of the most important commodity purchased in each sector. Numbers were computed using the Economic Census 2012.

Table 1.6: Input Price Elasticity Estimation–Other Measures of Firm Value

	(1) Change NI/AT	(2) Change EBIT/AT	(3) Change EBITDA/AT
Change Sector IPI	-0.00113*	-0.0000645	-0.000156
	(0.000515)	(0.000399)	(0.000407)
Change Sector IPI × lag Ind PO	0.00166**	0.000940*	0.000955*
	(0.000537)	(0.000421)	(0.000426)
Constant	-0.00227*	-0.00268***	-0.00252***
	(0.000889)	(0.000620)	(0.000625)
Observations	13771	13760	13664
R^2	0.001	0.003	0.003

Notes. This table reports the estimation of input price elasticity using additional measures of firm value. The estimated equation is 1.2. The Firm value measures are Net Income, Earnings Before Interest, and Taxes and Earnings Before Interest, Taxes, and Depreciation. All variables are normalized by total assets. Regression drops top and bottom 1% outliers for Δ Firms Value / Assets. Standard errors are clustered at the firm level and included in parenthesis. $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 1.7: Input-price elasticity estimation–other measures of firm value–FE

	(1)	(2)	(3)
	Change NI/AT	Change EBIT/AT	Change EBITDA/AT
Change Sector IPI	-0.00133*	-0.000159	-0.000270
	(0.000552)	(0.000466)	(0.000478)
Change Sector IPI $\times$ lag Ind PO	0.00168**	0.000972*	0.00102*
	(0.000583)	(0.000494)	(0.000503)
Constant	-0.00190***	-0.00248***	-0.00231***
	(0.000304)	(0.000240)	(0.000237)
Observations	13581	13570	13472
R^2	0.093	0.110	0.112
FE	Firm	Firm	Firm

Notes. This table reports the estimation of input-price elasticity using additional measures of firm value. The estimated equation is 1.2. The firm value measures are: Net Income, Earnings before interest and taxes and Earnings before interest taxes and depreciation. All variables are normalized by total assets. Additional controls include fixed effects. Regression drops top and bottom 1% outliers for Δ Firms Value / Assets. Standard errors are clustered at the firm level and included in parenthesis. $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 1.8: Linear Prob. Model Ind. PO

	(1)	(2)
	Ind PO	Ind PO
Working Capital/Assets	0.0161^{+}	0.0318
	(0.00932)	(0.0240)
Retained earnings/Assets	-0.000951	0.00256^{***}
	(0.000839)	(0.000610)
EBIT/Assets	-0.0146	-0.0350^{***}
	(0.0165)	(0.00819)
Market value/Liabilities	-0.0000536	-0.000354
	(0.000718)	(0.000380)
Sale/Assets	0.0137	0.0256
	(0.0195)	(0.0160)
log Cash	0.0200^{**}	0.00540
	(0.00754)	(0.00475)
log Assets	0.0650^{***}	0.0547^{***}
	(0.0124)	(0.0138)
log Inv Raw Mat	-0.00930	0.00667
	(0.00915)	(0.00728)
Constant	0.165^{**}	0.229^{**}
	(0.0582)	(0.0840)
Observations	12654	12475
R^2	0.093	0.786
FE	No	Firm

Notes. This table reports the estimation of a linear probability model of the PO indicator using firm characteristics and fixed effects as controls. The estimated equation is $\mathbb{I}_{PO_{i,t}>0} = \alpha + \sum_m \beta_m \, Control_{m,i,t} + error_{i,t}$. Standard errors are clustered at the firm level. $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 1.9: Input-price elasticity estimation–PO/COGS, Returns

	(1) log Returns	(2) log Returns	(3) log Returns
Change Sector IPI	-0.0111***	-0.0122***	-0.0128***
	(0.00109)	(0.00114)	(0.00122)
Change Sector IPI × lag PO/COGS	0.0169*	0.0169*	0.0153*
	(0.00681)	(0.00697)	(0.00766)
Constant	0.0175***	0.0188***	0.0213***
	(0.00465)	(0.00459)	(0.00115)
Observations	12989	12989	12826
R^2	0.014	0.019	0.155
FE	None	NAICS 3	Firm

Notes. This table reports the estimation of inputprice elasticity allowing for different coefficients according to the hedging intensity. The estimated equation is 1.3. The firm value measure used in this regression is stock returns. Each column includes different fixed effects. Regression drops top 2% outliers for PO/COGS. Standard errors are clustered at the firm level and included in parenthesis. $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 1.10: Input-price elasticity estimation–PO/COGS, NI

	(1) Change NI/AT	(2) Change NI/AT	(3) Change NI/AT
Change Sector IPI	-0.000337	-0.000363	-0.000503*
	(0.000229)	(0.000234)	(0.000250)
Change Sector IPI × lag PO/COGS	0.00375*	0.00389*	0.00348*
	(0.00156)	(0.00156)	(0.00170)
Constant	-0.00212^{+}	-0.00210^{+}	-0.00172
	(0.00123)	(0.00123)	(0.00126)
Observations	13541	13541	13352
R^2	0.000	0.001	0.097
FE	None	NAICS 3	Firm

Notes. This table reports the estimation of input price elasticity allowing for different coefficients according to the hedging intensity. The estimated equation is 1.3. The firm value measure used in this regression is net income. Each column includes different fixed effects. Regression drops top and bottom 1% outliers for Δ Firms Value / Assets and top 2% outliers for PO/COGS. Standard errors are clustered at the firm level and included in parenthesis. $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 1.11: Input Price Elasticity Estimation–PO/COGS, EBIT

	(1)	(2)	(3)
	Change EBIT/AT	Change EBIT/AT	Change EBIT/AT
Change Sector IPI	0.000458**	0.000453**	0.000313*
	(0.000143)	(0.000146)	(0.000155)
Change Sector IPI × lag PO/COGS	0.00181+	0.00189+	0.00241*
	(0.000966)	(0.000968)	(0.00105)
Constant	-0.00260***	-0.00260***	-0.00229**
	(0.000764)	(0.000765)	(0.000773)
Observations	13530	13530	13340
R^2	0.002	0.003	0.114
FE	None	NAICS 3	Firm

Notes. This table reports the estimation of input price elasticity allowing for different coefficients according to the hedging intensity. The estimated equation is 1.3. The firm value measure used in this regression is EBIT. Each column includes different fixed effects. Regression drops top and bottom 1% outliers for Δ Firms Value / Assets and top 2% outliers for PO/COGS. Standard errors are clustered at the firm level and included in parenthesis. $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 1.12: Input Price Elasticity Estimation–PO/COGS, EBITDA

	(1)	(2)	(3)
	Change EBITDA/AT	Change EBITDA/AT	Change EBITDA/AT
Change Sector IPI	0.000369**	0.000361*	0.000214
	(0.000140)	(0.000143)	(0.000152)
Change Sector IPI × lag PO/COGS	0.00194*	0.00204*	0.00272**
	(0.000948)	(0.000950)	(0.00103)
Constant	-0.00237**	-0.00237**	-0.00206**
	(0.000751)	(0.000752)	(0.000758)
Observations	13434	13434	13242
R^2	0.002	0.003	0.116
FE	None	NAICS 3	Firm

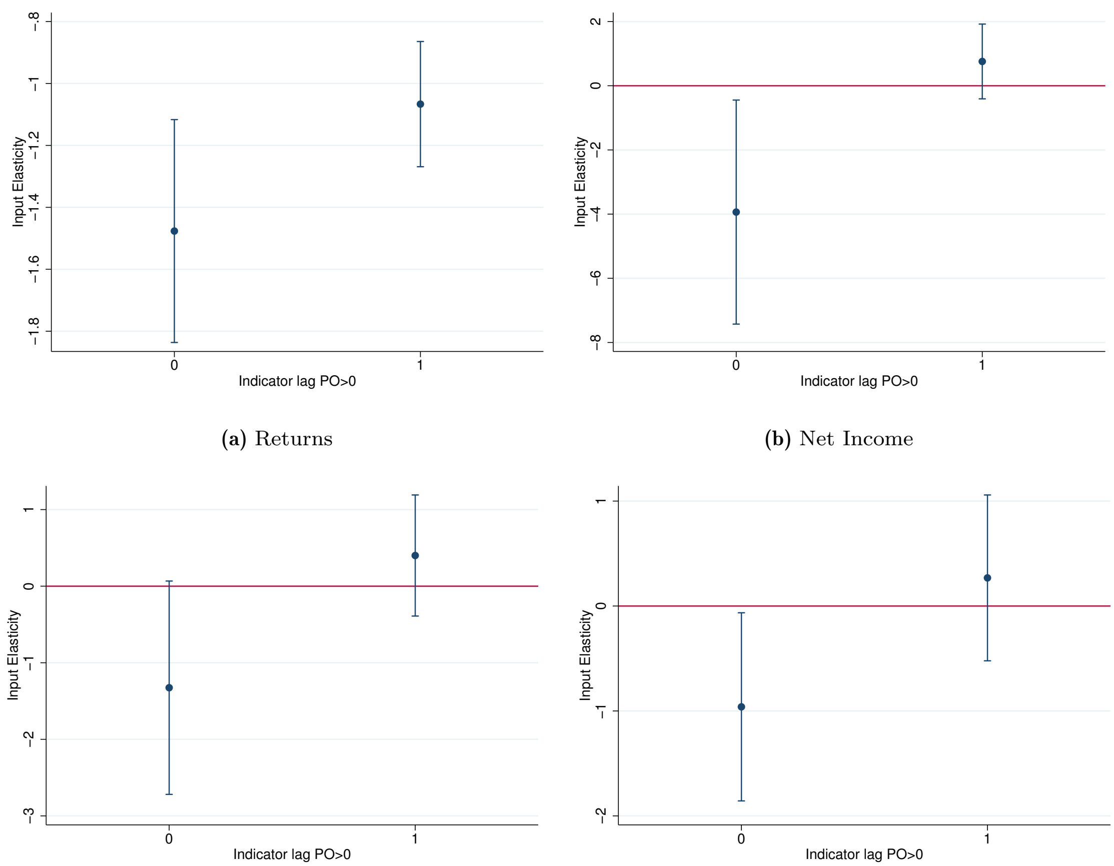
Notes. This table reports the the estimation of input-price elasticity allowing for different coefficients according to the hedging intensity. The estimated equation is 1.3. The firm value measure used in this regression is EBITDA. Each column includes different fixed effects. Regression drops top and bottom 1% outliers for Δ Firms Value / Assets and top 2% outliers for PO/COGS. Standard errors are clustered at the firm level and included in parenthesis. $^+$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 1.13: Input Price Elasticity Estimation–Ups and Downs, Returns

	(1) log Returns	(2) log Returns
Change Sector IPI	0.00105	0.00930***
	(0.00252)	(0.00257)
Change Sector IPI × lag Ind PO	-0.00301	-0.00343
	(0.00269)	(0.00277)
Change Sector IPI (+)	-0.0266***	-0.0469***
	(0.00397)	(0.00425)
Change Sector IPI (+) × lag Ind PO	0.0128**	0.0131**
	(0.00395)	(0.00412)
Constant	0.0524***	0.0985***
	(0.00615)	(0.00690)
Observations	13237	13237
R^2	0.023	0.038
FE	None	NAICS 3

Notes. This table reports the estimation of input price elasticity allowing for different coefficients for increases or decreases of input prices. The estimated equation is 1.4. Standard errors are clustered at the firm level and included in parenthesis. $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Figure 1.11: Input Price Elasticity Estimation–Indicator PO



(a) Returns

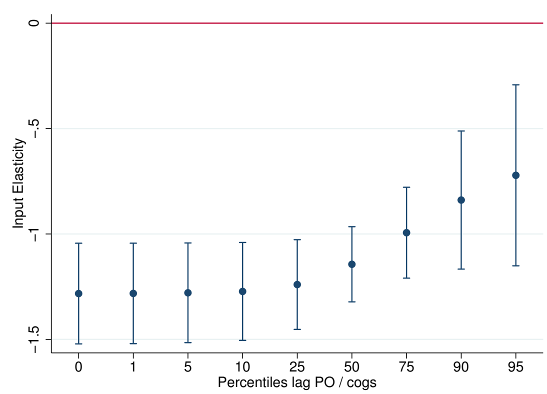
(b) Net Income

(c) EBIT

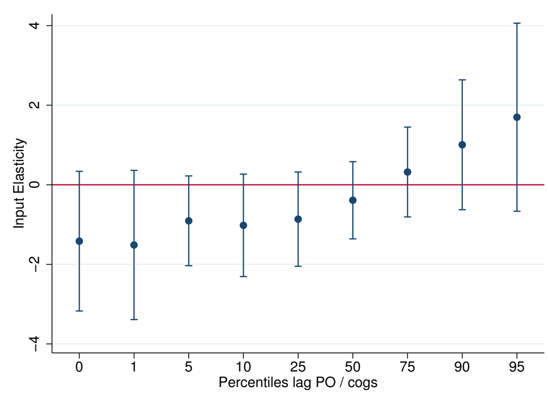
(d) EBITDA

Notes. This figure reports estimates of the input price elasticity for several firm value measures between PO and non-PO firms. Coefficients are taken from Table 1.2 for returns and Table 1.6 for NI, EBIT, and EBITDA (Column 3). Standard errors were computed using the delta method. For NI, EBIT and EBITDA I normalize the coefficients by the median firm value measure over total assets for better interpretation.

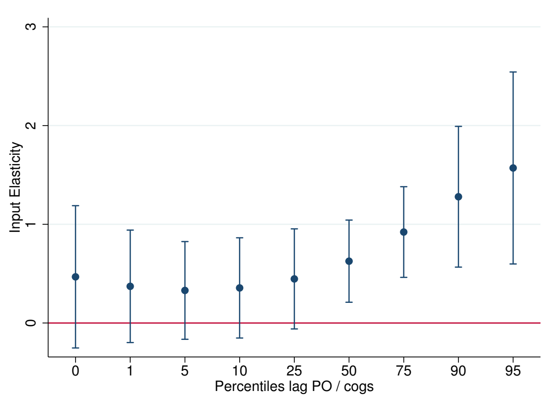
Figure 1.12: Input Price Elasticity Estimation–PO/COGS



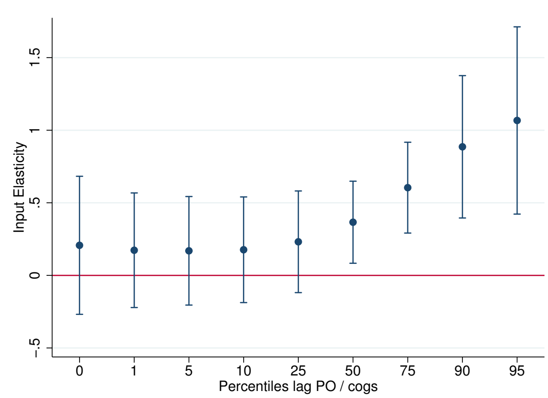
(a) Returns



(b) Net Income



(c) EBIT



(d) EBITDA

Notes. This figure reports estimates of the input elasticity for several firm value measures for different values of PO/COGS. Coefficients are taken from Tables 1.9 (Returns), 1.10 (NI), 1.11 (EBIT), and 1.12 (EBITDA). All coefficients come from Column 3. Standard errors were computed using the delta method. For NI, EBIT, and EBITDA, I normalize the coefficients by the median firm value measure over total assets for better interpretation.

Table 1.14: Summary Statistics Financial Characteristics

Variable	median	lowest 10%	lowest 25%	top 75%	top 90%
log Assets	6.407	3.797	5.013	7.811	9.011
Working Capital / Total Assets	0.284	0.059	0.153	0.466	0.632
Retained Earnings/ Total Assets	0.131	-1.870	-0.309	0.395	0.609
EBIT / Total Assets	0.076	-0.133	0.015	0.126	0.187
Sales / Total Assets	0.918	0.397	0.630	1.306	1.739
Market Value of Equity / Book value of Liabilities	2.638	0.608	1.253	6.205	14.939

Notes. This table shows summary statistics for the covariates used as controls in regression 1.5.

Table 1.15: Commodity price elasticity

Panel A: bottom 25% PO/COGS (2.8%)

	median	lowest 10%	lowest 25%	top 75%	top 90%
No PO firm elasticity	-1.28	-1.85	-1.62	-0.87	-0.45
PO firm elasticity	-1.24	-1.82	-1.58	-0.83	-0.42
p.p. difference	0.037	0.037	0.037	0.037	0.037
% difference	2.88%	2.00%	2.28%	4.26%	8.16%

Panel B: median PO/COGS (9%)

	median	lowest 10%	lowest 25%	top 75%	top 90%
No PO firm elasticity	-1.28	-1.85	-1.62	-0.87	-0.45
PO firm elasticity	-1.16	-1.73	-1.50	-0.75	-0.33
p.p. difference	0.119	0.119	0.119	0.119	0.119
% difference	9.27%	6.41%	7.33%	13.69%	26.24%

Panel C: top 75% PO/COGS (19%)

	median	lowest 10%	lowest 25%	top 75%	top 90%
No PO firm elasticity	-1.3	-1.9	-1.6	-0.9	-0.5
PO firm elasticity	-1.0	-1.6	-1.4	-0.6	-0.2
p.p. difference	0.251	0.251	0.251	0.251	0.251
% difference	19.58%	13.54%	15.48%	28.90%	55.39%

Notes. The table shows the implied commodity price elasticity using coefficients from Table 1.4 (column 3) and covariates from Table 1.14. Each panel computes the implied commodity price elasticity for different covariates values across the firm-size distribution (see Table 1.14). For the PO elasticity I use different values of the PO/COGS distribution: bottom 25% (2.8%, Panel A); median (9%, Panel B); top 75% (19%, Panel C). The % diff. elasticity PO is computed as the % difference between No PO and PO elasticities for each column within panel.

5.2 Appendix - Data Collection

The dataset used in this Chapter is a combination of firm balance sheet, industry, and text-based characteristics. I constructed the dataset in several steps:

1. **Scope.** Using COMPUSTAT, I downloaded the CIK (SEC identifier) for all public firms in the manufacturing sector (NAICS 31-33). The Securities and Exchange Commission keeps an online repository of all filings starting in 1993. These can be accessed through the website `https://www.sec.gov/Archives/edgar/full-index/`. I downloaded the header of all reports filed between 2003 and 2019 for companies with CIKs found on COMPUSTAT and belonging to the manufacturing sector. I kept only company-year observations with a 10-K report in the EDGAR repository.

2. **Firm Characteristics.** I used COMPUSTAT to obtain earnings and costs measures used throughout the Chapter and CRSP for stock returns.

3. **Purchase Obligations.** I constructed the purchase obligations dataset in three steps, following Almeida et al. (2017) and Moon and Phillips (2020).

   For each company-year in the scope, I downloaded the purchase obligation table using a scrapping algorithm in Python. For each 10-K in **Scope**, the algorithm reads through the 10-K and finds the table with the purchase obligation amount. The key-words used were `Purchase Obligations`, `Purchase Commitments`, `Purchase Orders`, and `Contractual Obligations`.[12]

   Companies do not follow a strict reporting procedure and therefore some adjustments are needed. In the first place, the unit of account of PO is problematic. Some companies report explicitly the unit (dollars, thousands or millions), but others fail to do so. I

[12] Also letter-case variations such as `Purchase obligations`, `purchase obligations`, etc.

solve this issue by extracting the unit of account from the table if it is available. If the unit is missing, I compute the ratio PO/Cost of Goods Sold and define the unit of measure based on three thresholds.

Unit	Threshold $PO/COGS$
Millions	< 0.45
Thousands	< 2.7 & > 0.45
Dollars	$> 10,200$

I verify that this process correctly accounts for the unit of measure by manually checking the annual reports of about 1% of the sample.

4. **Input Price Index.** I constructed a Laspeyres price index from materials used by sector using the Economics Census 2012 and the BLS or World Bank.[13] I first assign the closest price index to each commodity using BLS data based on the industry code using price indexes by industry.[14] If there is no price, I manually assign the closest commodity based on the name on the Economic Census.[15]. Finally, for some commodities, only World Bank Commodity Data have a relevant price. [16]

   The next set is to construct expenditure shares of each sector (NAICS-3) on all other sectors using the Economic Census Materials Consumed by Kind of Industry. For each 3-digit manufacturing sector, the input price index is the sum of the product of the price index of each commodity and its share in that sector.

[13] The Economic Census can be accessed on https://www.census.gov/data/datasets/2012/econ/census/2012-manufacturing.html.

[14] https://download.bls.gov/pub/time.series/pc/.

[15] See https://download.bls.gov/pub/time.series/wp/

[16] See https://www.worldbank.org/en/research/commodity-markets However, only 0.45% of the commodity prices I used were from the World Bank.

Chapter 2

Aggregate consequences of commodity price hedging: Evidence from Purchase Obligations

1. Introduction

In this Chapter I introduce a tractable theoretical model that showcases the empirical findings of Chapter 1. It extends a basic trade model, similar to Melitz (2003), with no entry and exit and featuring purchase obligations. There will be two countries (home and rest of the world) in which home firms require labor and imported material inputs to produce goods. I model the home country as a small open economy. Input materials can be bought on the spot market or one period ahead using a purchase obligation contract. Both markets are assumed to have a perfectly elastic supply, in line with the small open economy assumption.

The model has two stages. In the first stage, the spot price is unknown and companies choose their purchase obligations conditional on the distribution of spot prices and their expected profit in the second stage. These purchase obligations consist of a future contract for the delivery of a fixed quantity of input materials at a fixed price on the next stage.

In the second stage, each firm produces a differentiated variety using labor and imported material inputs. They sell their output to a representative firm that bundles all varieties and sells to domestic or foreign consumers. The key difference with standard trade models is that firms borrow funds to cover their costs, facing financial constraints. I model these along the lines of Froot et al. (1993). Firms use profits as collateral for borrowing. If profits are large, firms can finance their operations internally at no extra cost. However, when profits are below a threshold, firms are constrained and need external financing. This requires additional expenses (distress costs) that I model as an interest-rate premium. This happens when input prices are high.

Purchase obligations are modeled as an input supply forward contract that yields positive income if spot prices are larger than future prices. These financial assets can increase income precisely when firms are constrained and compensate for the decline in profits from a surge in input prices. By increasing the quantity of assets traded, the firm can raise income and reduce expected interest payments on externally borrowed funds.

In general equilibrium, the use of purchase obligations can reduce the transmission of input price shocks to aggregate variables. An increase in input prices reduces sales, and a larger share of firms will face distress costs. Constrained firms raise prices and reduce labor demand to offset the burden of external financing. This implies that wages and real consumption react more to input price shocks. When firms ex ante buy purchase obligations, they can reduce their external financing; therefore, this can dampen the transmission to aggregate variables.

The model matches empirical facts of the dataset across the firms' size distribution. In particular, there is a size threshold for the use of purchase obligations. Small firms are constrained for most of the distribution of input prices. Buying purchase obligations reduces their income when the future price exceeds the spot price. This implies that if small firms buy purchase obligations, they will increase their expected financial distress costs. Only large firms benefit from hedging, because they can reduce their expected distress costs by buying purchase obligations. Along the intensive margin, the model predicts a hump-shaped distribution. Larger firms benefit more because they can reduce their distress costs more than smaller firms with the same purchase obligation quantity. However, the largest firms are rarely constrained and find it optimal to trade smaller purchase obligations contracts.

I use the model to study quantitatively aggregate implications. I simulate the model to match stylized facts of the U.S. economy and compare the solution to a counterfactual in which firms are not allowed to trade purchase obligations. I find that there are positive aggregate effects on real consumption and employment. I measure welfare gains by computing the equivalent variation between these two models. On one hand, for low spot prices, there are welfare losses due to negative income from the future contract. On the other hand, for large spot prices, firms can increase income from the forward operation and reduce their distress costs. The results show that the representative consumer is willing to sacrifice 1.8% of her consumption to allow firms to trade these supply contracts.

Finally, I compute the relative response of aggregate variables to input price shocks between the calibrated model with purchase obligations and the counterfactual. I find a strong reduction of aggregate transmission when firms trade purchase obligations. For example, when firms engage in purchase obligations, real consumption has a relative response of 4% less to a 10% commodity price shock.

Related Literature. This Chapter is connected to two strands of the literature. First, the international economics literature has studied, in great detail, the transmission of commodity price shocks, mainly focusing on oil price shocks. Examples are Blanchard and Gali (2009);

Davis and Haltiwanger (2001); Hamilton (2003); Başkaya et al. (2013); Guo et al. (2005); Kilian (2009) and Fernández et al. (2017). This Chapter is mostly related to Blanchard and Gali (2009), who study oil shocks in several developed economies. Their empirical results show a large decrease in output and employment after an oil shock. They also find a substantial increase in nominal wages and consumer prices. On the other hand, Fernández et al. (2017) estimate a Structural Vector Auto Regression (SVAR) model to understand the contribution of commodity shocks to domestic business cycles. Their results show that commodity prices explain about a third of the variance of output and 20% of the variances of consumption and investment. In this Chapter, I allow for the possibility that the transmission of commodity price shocks could be partially offset through the use of risk-management tools. In particular, I study the role of supply contracts with fixed prices as a hedging device. The results suggest that this new channel plays an important part in dampening the propagation of these shocks.

Second, risk-management has been extensively studied in finance. The Modigliani-Miller theorem suggests that hedging will not increase firm value, and therefore firms should avoid using these instruments. However, the literature has shown several deviations from this theorem. These include risk-averse managers, convex tax schedules, and external financing costs.[1] This Chapter will follow Froot et al. (1993), in the sense that firms will face external financing costs. In the model, the use of purchase obligations could reduce their external financing burden and increase profits. Another set of related papers includes Rampini and Viswanathan (2010) and Rampini et al. (2014). These papers study the relationship between financing and risk management, but only focus on individual firms. This Chapter will extend their analysis by studying aggregate implications of risk-management policies.

Layout. The rest of the Chapter is organized as follows. Section 2 introduces the general

[1] For example Smith and Stulz (1985), Froot et al. (1993) and Nance et al. (1993).

equilibrium model of purchase obligations and studies its predictions. Section 3 quantitatively analyzes how the use of purchase obligations can dampen the propagation of input price shocks, and Section 4 concludes.

2. A Model of Purchase Obligations

In this section I introduce the general equilibrium model that explains why firms use purchase obligations and highlights the macroeconomic implications of commodity price hedging. I extend a heterogeneous firm trade model (Melitz (2003)) without entry and exit, materials required for production, and sectoral heterogeneity along the lines of Caliendo and Parro (2015). The model will also feature financial constraints that will create incentives to hedge commodity price shocks using purchase obligations.

There will be heterogeneous monopolistic firms in two sectors, manufacturing and services that require materials and labor to produce differentiated varieties. I use the notation i and $v = m, s$ to denote firm i belonging to sector v. There will be also be a representative firm in each sector that will bundle all varieties into a final sectoral good.

The model will have one time period and two stages. In the first stage, firms in the manufacturing sector set up their purchase obligation contracts. These are modeled as a supply contract for the delivery of a fixed quantity of material inputs at a fixed price (future price). Firms maximize expected profits conditional on the distribution of material prices in the second stage (spot prices). The main benefit of using purchase obligations is to ease the financial constraints present in the next stage.

In the second stage, all firms will make production and pricing decisions conditional on their productivity and the spot price, following a production function that requires labor and materials. Firms in the manufacturing sector will have to finance their costs through borrowing. They could do this internally at zero interest rate, or externally at a positive interest rate. They main feature of the model is that firms will face a financial constraint that will limit their capacity for internal borrowing. Purchase obligations allow firms to reduce the negative consequences of commodity price shocks by easing the distress costs associated with the financial constraint.

To close the model, I assume a representative consumer/worker demanding goods from both sectors and supplying labor. All materials will be imported from the rest of the world and paid for using exports of the manufacturing bundle.

I include services in the model for the following reasons. First, I match the sectorial composition of developed economies: services represent a large share of GDP. In the data, firms in service sectors do not report using PO for material purchases. They contract on other services such as advertising or information technology. The main driver of this fact is that firms in the service sector require a low share of material inputs in production and are less exposed to commodity price risk. Secondly, the service sector will benefit from the PO decisions from manufacturing firms and this will increase the aggregate benefit of the use of purchase obligations.

2.1 Model Description

First Stage

Firms in manufacturing sector m can trade purchase obligations. Each firm i will choose its purchase obligations contracts quantity $\bar{m}_i^m$ by maximizing expected profits, where short positions are not allowed. Firm productivity z_i^m is constant and known in all stages. However, the spot price of raw material q is not observable at this stage. Firms will have to pay a purchase obligation price $\bar{q}$ for each unit of the future contract they purchase and face a contracting cost function $\kappa \bar{m}_i^m$ to access this market. I assume fair pricing by setting $\bar{q} = \mathbb{E}_q[q]$. Firm's i problem results in

$$\max_{\bar{m}_i^m} \ \mathbb{E}_q[\Lambda(q)\pi_i^m(z_i^m, q, \bar{m}_i^m)] - \kappa \bar{m}_i^m \quad \bar{m}_i^m > 0, \tag{2.1}$$

where $\pi_i^m(z_i^m, q, \bar{m}_i^m)$ will be the firm's profit conditional on spot price q, and $\Lambda(q)$ is the stochastic discount factor of the representative consumer who owns all the firms. These functions will be derived in the next stage of the model.

Second Stage–Production

In the second stage, the spot price becomes public information. All firms make their production and pricing decisions. I first describe the production decisions of firms in the manufacturing sector. I assume there will be a unit mass of firms with cumulative density function H^m, where each firm behaves as a monopolist when selling its variety, but taking as given the price of the materials used in production and wages. Materials can be purchased in two markets: a spot market and a purchase obligations market, with perfectly competitive prices q and $\bar{q}$. Let $\{m_i^m, \bar{m}_i^m, l_i^m\}$ be firm's i input choice: spot material purchase, purchase obligations material purchases, and labor demand. I assume the production function of firm i in manufacturing is

$$y_i^m = z_i^m(\bar{m}_i^m + m_i^m)^{\gamma^m}(l_i^m)^{1-\gamma^m}, \tag{2.2}$$

where z_i^m represents productivity and γ^m the materials share of production in the manufacturing sector. Notice that spot purchases m_i^m and PO purchases $\bar{m}_i^m$ are assumed to be perfect substitutes. Moreover, $\bar{m}_i^m$ is exogenous at this stage, since it was chosen in the first stage. Firms are allowed to sell their PO materials with no penalty. This implies that m_i^m can be negative.

The cost minimization problem of firm i results in

$$\max_{m_i^m, l_i^m} \; q m_i^m + \bar{m}_i^m \bar{q} + w l_i^m \text{ s.t. } z_i^m (\bar{m}_i^m + m_i^m)^{\gamma^m} (l_i^m)^{1-\gamma^m} \geq y_i^m. \tag{2.3}$$

The solution of the problem yields the following equations:

$$\begin{aligned} C_i^m(w,q,\bar{q}) &= \frac{y_i^m}{z_i^m} MC^m + \bar{m}_i^m[\bar{q} - q] \quad & MC^m(q,w) &= \left(\frac{q}{\gamma^m}\right)^{\gamma^m} \left(\frac{w}{1-\gamma^m}\right)^{1-\gamma^m} \\ l_i^m(q,w) &= \frac{y_i^m}{z_i^m} MC^m \frac{1-\gamma^m}{w} & m_i^m(q,w) &= \frac{y_i^m}{z_i^m} MC^m \frac{\gamma^m}{q} - \bar{m}_i^m, \end{aligned} \tag{2.4}$$

These represent total cost C_i^m, common marginal cost component for manufacturing firms MC^m, labor demand l_i^m, and spot material demand m_i^m. The critical deviation from a standard Cobb-Douglas cost function is the second term in the cost equation. Because firms will have an "endowment" of materials coming from the purchase obligation market, they will receive an income effect that will change the effective total cost. This income effect will depend on the difference between the spot and the PO price.

For instance, if the PO price is higher than the spot price, firms will face higher total costs. Because there are no costs for selling the PO position, firms will completely sell out their PO materials at price q and repurchase the optimal quantity. The firm's financial gain or loss will depend on the price difference times the units traded: $\bar{m}_i^m[\bar{q} - q]$.

Firms in the service sector do not face financial constraints and cannot trade purchase obligations. I assume an analogous cost minimization problem as in manufacturing, with material cost share γ^s. To keep the model tractable, I assume that all firms in this sector are identical, with productivity Z^s. The relevant equations for firms in this sector are

$$\begin{aligned} C^s(w,q) &= \frac{y^s}{Z^s} MC^s \quad & MC^s(q,w) &= \left(\frac{q}{\gamma^s}\right)^{\gamma^s} \left(\frac{w}{1-\gamma^s}\right)^{1-\gamma^s} \\ l^s(q,w) &= \frac{y^s}{Z^s} MC^s \frac{1-\gamma^s}{w} & m^s(q,w) &= \frac{y^s}{Z^s} MC^s \frac{\gamma^s}{q}. \end{aligned} \tag{2.5}$$

2nd Stage–Financing

Firms in the manufacturing sector borrow funds to cover their operational costs from foreign lenders with deep pockets. I define operational costs as the portion of total cost unrelated to purchase obligations, i.e. $\frac{y_i^m}{z_i^m} MC^m$ from Equation (2.4). Firms borrow funds and repay the loan plus interests in the same stage. Both actions take place after the uncertainty over the material input spot price has realized. I assume that lenders have deep pockets in the sense that they have unlimited amount of funds to lend. On the other hand, manufacturing firms face financial constraints, which I model as an interest-rate premium that inversely follows profits. I build on Schmitt-Grohé and Uribe (2003) by assuming an elastic functional form for interest rates:

$$1 + r_i^* = \max\{e^{-\iota(\pi_i^m - \bar{B})}, 1\}, \tag{2.6}$$

where π_i^m represents profits, $\bar{B} > 0$, and $\iota > 0$. The model follows Rampini and Viswanathan (2010) assuming limited enforcement in repayments. Let $\bar{B}$ be the revenue pledgeability parameter, in the sense that lenders can only capture a fraction of profits if the firm faces distress ($\pi_i^m < \bar{B}$). In this case, lenders will require a firm-specific interest-rate premium $r_i^* > 0$ to compensate for the additional risk. On the other hand, if profits exceed $\bar{B}$, the interest rate is zero. Finally, the parameter ι captures how interest rates change with profits.

Let p_i^m be the price chosen by firm i and $y_{i,m}$ its product demand. Profits are

$$\pi_i^m = p_i^m y_i^m - \frac{y_i^m}{z_i^m} MC^m (1 + r_i^*) + \bar{m}_i^m [q - \bar{q}]. \tag{2.7}$$

These assumptions follow standard hedging determinants, as in Froot et al. (1993), where there are distress costs associated with differences between internal and external financing. The model builds on these by assuming that internal financing occurs when firms are financially solvent, $\pi_i^m \geq \bar{B}$. If this is not true, firms will require external financing, which are be more costly.

Purchase obligations consist of a supply contract that changes profits according to the difference between spot and future prices (see equation (2.7)). For large input prices ($q > \bar{q}$), the firm receives positive income and can reduce the interest premium charged by lenders by reducing the difference between profits and the threshold $\bar{B}$.

Second Stage–Firms' Profits

Firms will choose prices to maximize profits conditional on their variety demand. I assume there is a representative firm that aggregates all varieties within a sector, as in Dixit and Stiglitz (1977). Elasticities of substitution are σ^m and σ^s for manufacturing and services, respectively, and both are larger than 1. Demand for variety i in sector $v = m, s$ is then $\left(\frac{p_i^v}{P^v}\right)^{-\sigma^v} Y^v$, where P^v and Y^v represent the price index and total demand for sector v.

The pricing decision for firms in the manufacturing industry will be the solution of the problem

$$\max_{p_i^m} \; p_i^m y_i^m - \frac{y_i^m}{z_i^m} MC^m (1 + r_i^*) + \bar{m}_i [q - \bar{q}] \quad \text{s.t.} \quad y_i^m = \left(\frac{p_i^m}{P^m}\right)^{-\sigma^m} Y^m. \tag{2.8}$$

I characterize the pricing rule that maximizes profits, conditional on the interest rate:

$$p_i^m = \frac{\sigma^m}{\sigma^m - 1} \frac{MC^m}{z_i^m} (1 + r_i^*) \tag{2.9}$$

Firms will adjust their prices following the marginal costs adjusted by interest rates. A surge in input prices will generate two effects on prices. First, production costs will increase through the marginal cost and firms will raise prices. Second, as profits decrease, firms will face a larger interest-rate premium and further increase prices.

Using the optimal pricing rule, firms profits are

$$\pi_i^m = \Theta^m (z_i^m)^{\sigma^m - 1} \left(\frac{q}{\gamma^m}\right)^{\gamma^m} \left(\frac{w}{1 - \gamma^m}\right)^{1-\gamma^m} (1 + r_i^*)^{1-\sigma^m} (P^m)^{\sigma^m} Y^m + \bar{m}_i^m [q - \bar{q}], \tag{2.10}$$

where $\Theta_m \equiv \left(\frac{\sigma^m - 1}{\sigma^m}\right)^{\sigma^m} \frac{1}{\sigma^m - 1}$.

One one hand, profits are decreasing in spot prices though changes in the marginal cost and interest rates. On the other hand, they are proportional to the financial gain $\bar{m}_i^m[q - \bar{q}]$. For large spot prices, companies with purchase obligations receive positive income from the forward operation and can partially offset the reduction in sales from surges in input prices.

It is convenient to define the constrained threshold following Definition 1: Firms will face a positive interest rate for spot prices over the threshold $q > \tilde{q}_i^m$

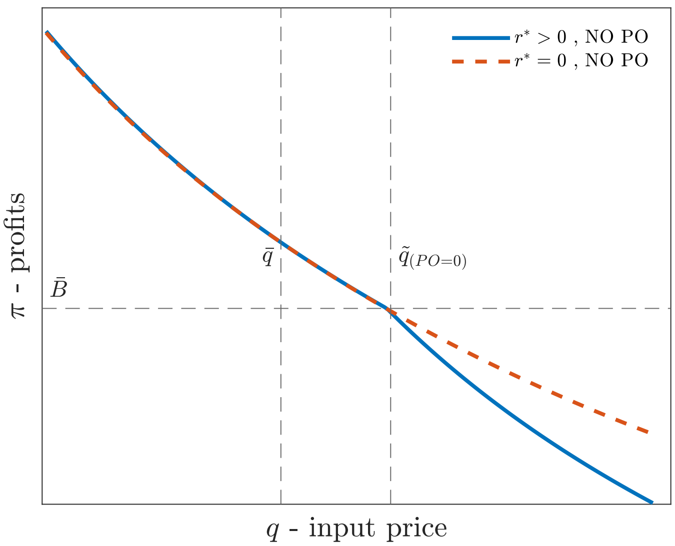
Definition 1 (Constrained threshold)**.** Let the constrained threshold be the spot price $\tilde{q}_i$ such that the firm faces zero interest rate:

$$\Theta_m z_i^{\sigma_m - 1} \left(\frac{\tilde{q}_{i,m}}{\gamma_m}\right)^{\gamma_m(1-\sigma_m)} \left(\frac{w(\tilde{q}_{i,m})}{1-\gamma_m}\right)^{(1-\gamma_m)(1-\sigma_m)} P_m(\tilde{q}_{i,m})^{\sigma_m} Y_m(\tilde{q}_{i,m}) + \bar{m}_{i,m}[\tilde{q}_{i,m} - \bar{q}] = \bar{B}. \tag{2.11}$$

I compare profits when firms do not face a positive interest rate in Figure 2.1. The main-impact of the external financing cost is that it drastically reduces profits in the constrained region $q > \tilde{q}_i^m$. This is captured graphically by the difference between the two curves in the region to the right of the constrained threshold. Since firms earn less income due to increases in spot prices, they face tighter financial constraints (larger r^*).

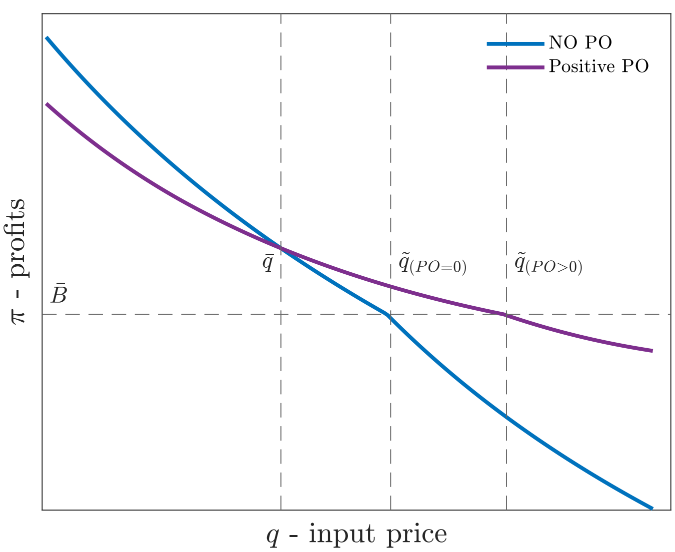
The main reason firms choose positive purchase obligations is to reduce the external financing burden. This is shown graphically in Figure 2.2. The introduction of purchase obligations makes two main contributions to firm profits. First, firms receive a negative income effect if spot prices are low. This happens because the financial hedge only protects the firm for large realizations of input prices. This is shown in the figure as the difference between the curves in the left region. Second, having purchase obligations increases financial income for large spot prices. This additional financial income increases profits and allows the firm to reduce interest expenses, because profits are closer to the threshold $\bar{B}$. This also means that the company can shift the constrained threshold $\tilde{q}_i^m$ with the supply contracts.

Figure 2.1: Firm's Profits–Zero Purchase Obligations



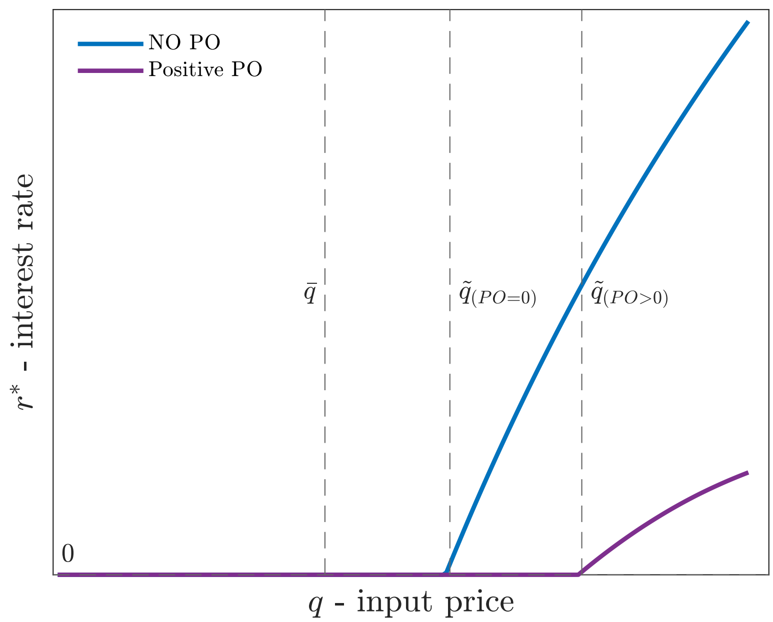
Notes. The figure shows profits π as a function of spot prices q and highlights the difference between profits when firms face financial constraints (the difference between dashed orange line and solid blue). I removed index i, m for exposition.

Figure 2.2: Firm's Profits–Adding Purchase Obligations



Notes. The figure shows the relationship between profits π and spot prices q and shows the benefit of contracting purchase obligations. I removed index i, m for exposition.

Figure 2.3: Interest Rates



Notes. The figure shows the relationship between interest rates r^* and spot prices q. Firms can reduce interest expenses by trading purchase obligations. I removed index i, m for exposition.

I plot the changes in interest rates when using purchase obligations in Figure 2.3. The interest rate is increasing in input prices because firms receive less income. When a firm trades purchase obligations, it will receive additional income that will generate a reduction in interest rates.

Second Stage–Consumer

To close the model, I include a representative consumer/worker and the rest of the world. I assume preferences as in Greenwood et al. (1988) over hours and aggregate consumption. I also assume a Cobb-Douglas aggregator between sectors, with α being the share of income spent on manufacturing goods. Preferences are

$$U(C,L)=\log\left(C-\xi\frac{L^{1+\eta}}{1+\eta}\right)\quad C=(C^m)^{\alpha}(C^s)^{1-\alpha}\quad C_v=\left(\int(c_i^v)^{\frac{\sigma_v-1}{\sigma_v}}dH^v\right)^{\frac{\sigma^v}{\sigma^v-1}}\quad v=s,m. \tag{2.12}$$

The budget constraint is $PC=wL+\Pi-\kappa^A$, where P stands for the final good price index, P^v for the price for sector v bundle, w for wages, Π for aggregate profits, L for hours worked, C for real consumption and κ^A for aggregate purchase obligations contracting costs.[2] Notice that the consumer will receive profits from all firms. This is important, because the hedging outcome will generate an income effect on consumers.

Given these assumptions, labor supply and goods demand are determined by the first-order conditions:

$$\begin{aligned} L&=\left(\frac{w}{P\xi}\right)^{\frac{1}{\eta}} \qquad PC=wL+\Pi-\kappa^A \\ C^mP^m&=\alpha PC \quad C^sP^s=(1-\alpha)PC. \end{aligned} \tag{2.13}$$

Definition 2 (Aggregate productivity)**.** Let $(Z_1^m)^{\sigma^m-1}\equiv\int\left(\frac{z_i^m}{1+r_i^*}\right)^{\sigma^m-1}dH^m$ be the interest-rate adjusted productivity measure of manufacturing firms.

Using Definition 2, price indexes are

$$\begin{aligned} P&=\left(\frac{P^m}{\alpha}\right)^{\alpha}\left(\frac{P^s}{1-\alpha}\right)^{1-\alpha} \\ P^m&=\frac{\sigma^m}{\sigma^m-1}\left(\frac{q}{\gamma^m}\right)^{\gamma^m}\left(\frac{w}{1-\gamma^m}\right)^{1-\gamma^m}\frac{1}{Z_1^m} \\ P^s&=\frac{\sigma^s}{\sigma^s-1}\left(\frac{q}{\gamma^s}\right)^{\gamma^s}\left(\frac{w}{1-\gamma^s}\right)^{1-\gamma^s}\frac{1}{Z^s}. \end{aligned} \tag{2.14}$$

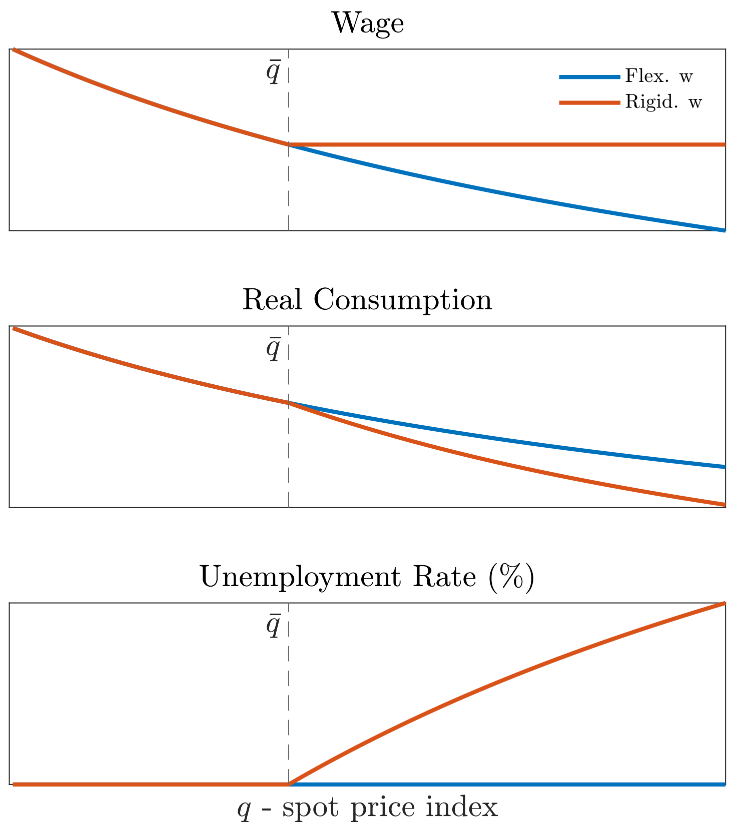
[2] $\kappa^A\equiv\int\kappa(\bar{m}_i^m)dH^m$.

Second Stage–Downward Nominal Wage Rigidity

I assume that nominal wages face downward rigidities along the lines of Schmitt-Grohé and Uribe (2016). In particular, I assume that wages are fixed if there is an increase in input prices, but they are flexible when input prices decrease, starting from mean spot prices. This is consistent with Blanchard and Gali (2009), because the short-run response of wages to positive input price shocks is almost zero after the 2000s. This is also consistent with the asymmetric effects of commodity price shocks studied in the literature (e.g., Hamilton (2011)). In the quantitative exercises below, I study positive input price shocks, and therefore this assumption is relevant to match these empirical facts documented in the literature.

In general equilibrium there will be involuntary unemployment, denoted by u. In particular, u will be defined as the difference between labor supply and demand for fixed wage $\bar{w}$: $u(q, \bar{w}) = L^s(q, \bar{w}) - L^d(q, \bar{w})$. The downward rigidity implies that $u > 0$ when input prices increase, but $u = 0$ for decreases. Finally, $\bar{w}$ will be set as the flexible wage for the mean spot price $\mathbb{E}_q[q]$. For clarity, I plot the evolution of nominal wages, real consumption, and unemployment in Figure 2.4.

Figure 2.4: Downward Nominal Wage Rigidity



Notes. The figure shows the assumed relationship between nominal wages and spot prices. I also plot the model-implied relationship between spot prices and real consumption, and involuntary unemployment.

Second Stage–Foreign Economy

I assume two regions in the model: a domestic country and the rest of the world. It is easier to think about the domestic country as being the U.S., given the data on purchase obligations. Therefore, the domestic currency will be dollars. I assume the domestic country is a small open economy facing a perfectly elastic supply of material inputs (spot and futures).

The rest of the world will have preferences over the manufacturing domestic bundle and foreign final good, with ν being the elasticity of substitution and $1-\zeta$ its home bias:

$$C^* = \left((1-\zeta)^{\frac{1}{\nu}}(C^{m,*})^{\frac{\nu-1}{\nu}} + \zeta^{\frac{1}{\nu}}(C^{F,*})^{\frac{\nu-1}{\nu}}\right)^{\frac{\nu}{\nu-1}}. \tag{2.15}$$

The manufacturing bundle will be exported with foreign demand $X = \left(\frac{\tilde{P}^m}{P^*}\right)^{-\nu} \zeta Y^*$, where P^* is the price index abroad, Y^* is real foreign income and $\tilde{P}^m$ is the price of the domestic manufacturing good abroad. I assume that the law of one price holds in this economy: $\tilde{P}^m = P^m E$, where E is the exchange rate (measured as the purchasing power of domestic currency). I measure all variables in domestic currency (dollars) by setting the exchange rate to 1.

On the other hand, imports I will be all the materials needed for production measured in dollars. Capital inflows (EF) will be the external financing requirements of firms. Since I solve for an balanced-trade equilibrium, the following equation must hold: $XP^m = I + EF$. Therefore, the domestic manufacturing price will adjust perfectly to reach balanced trade (including external financing).

2.2 Model Implications

In this section, I study the implications of the model. Subsection 2.2 defines an equilibrium and shows how distress costs increase the negative consequences of input price shocks. Subsection 2.2 shows how companies optimally engage in purchase obligations contracts.

Implications for Second Stage

Definition 3 describes a general equilibrium in the second stage.[3] Proposition 1 shows the relationship between distress costs and real wages in equilibrium and highlights the fact that distress costs increase the negative consequences of commodity price shocks.

[3] See Appendix 5.2 for a more detailed explanation of the algorithm.

Definition 3. A general equilibrium in this economy conditional on $(q, \bar{m}_i \forall\, i)$ for the second stage is defined as a set of aggregate prices (P, P^m, P^s, w) and firm choices $(p_i^v, m_i^v, l_i^v, y_i^v \forall\, i, v)$ and aggregate variables $(C, C^m, C^s, L, Y, Y^m, Y^s)$ such that

- Consumer is maximizing: Equation bloq (2.13)
- Firms are maximizing: Equations (2.10) and (2.6)
- Markets clear and balanced trade holds.

Proposition 1. *Changes in real wages from an increase in commodity prices (in constant wage region) can be expressed as:*

$$d \log \frac{w}{P} = -\Gamma_q d \log q + \alpha d \log Z_1^m,$$

where $\Gamma_q = \gamma^m \alpha + \gamma^s (1 - \alpha)$.

Proof. With fixed nominal wages $d \log \frac{w}{P} = -d \log P$. Using Equation bloq 2.14 and Definition 2, I arrive at the result. □

This proposition shows that an input price shock decreases real wages. However, due to the existence of distress costs, the impact of an input price shock can be larger depending on how interest rates react after the shock. This is captured by the reduction in measured productivity Z_1^m. The direct effect of input price shocks reduces profits for all firms, and hence interest rates increase. This further lowers wages, because these firms increase prices to offset the distress costs and reduce labor demand. Overall, the impact of the input price shock is larger.

Hedging determinants

Firms maximize expected profits conditional on the distribution of spot prices. Purchase obligations can ease the financial constraints by reducing interest rates and increasing expected profits.

Firm i's problem in the first stage is

$$\max_{\bar{m}_i^m} \ \mathbb{E}_q[\Lambda(q)\pi_i^m(z_i^m, q, \bar{m}_i^m, \bar{m}_{-i}^m)] - \kappa \bar{m}_i^m \quad s.t. \quad \bar{m}_i^m > 0,$$

Using the utility function, the discount factor $\Lambda(q)$ is $\frac{\partial U}{\partial C} = \left[C - \xi \frac{L^{1+\eta}}{1+\eta}\right]^{-1}$. Assuming that firms are small enough and do not internalize the aggregate effects of hedging ($\frac{\partial \Lambda}{\partial \bar{m}_i^m} = 0$), the first-order condition is

$$(\bar{m}_i^m): \quad \mathbb{E}_q\left[\Lambda(q)\frac{\partial \pi_i^m}{\partial \bar{m}_i^m}\right] \leq \kappa \quad \text{with equality if } \bar{m}_i^m > 0. \tag{2.16}$$

I characterize the solution using the definition of profits:

$$\frac{\partial \pi_i^m(q)}{\partial \bar{m}_i^m} = \begin{cases} q - \bar{q} & if \quad q < \tilde{q}_i^m \\ [q - \bar{q}] \dfrac{1}{1 - (\pi_i^m - \bar{m}_i^m[q - \bar{q}])\iota(\sigma^m - 1)} & if \quad q > \tilde{q}_i^m \ . \end{cases} \tag{2.17}$$

If the firm is facing zero interest rates (for $q < \tilde{q}_i^m$), a small increase in PO quantities only changes income according to the forward income $q - \bar{q}$– i.e., the difference between spot and future prices. However, if the firm is facing positive interest rates due to the financial constraint, the contribution of purchase obligations is larger. Increasing PO quantities slightly will add the forward income to profits, but the firm differently values this income effect depending on how it affects interest rates. A positive income effect will reduce interest rates and benefit the firm more. This is because the marginal value of cash is larger in situations in which financial constraints are tighter.

3. Quantitative Exercises

I explore a series of quantitative exercises to understand the role of purchase obligations in the transmission of input price shocks. The main role of purchase obligations is to reduce the distress costs paid by firms when input prices increase. This is done by increasing income enough such that firms can reduce interest-rate expenses. In the aggregate economy, I find that the use of these contracts can provide insurance on input price shocks and dampen the aggregate transmission.

3.1 A stylized example

This section performs a simple counterfactual to provide insight into the main role of purchase obligations in the transmission of input price shocks. Imagine that spot prices start at a low value, with all firms unconstrained and no purchase obligations. The economy faces an input price shock whereby the new spot price increases and all firms become constrained. Although nominal wages are fixed, using Proposition 1, the solution for the change in equilibrium real wage can be written as

$$d\log\frac{w}{P} = -\underbrace{\Gamma_q d\log q}_{direct\ effect} - \underbrace{\frac{\alpha}{\sigma^m - 1}\log\left(\frac{\int_i (z_i^m)^{\sigma^m-1} dH^m(z_i^m)}{\int_i \left(\frac{z_i^m}{1+r_i^*}\right)^{\sigma^m-1} dH^m(z_i^m)}\right)}_{distress\ costs}.$$

Two main effects explain the negative impact of input price shocks on real wages. On one hand, the shock affects aggregate variables directly by increasing input costs: Firms lower labor demand and increase prices due to the cost change. On the other hand, the increase in input costs reduces profits, and all firms become constrained. Notice that the aggregate productivity measure declines due to the increase in interest rates. These are indirect costs, since firms now have to borrow externally and pay a positive interest rate on these funds. As firms further raise prices and reduce labor demand, the equilibrium wage decreases further due to distress costs.

To study the role of purchase obligations, imagine a counterfactual situation in which all firms had a positive amount of these contracts that allowed them to avoid being constrained after the shock. An increase in the spot price will generate positive revenues from the hedge. In this counterfactual, I are assuming that this extra revenue will be large enough that none of the firms in the economy will require external financing ($r_i^* = 0 \; \forall$ i). Therefore, the wage response to an input price shock is lower.

$$d\log\frac{w}{P}^{PO} = -\Gamma_q d\log q.$$

As firms reduce their exposure to the shock, they do not need to borrow funds externally. This provides insurance for the economy by reducing distress costs.

3.2 The role of purchase obligations

In this section I quantitatively study the contribution of purchase obligations to the transmission of input price shocks. I first discuss the calibration and then turn to several quantitative exercises. In particular, I compare the calibrated economy with an equilibrium in which firms cannot trade purchase obligations. I show that purchase obligations improve welfare and dampen the transmission of commodity price shocks.[4]

[4]See Appendix 5.3 for the algorithm used to solve the model.

Calibration

Parameters were chosen to match stylized facts of the U.S. economy and are shown in Table 2.1. Overall, the calibration follows targeted moments (see Table 2.2).

Table 2.1: Calibration

Parameter	Role	Value	Moment
$G(q)$	distribution spot prices	$\log \mathcal{N}(0.9751, 0.082^2)$	IPI empirical distribution
$H^m(z)$	distribution of productivities	$\log \mathcal{N}(-1, 1.105)$	employment distribution manufacturing 2012
Z^s	productivity services	10	relative size manuf./services
γ^m	share of materials on cost (manuf.)	0.8	Avg. Expenditures in Int. Inputs (BEA) - Manufacturing
σ^m	elasticity of substitution (manuf.)	3	Avg. Markup Manuf.
γ^s	share of materials on cost (services)	0.2	Avg. Expenditures in Int. Inputs (BEA) - economy-wide
σ^s	elasticity of substitution	6	Standard
α	share manuf. /GDP	0.13	Share Manuf./GDP
ι	interest-rate elasticity	0.01	Agg. PO/Gross Output Manuf. for 2012
$\bar{B}$	sales pledgeability	31	Average PO/COGS
$\bar{q}$	PO unit price	$\mathbb{E}[q]$	efficient markets
κ	PO negotiation cost	0.02	Measure PO firms
ν	export elasticity	2	Tokarick (2010)
η	inv. Frisch elasticity	2	Auclert et al. (2022)
ξ	level employment	47.18	Employment Manuf. 2012
P^*	foreign price level	1	normalization
Y^*	foreign real output	58.97	World GDP
ζ	foreign bias	0.4	Auclert et al. (2022)

Manufacturing Sector. I use BEA data to compute the average expenditure share of gross output in intermediate inputs between 1997 and 2018. The parameter γ_m, was chosen to match this statistic in the model. For the elasticity of substitution across varieties σ_m I use the statistics from the manufacturing sector from Ahmad and Riker (2019), who construct an average elasticity of substitution by sector (NAICS 3) using total sales and total costs from the Economic Census 2012. I choose σ^m in the model to match the weighted average markup for the manufacturing sector, using each sector's gross output from the BEA as weights. For services, I use a standard parameter σ^s to obtain markups of 20%. The relative size of services and manufacturing is captured by the parameter Z^s. I attempt to match the relative sectors gross output in 2012.

I match the distribution of spot prices and productivity in the model with the distribution of my measures of the input price index and employment in manufacturing for 2012. In particular, I set the mean of the spot price distribution so that gross output in the model matches manufacturing gross output in 2012. For labor parametersI set ξ to match the level of employment in manufacturing in 2012, assuming in that in full employment, the representative consumer spends one-third of her time working. Finally, I take the inverse Frisch elasticity η from the macro-finance literature (e.g., Auclert et al. (2022)).

Financial Constraints. I calibrate financial financial constraints parameters $(\iota, \bar{B})$ to match statistics from the database for 2012. The moments chosen are the share of total purchase obligation value relative to gross output in manufacturing and the average share of purchase obligations value relative to the cost of goods sold.

Purchase Obligations. The parameter κ is related to the marginal cost of negotiation when firms choose to use purchase obligations. I target matching the share of firms engaging in purchase obligations.

Rest of the world. Parameters for the rest of the world are chosen to match the world GDP in 2012. I take the remaining parameters from the literature. In particular, I take trade elasticity ν from Tokarick (2010) and foreign bias ζ from Auclert et al. (2022)

Firm-size distribution

In this section, I study the quantitative predictions of the model in terms of the purchase obligation choice over the firm-size distribution. In Figure 2.5 I present the optimal purchase

Table 2.2: Model Fit

Moment	Data	Model
Average Expenditures in Intermediate Inputs Manuf. (BEA)	54%	44.13%
Average Markup	1.53	1.5
Average PO/COGS 2012	13%	19.76%
Agg. PO / Manuf. Gross Output 2012	4.5 %	1.62%
Measure PO Firms 2012	0.5%	0.81%
Ratio Services/Manuf. Gross Output 2012	4	1.56

obligations value as a share of COGS for mean spot prices across the firm-size distribution.[5] Purchase obligations value is the product of the supply contract quantity and price: $\bar{m}_i^m \bar{q}$. In Figure 2.12, I include the distribution of PO over COGS across the productivity and spot price distribution.

The figure shows that only large firms will choose positive purchase obligations. Also, the purchase obligation value is increasing in firm size for productivities below z^{int} and decreasing above this threshold. This is broadly in line with the empirical distribution of purchase obligations across the firm size distribution.

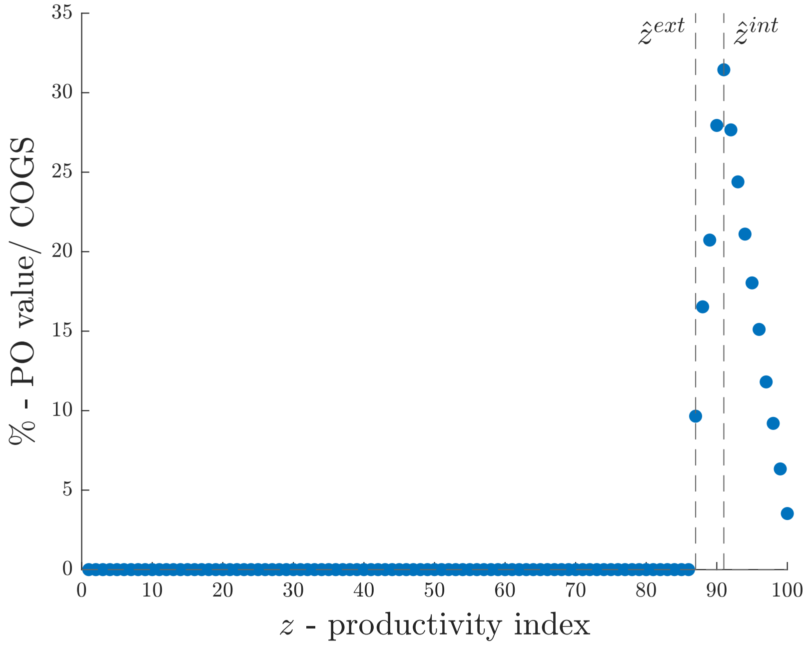
The intuition of this pattern is a follows. The size of a firm in the model is determined by its productivity and there is a one-to-one mapping to the natural constrained threshold (see Equation (2.11) when $\bar{m} = 0$). Even without purchase obligations, a large firm will be constrained for a smaller range of spot prices. This implies that a small firm will increase its expected distress costs if they buy purchase obligations, because it will receive negative income for spot prices below the PO price $\bar{q}$.[6] An intermediate firm with $z \in (z^{ext}, z^{int})$ will benefit from contracting purchase obligations to reduce distress costs. Taking two firms in this range, the larger will have more incentive to hedge because it can reduce the distress costs more with less forward contracts. Finally, a large firm with $z > z^{int}$ will benefit from hedging but has less incentive than smaller firms. These firms are already constrained for a

[5] I use a discrete vector of productivities to obtain 100 firm sizes.

[6] See Figure 2.13 and Figure 2.13.

smaller set of spot prices and benefits relatively less.

Figure 2.5: Model-implied Purchase Obligations



Notes. The figure shows the optimal purchase obligation choice along the firm-size distribution. I normalize the coefficients by COGS in the model.

Exposure reduction

Using the calibrated model, I compute the implied commodity price elasticity. I compare this model statistic with the empirical estimates found above.

I compute the commodity price elasticity, conditional on PO use, as

$$\left.\frac{d\log\pi^m}{d\log q}\right|_{PO=0} = \int_q \frac{d\log\pi_i^m}{d\log q} dG(q) \frac{dH^m(z_i^m)}{\int_i dH^m(z_i^m)\mathbb{I}_{\bar{m}_i^m=0}}$$
$$\left.\frac{d\log\pi^m}{d\log q}\right|_{PO>0} = \int_q \frac{d\log\pi_i^m}{d\log q} dG(q) \frac{dH^m(z_i^m)}{\int_i dH^m(z_i^m)\mathbb{I}_{\bar{m}_i^m>0}}.$$

I also compute a counterfactual elasticity of PO firms if they did not use purchase obligations.

Table 2.3 shows model results for a 10% increase in commodity prices. The results are in line with the reduced-form estimates presented above. Also, I report the percentage of reduced exposure for firms using purchase obligations. This is computed as the ratio of the difference in commodity price elasticity for PO firms and the non-PO counterfactual elasticity divided by counterfactual elasticity. Specifically, $\frac{-9.77-(-4.05)}{-9.77} * 100 = 58.57$. This number is also roughly in line with the estimates in Table 1.3.

Table 2.3: Model-implied commodity price elasticity

Non-PO Firms	PO Firms	PO Firms (counterfactual No PO)	Reduced Exposure (p.p.)	Reduced Exposure (%)
-6.76	-4.05	-9.77	5.72	58.57

Notes. The table reports the model-implied elasticity of profits to commodity prices. Coefficients are normalized to a 10% increase in commodity prices to compare with empirical results in Section 3.1.

The main takeaway of this section is that the model shows that firms can substantially reduce their exposure to commodity price risk by using purchase obligations.

Aggregate effects

In this section, I discuss the aggregate effects of hedging. I solve the model for two specifications. First, a benchmark model in which firms optimally set their PO, and second, a model in which firms are not allowed to use purchase obligations ($\kappa \to \infty$).

Table 2.4 reports the results. I show the percentage difference in the mean and standard deviation of aggregate variables between both models. The results show a positive effect on aggregate variables. Qualitatively, the results seem to suggest that risk-management policies have a positive impact on aggregate variables. For mean differences, both models yield approximately the same results, with a small positive difference for the PO model. Notice that the PO model yields a lower mean price level, but also a lower mean wage and real wage;

however the results are not too large. On the other hand, when firms can trade purchase obligations, the standard deviation of aggregate variables is smaller. Only the price level is slightly more volatile, but the volatility difference is limited. This suggests a substantial aggregate risk-exposure reduction.

Figures 2.6 shows the distribution of percentage differences across spot prices.[7] Firms can reduce interest expenses with the extra income from the forward operation. I see this in the profits figure. For low spot prices, firms reduce their income because there are financial losses associated with purchase obligations. For high spot prices, profits are larger in a world with purchase obligations precisely because of the additional financial income. Labor and output follow aggregate profits, because the representative consumer owns the firms. For prices, the response is smaller given that the interest rates change is smaller.

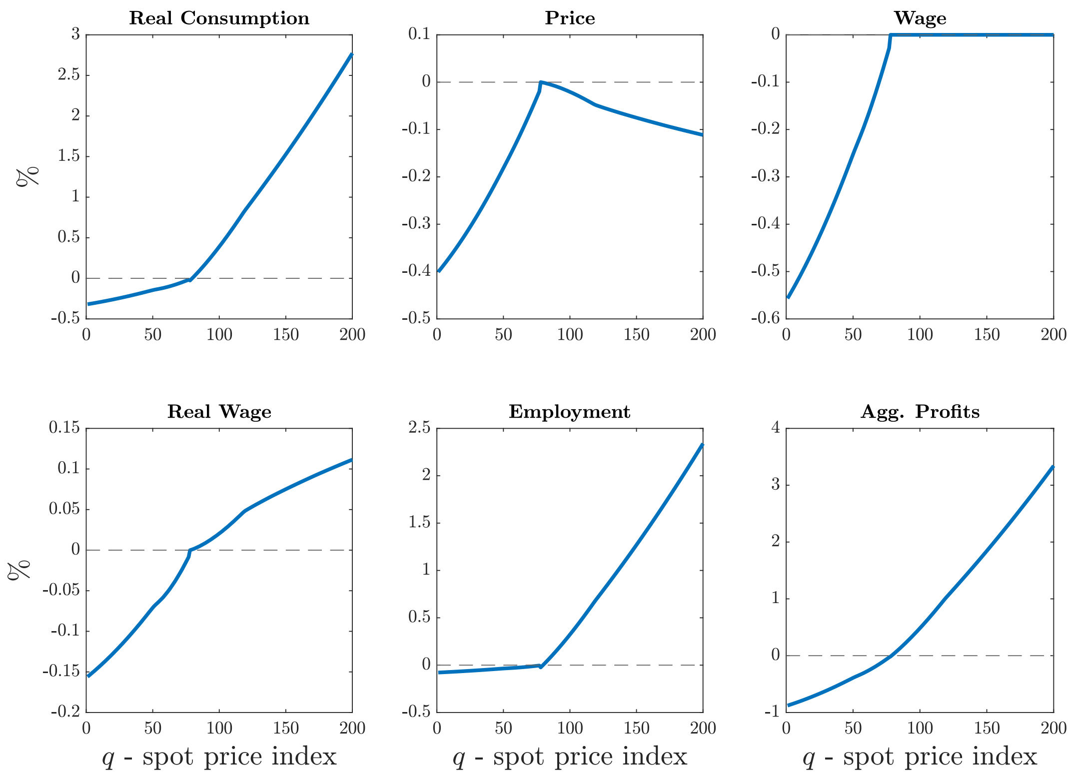
Table 2.4: Counterfactual Differences (%)

Variable	Mean	Std. Dev.
Real Consumption	0.081	-3.456
Employment	0.103	-4.392
Agg. Profits	0.035	-5.802
Price	-0.066	0.4667
Wage	-0.085	-4.204
Real Wage	-0.017	-1.295

Notes. The table shows differences in mean and standard deviation between the model with purchase obligations and the counterfactual in which firms are not allowed to trade these contracts. The second column computes the percentage difference between the std. dev. of the counterfactual and the benchmark.

[7] The simulations use a discrete vector of 200 spot prices.

Figure 2.6: Distribution of % differences



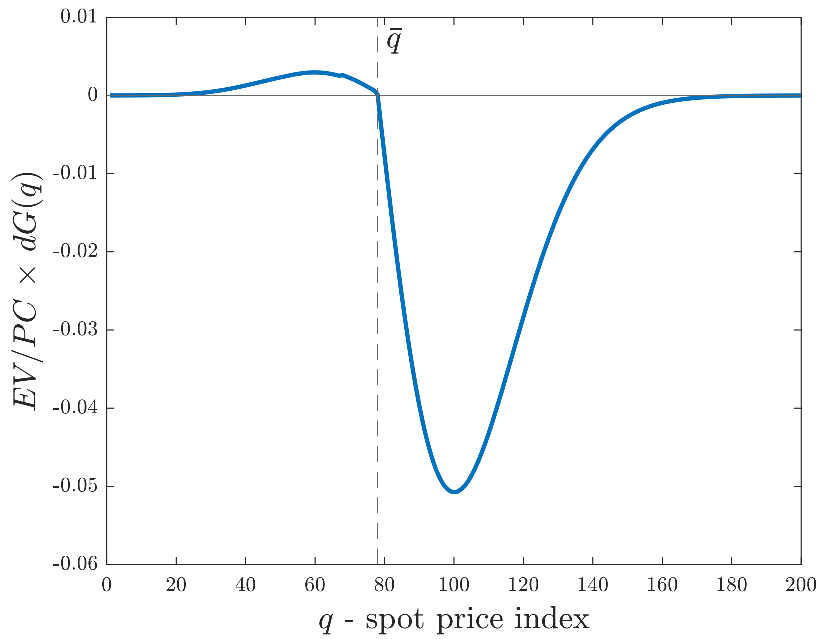
Notes. The figure shows the percentage difference between the calibrated model and the counterfactual in which firms are not allowed to trade purchase obligations for relevant aggregate variables.

Welfare implications

I compute the equivalent variation (EV) as a percentage of consumption the representative consumer is willing to sacrifice to allow firms to trade purchase obligations. The calibrated model predicts a 1.86% welfare gain. This shows that the use of purchase obligations can improve welfare by partially offsetting the negative consequences of input price shocks.

I plot the distribution of EV as a share of consumption in Figure 2.7. The figure also includes the probability distribution of spot prices to measure the relative weight under the mean. For reference, I plot the unweighted EV in Figure 2.15. For low spot prices (below $\bar{q}$), there

Figure 2.7: Distribution of Equivalent Variation



Notes. This figure shows the EV as a ratio of consumption weighted by the density of spot prices.

are financial losses associated with purchase obligations: hence the consumer is willing to receive extra income. For high spot prices (above $\bar{q}$), firms receive positive income from the forward and the consumer is better off. She values the welfare gains in this region and hence the EV is negative.

Table 2.5 shows the relative magnitudes. The model predicts that the income from the region $q > \bar{q}$ is predominant. This implies that overall, the consumer is willing to sacrifice 1.86% of her consumption to allow firms to trade purchase obligations.

Table 2.5: Equivalent Variation–% of Consumption

Region	$q < \bar{q}$	$q > \bar{q}$	Total
EV	0.103	-1.966	-1.863

Transmission of commodity price shocks

In this section I study the response of aggregate variables to commodity price shocks. I first show how aggregate variables react to commodity price shocks in Figure 2.8. Commodity price shocks negatively affect the economy by raising the cost of the material inputs needed for production. Also, since face firms face financial constraints, these shocks increase the share of financially constrained firms. This generates adverse conditions for firms and, in turn, enlarges the consequences of commodity price shocks. For instance, a 10% commodity price shock reduces employment and real consumption by 7% and 10%, respectively.

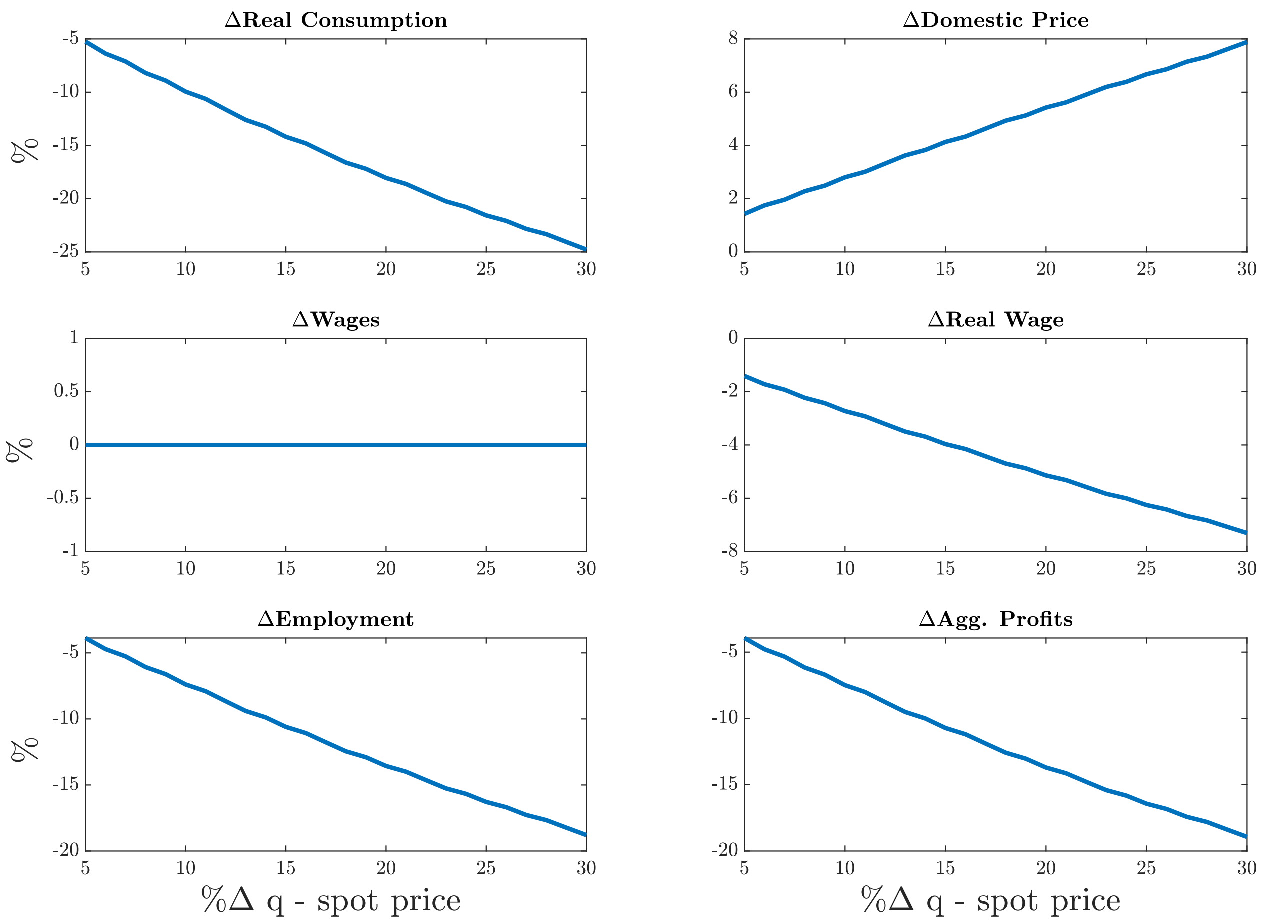
Next, I compare the transmission in the calibrated model with purchase obligations with the counterfactual in which firms are not allowed to engage in these contracts. I compute the percentage change in each aggregate variable for difference percentage changes in spot prices. I repeat this calculation for the two model and plot the relative percentage change in Figure 2.9. I also report the p.p. difference in Figure 2.16. For illustration, Table 2.6 shows the results for a 10% increase in commodity prices.

Table 2.6: Agg. Elasticity

Agg. Variable	%Δ (No PO)	%Δ (PO)	p.p diff.	% diff.
Consumption	-10.37	-9.95	0.43	4.3
Employment	-7.76	-7.39	0.36	4.9

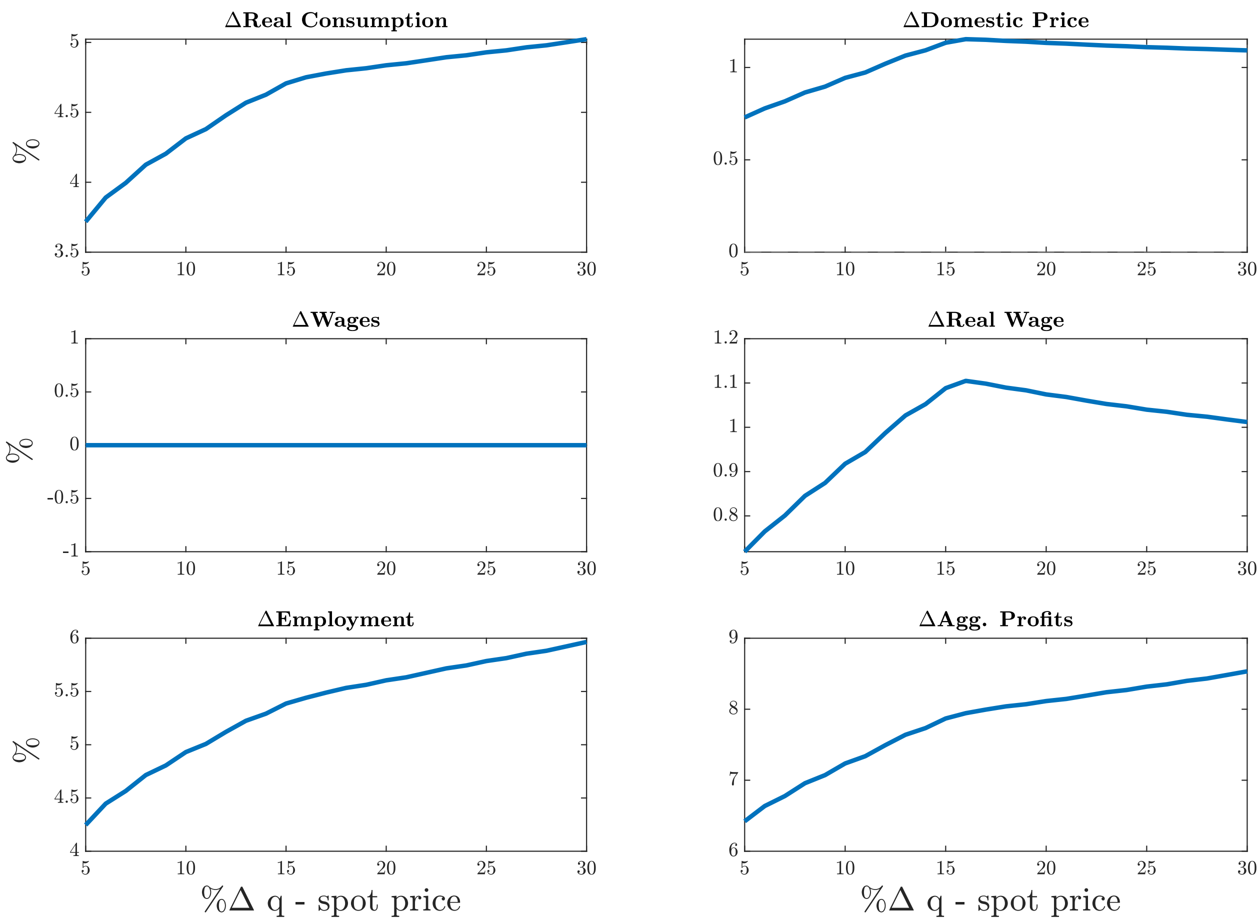
Firms are less sensitive to changes in commodity prices when they can trade purchase obligations, as I have seen in previous sections. This smaller response at the firm level is translated into the aggregate economy due to extra income from the forward operation. Quantitatively, I find a positive aggregate contribution of purchase obligations to dampening the transmission of commodity price shocks. For instance, aggregate real consumption reacts 4.32% less in the model with purchase obligations when the spot price increases by 10%.

Figure 2.8: Transmission–Commodity Price Shock



Notes. This figure shows the transmission of commodity price shocks when firms can trade purchase obligations. The x-axis shows the percentage change in spot price. The y-axis shows the percentage change of each aggregate variable compared with the benchmark economy (calibrated to match stylized facts for the U.S. in 2012)

Figure 2.9: Relative Transmission–Commodity Price Shock, % difference

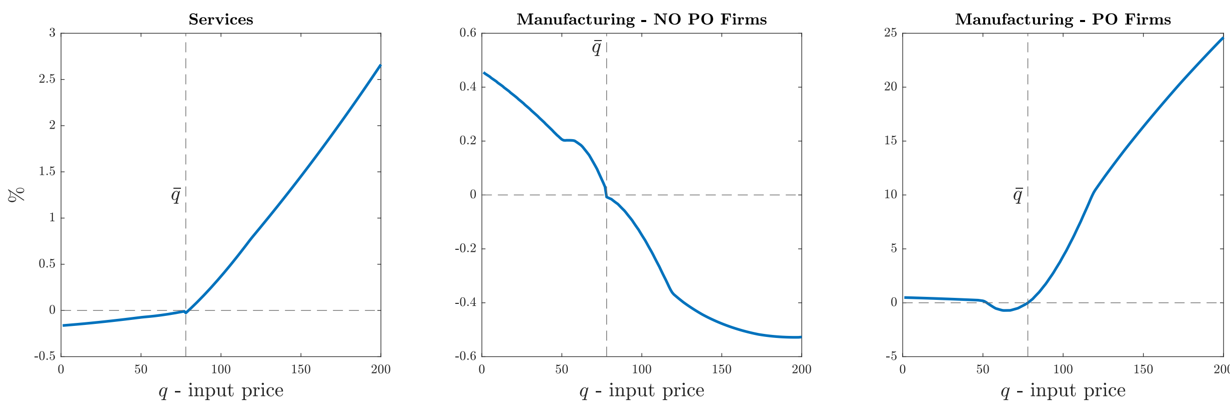


Notes. This figure shows the relative transmission of commodity price shocks. The x-axis shows the percentage change in spot prices. The y-axis shows the percentage difference between the response of each aggregate variable to a change in the spot price in the two models (PO vs non-PO).

Unpacking the mechanism

In this section I explore quantitative the mechanism behind why purchase obligations can dampen the transmission of commodity price shocks. First, there are strong reallocation effects across firms. Firms in the service sector benefit because the income effect from purchase obligations increases demand of all goods. This logic also applies to the manufacturing sector. However, relative prices between PO and non-PO firms change implying that only PO firms reap the aggregate benefits.

Figure 2.10: Employment changes



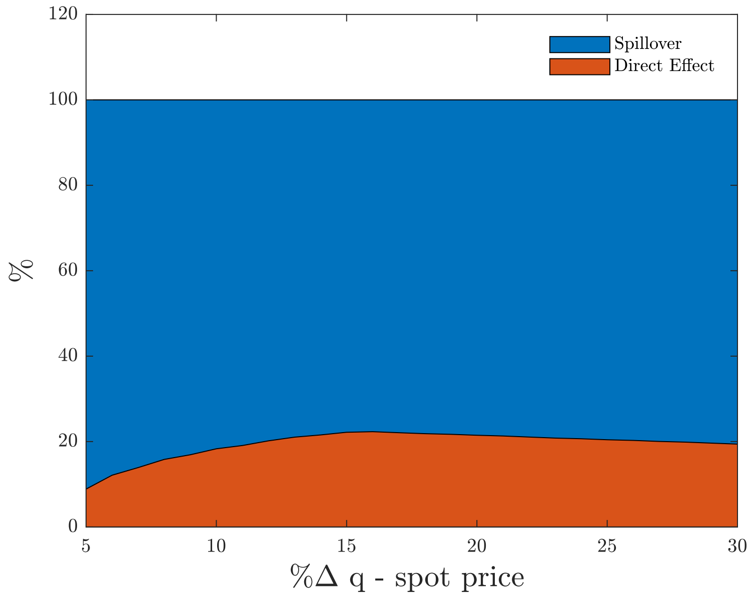
Notes. This figure shows the percentage difference in employment across firm groups between the calibrated economy and the counterfactual without purchase obligations. For each firm group I compute the average within firms.

Figure 2.10 shows the employment difference between the calibrated model and the counterfactual without purchase obligations for each spot price. Each subplot shows difference subsets of firms: services, manufacturing engaging in PO and manufacturing non-PO. Several facts are worth mentioning. First, firms in the services sector benefit from purchase obligations when the income effect is positive i.e. $q > \bar{q}$. All firms within services benefit homogeneously because I assume there is no heterogeneity within services. Second, the employment change in firms in the manufacturing sector follows inversely the PO income: they shrink in size when the hedge turns out to be profitable. Briefly, these firms see their relative prices increase compared to PO firms and hence their sales become lower. Third, PO firms are the ones that benefit the most from trading purchase obligations. These firms are between 5 to 25 percent larger when $q > \bar{q}$ compared to the counterfactual. For situations where the forward operation delivers negative income ($q < \bar{q}$), these firms become smaller. Nevertheless, there is a set of low spot prices where even with negative income from POs, these firms are larger than in the counterfactual. This is due to the fact that they become unconstrained and can keep their prices lower than their non-PO competitors.

In second place, the transmission results from the previous sections can be decomposed into two channels: (i) a direct effect coming from the income change from purchase obligations and (ii) general equilibrium effects from this additional income. In Figure 2.11 I plot the decomposition for different commodity price shocks.

In a nutshell, when firms trade purchase obligations they receive additional financial income from the forward operation. This extra income is consumed by households. The direct effect only accounts for the transmission differential in consumption only taking this effect into account. On the other hand, the consumer will increase expenditures from all firms. This in fact increases production and income further more. In general equilibrium, the existence of this income effect generates addicional effects. For instance, after a 10% in commodity prices, my results show that 18% of the transmission difference is due to the income effect. The general equilibrium effects account for the remaining share.

Figure 2.11: Transmission Decomposition



Notes. This figure shows the decompossiion of the transmisison difference between the model with PO and the counterfactual without PO. For each change in commodity price shocks studied in Fig: 2.16 I split the effects between the direct effect and the genearl equilibirum spillover.

4. Conclusion

In this Chapter I study the aggregate implications of risk-management policies. In particular, I leverage a novel dataset on supply contracts with fixed prices for public companies in the manufacturing sector in the United States. Firms rely on these tools to reduce their exposure to input price risk. I find a substantial decrease in exposure to input price changes for firms using these contracts. Also, I develop a general equilibrium model that features purchase obligations to show how firm risk-management policies can insure the economy against input price shocks and increase welfare.

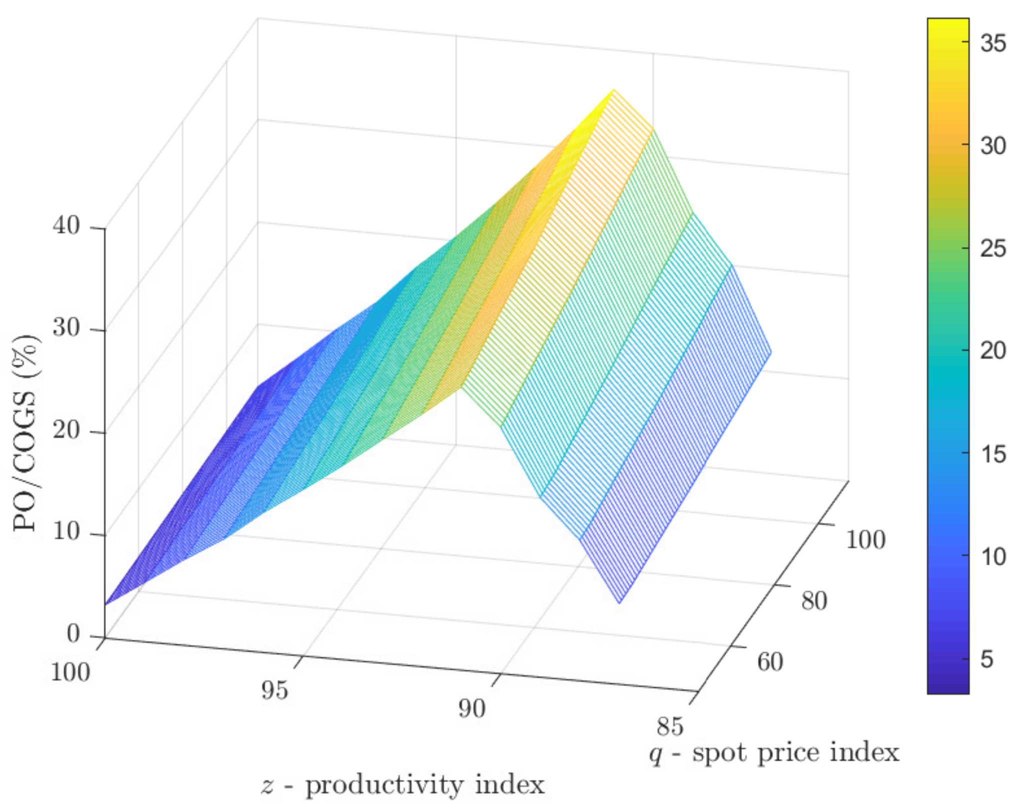
These results suggest that governments and central banks should pay close attention to the risk-management strategies used by corporations. These provide strong exposure reduction at the firm level, which can be transmitted to the aggregate economy. Consumers can reap the benefits of these policies by facing a lower volatility of consumption and employment.

Moreover, the results have suggest several policy implications. Central Banks have been actively managing interest rates to control inflation due to surges in commodity prices. This study suggests that although short-run interest rates could control inflation, Central Banks should take risk-management policies into account because the recession induced could be lower. Hence, the trade-off between controlling inflation and economic activity could be improved, since the financial market can help overcome the negative consequences of these shocks. On the other hand, my results also suggest that these instruments could be under-supplied in equilibrium. For instance,only a small measure of firms in the model and the data engage in purchase obligations, although the benefits seem to be large. This suggests that there might be room for policy interventions to reduce participation costs: for example, regulatory costs.

5. Appendix

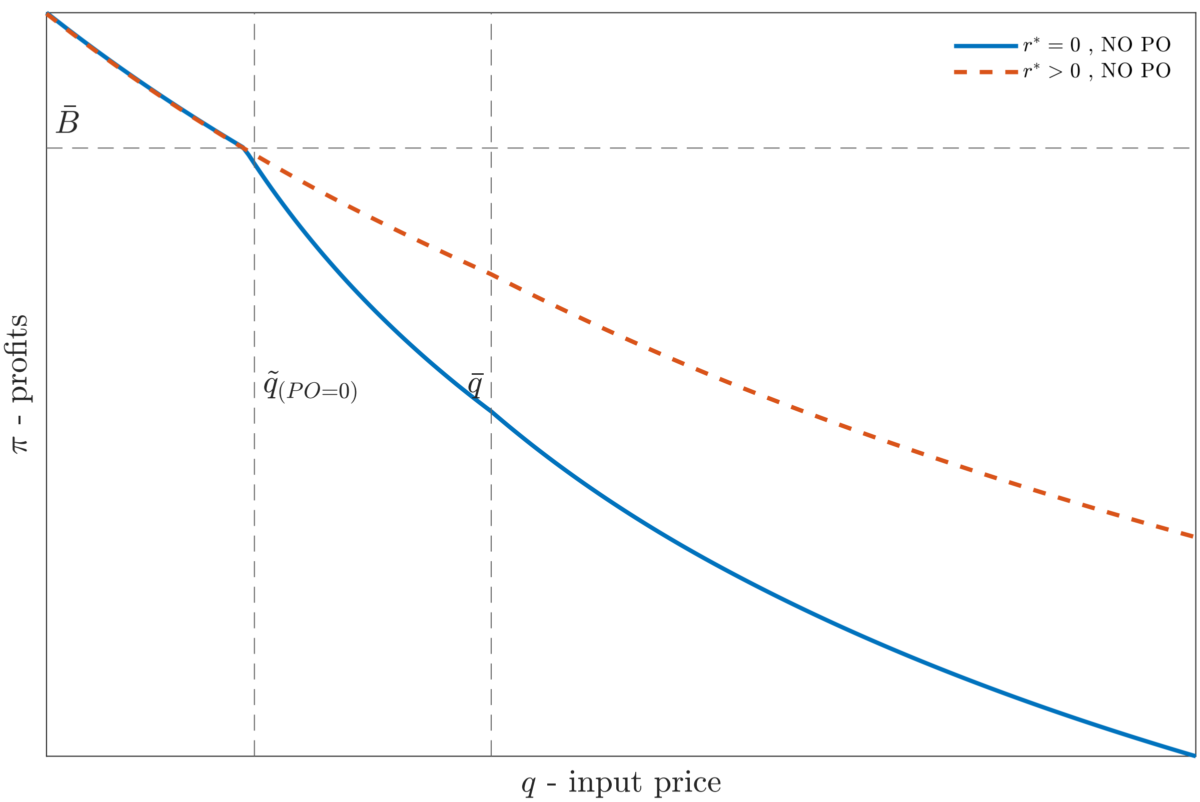
5.1 Additional Figures

Figure 2.12: Model-implied PO/COGS



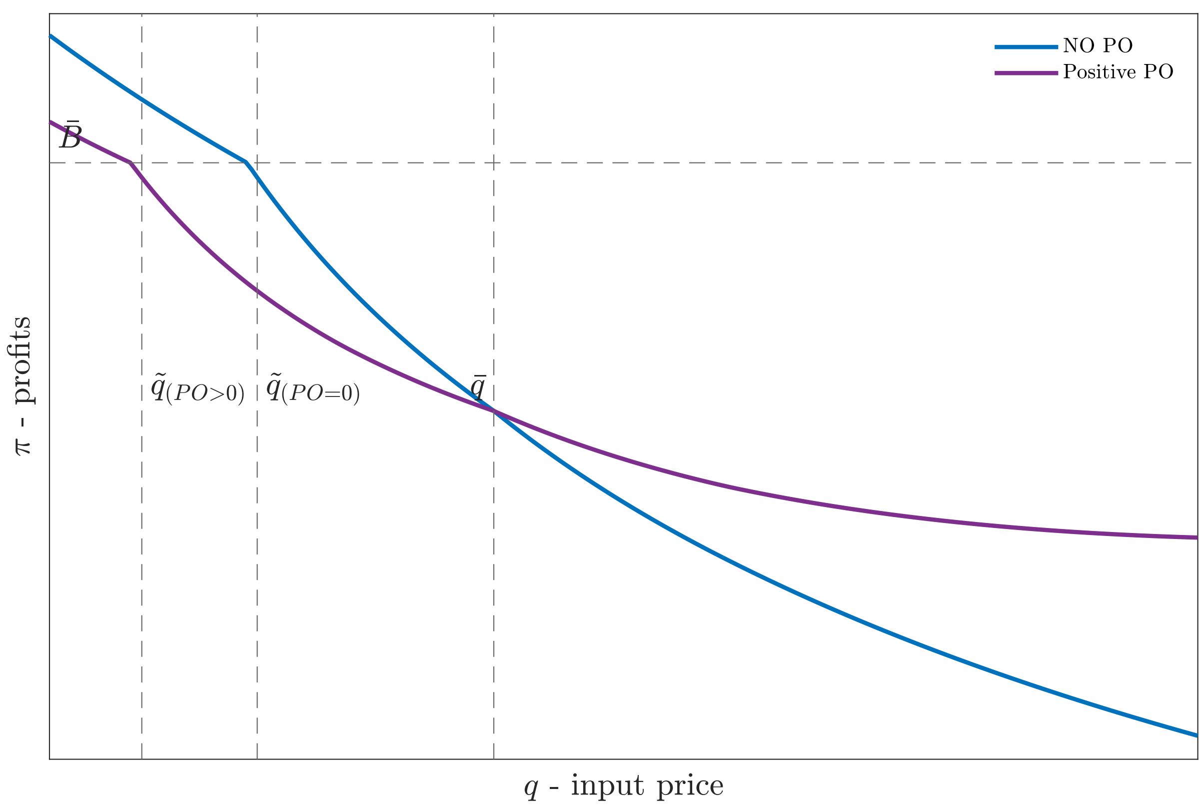
Notes. This figure reports the ratio of purchase obligations value to total cost in the quantitative exercise for different productivities and spot prices.

Figure 2.13: Firm's Profits–Zero Purchase Obligations, Small Firm



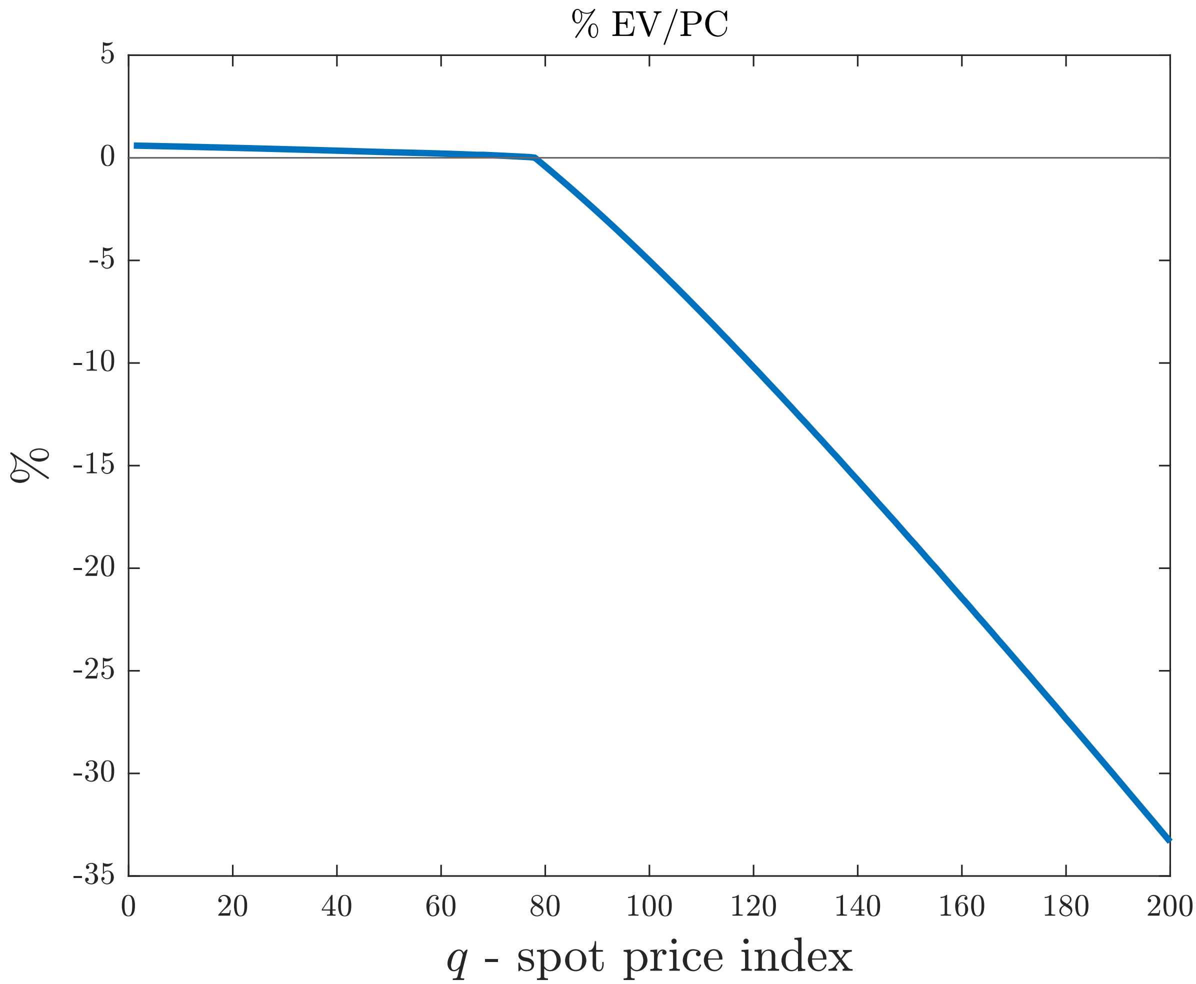
Notes. The figure shows profits π as a function of spot prices q (for a small firm) and highlights the difference between profits when firms face financial constraints (the difference between dashed orange line and solid blue). I removed index i, m for exposition.

Figure 2.14: Firm's Profits–Adding Purchase Obligations, Small Firm



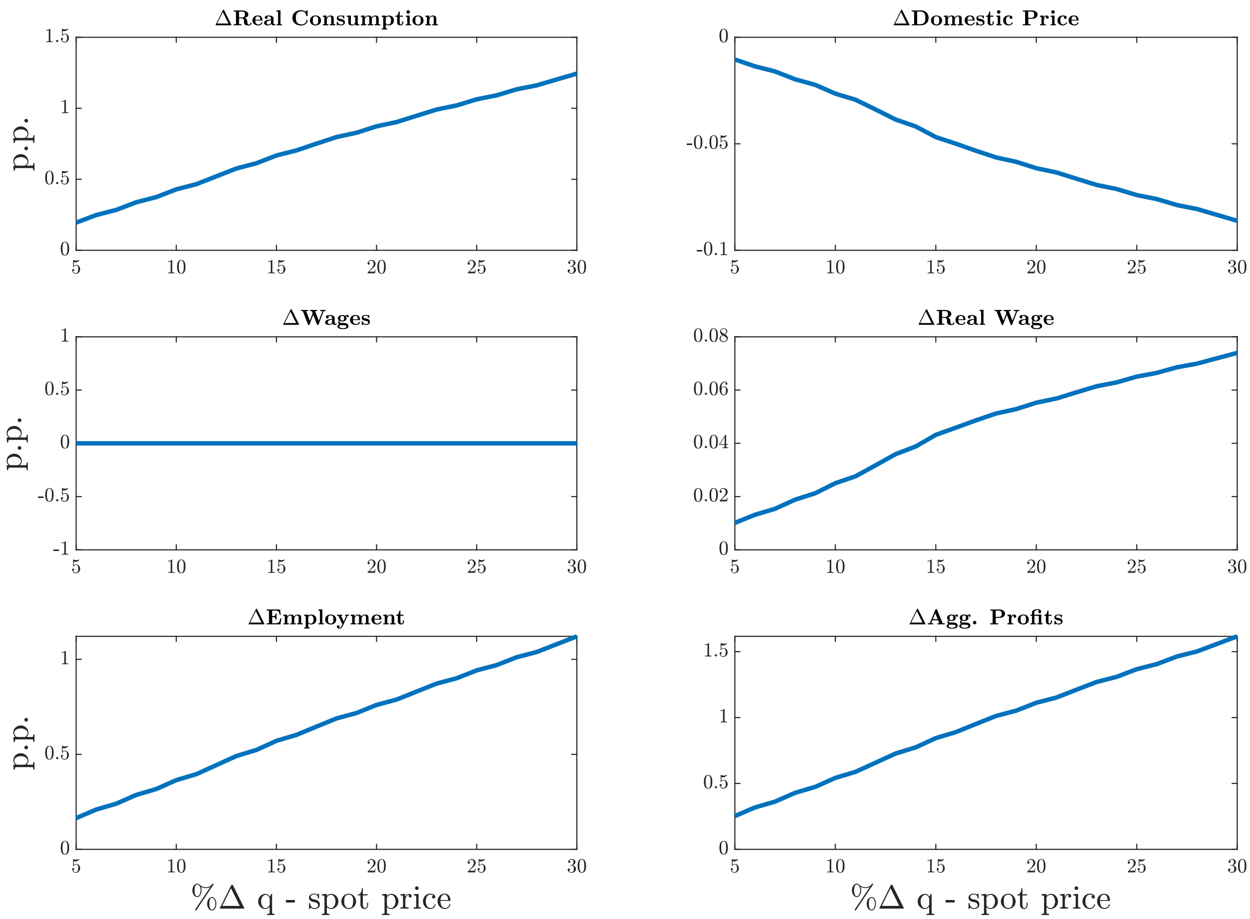
Notes. The figure shows the relationship between profits π and spot prices q for a small firm. Using purchase obligations increases the financial costs arising from financial constraints. I removed index i, m for exposition.

Figure 2.15: Distribution of Equivalent Variation–No Weights



Notes. This figure shows the EV as a ratio of consumption for each spot price.

Figure 2.16: Relative Transmission–Commodity Price Shock, p.p. difference



Notes. This figure reports the p.p. difference in transmission between the model with purchase obligation and the counterfactual in which firms are not allowed to trade these contracts.

5.2 Solution Algorithm - Second Stage

In this appendix, I explain the algorithm used to solve for the equilibrium in the second stage.

Flexible wage

I allow the economy to have flexible wages for $q \leq \bar{q}$. The steps below describe the algorithm used to solve the second stage conditional on $(q, \bar{m}_i^m, \bar{m}_{-i}^m)$.

1. Guess w, P^m, Y^m, Y^s

2. Solve for price index in services:

$$P^s = \frac{\sigma^s}{\sigma^s - 1} \left(\frac{q}{\gamma^s}\right)^{\gamma^s} \left(\frac{w}{1-\gamma^s}\right)^{1-\gamma^s} \frac{1}{Z^s}$$

3. Economy-wide price index is

$$P = \left(\frac{P^m}{\alpha}\right)^{\alpha} \left(\frac{P^s}{1-\alpha}\right)^{1-\alpha}$$

4. Solve for firm profits in manufacturing and interest rates ($\forall\ i$):

$$\pi_i^m = \left(\frac{\sigma^m - 1}{\sigma^m}\right)^{\sigma^m} \frac{1}{\sigma^m - 1}(z_i^m)^{\sigma^m - 1}\left(\frac{q}{\gamma^m}\right)^{\gamma^m}\left(\frac{w}{1-\gamma^m}\right)^{1-\gamma^m}(1+r_i^*)^{1-\sigma^m}(P^m)^{\sigma^m} Y^m$$
$$+ \bar{m}_i^m[q - \bar{q}]$$
$$1 + r_i^* = \max\{e^{-\iota(\pi_i^m - \bar{B})}, 1\}$$

5. For firms in the service sector:

$$\pi^s = \left(\frac{\sigma^s - 1}{\sigma^s}\right)^{\sigma^s} \frac{1}{\sigma^s - 1}(Z^s)^{\sigma^s - 1}\left(\frac{q}{\gamma^s}\right)^{\gamma^s}\left(\frac{w}{1-\gamma^s}\right)^{1-\gamma^s}(P^s)^{\sigma^s} Y^s$$

6. Compute aggregate profits as: $\Pi = \int \pi_i^m dH_m + \pi^s$

7. Compute total factor productivities

$$(Z_1^m)^{\sigma^m-1} = \int_i \left(\frac{z_i^m}{1+r_i^*}\right)^{\sigma^m-1} dH^m \quad (Z_2^m)^{\sigma^m-1} = \int_i \left(\frac{z_i^m}{1+r_i^*}\right)^{\sigma^m-1} (1+r_i^*)dH^m$$

8. For wages, use the price index definition for the manufacturing sector

$$w = \left(\frac{\sigma^m - 1}{\sigma^m}\right)^{\frac{1}{1-\gamma^m}} \left(\frac{q}{\gamma^m}\right)^{-\frac{\gamma^m}{1-\gamma^m}} (Z_1^m)^{\frac{1}{1-\gamma^m}}(1-\gamma^m)(P^m)^{\frac{1}{1-\gamma^m}}$$

9. Labor supply: $L^s = \left(\frac{w}{P\xi}\right)^{\frac{1}{\eta}}$

10. For output Y^m, use $L^d = L^s$, where:

$$L^d = \left(\frac{\sigma^m - 1}{\sigma^m}\right)^{\sigma^m} \left(\frac{q}{\gamma^m}\right)^{\gamma^m(1-\sigma^m)} \left(\frac{w}{1-\gamma^m}\right)^{(1-\gamma^m)(1-\sigma^m)} (P^m)^{\sigma} Y^m \frac{1-\gamma^m}{w} (Z_2^m)^{\sigma^m - 1} +$$
$$\left(\frac{\sigma^s - 1}{\sigma^s}\right)^{\sigma^s} \left(\frac{q}{\gamma^s}\right)^{\gamma^s(1-\sigma^s)} \left(\frac{w}{1-\gamma^s}\right)^{(1-\gamma^s)(1-\sigma^s)} (P^s)^{\sigma^s} Y^s \frac{1-\gamma^s}{w} (Z^s)^{\sigma^s - 1}$$

11. Solving for consumption:

$$C = \frac{wL^d + \Pi - \kappa^A}{P}$$
$$C^m = \alpha \frac{PC}{P^m}$$
$$C^s = (1-\alpha)\frac{PC}{P^s}$$

where $\kappa^A \equiv \int \kappa(\bar{m}_i^m) dH^m$

12. For P^m, use market clearing for the home tradeable good:

$$Y^m = C^m + (P^m)^{-\nu}(P^*)^{\nu}\zeta Y^*$$

13. For Y^s use equilibirum in non-tradeables $Y^s = C^s$

14. Iterate over equations for w, Y^m, P^m and Y^s

Fixed wage

For $q > \bar{q}$, I include downward nominal wage rigidities that imply $w = \bar{w}$, where $\bar{w} = w(\mathbb{E}_q[q])$. The steps below describe the algorithm used to solve the second stage conditional on $(q, \bar{m}_i^m, \bar{m}_{-i}^m)$.

1. Guess u, P^m, Y^m, Y^s

2. Solve for the price index in services:

$$P^s = \frac{\sigma^s}{\sigma^s - 1}\left(\frac{q}{\gamma^s}\right)^{\gamma^s}\left(\frac{\bar{w}}{1-\gamma^s}\right)^{1-\gamma^s}\frac{1}{Z^s}$$

3. Economy-wide price index is

$$P = \left(\frac{P^m}{\alpha}\right)^{\alpha}\left(\frac{P^s}{1-\alpha}\right)^{1-\alpha}$$

4. Solve for firm profits in manufacturing and interest rates ($\forall\ i$):

$$\begin{aligned}\pi_i^m = &\left(\frac{\sigma^m - 1}{\sigma^m}\right)^{\sigma^m}\frac{1}{\sigma^m - 1}(z_i^m)^{\sigma^m - 1}\left(\frac{q}{\gamma^m}\right)^{\gamma^m}\left(\frac{\bar{w}}{1-\gamma^m}\right)^{1-\gamma^m}(1+r_i^*)^{1-\sigma^m}(P^m)^{\sigma^m}Y^m \\ &+ \bar{m}_i^m[q - \bar{q}] \\ 1 + r_i^* &= \max\{e^{-\iota(\pi_i^m - \bar{B})}, 1\}\end{aligned}$$

5. For firms in the service sector:

$$\pi^s = \left(\frac{\sigma^s - 1}{\sigma^s}\right)^{\sigma^s}\frac{1}{\sigma^s - 1}(Z^s)^{\sigma^s - 1}\left(\frac{q}{\gamma^s}\right)^{\gamma^s}\left(\frac{\bar{w}}{1-\gamma^s}\right)^{1-\gamma^s}(P^s)^{\sigma^s}Y^s$$

6. Compute aggregate profits as: $\Pi = \int \pi_i^m dH_m + \pi^s$

7. Compute total factor productivities

$$(Z_1^m)^{\sigma^m-1} = \int_i \left(\frac{z_i^m}{1+r_i^*}\right)^{\sigma^m-1} dH^m \quad (Z_2^m)^{\sigma^m-1} = \int_i \left(\frac{z_i^m}{1+r_i^*}\right)^{\sigma^m-1} (1+r_i^*)dH^m$$

8. Labor supply: $L^s = \left(\frac{\bar{w}}{P\xi}\right)^{\frac{1}{\eta}}$

9. For output Y^m, use $L^s = L^d + u$, where:

$$L^d = \left(\frac{\sigma^m-1}{\sigma^m}\right)^{\sigma^m} \left(\frac{q}{\gamma^m}\right)^{\gamma^m(1-\sigma^m)} \left(\frac{\bar{w}}{1-\gamma^m}\right)^{(1-\gamma^m)(1-\sigma^m)} (P^m)^{\sigma} Y^m \frac{1-\gamma^m}{\bar{w}} (Z_2^m)^{\sigma^m-1} + \left(\frac{\sigma^s-1}{\sigma^s}\right)^{\sigma^s} \left(\frac{q}{\gamma^s}\right)^{\gamma^s(1-\sigma^s)} \left(\frac{\bar{w}}{1-\gamma^s}\right)^{(1-\gamma^s)(1-\sigma^s)} (P^s)^{\sigma^s} Y^s \frac{1-\gamma^s}{\bar{w}} (Z^s)^{\sigma^s-1}$$

10. For P^m, use:

$$P^m = \frac{\sigma^m}{\sigma^m-1} \left(\frac{q}{\gamma^m}\right)^{\gamma^m} \left(\frac{\bar{w}}{1-\gamma^m}\right)^{1-\gamma^m} \frac{1}{Z_1}$$

11. Solving for consumption:

$$C = \frac{wL^d + \Pi - \kappa^A}{P}$$
$$C^m = \alpha \frac{PC}{P^m}$$
$$C^s = (1-\alpha)\frac{PC}{P^s}$$

where $\kappa^A \equiv \int \kappa(\bar{m}_i^m) dH^m$

12. For unemployment u, use:

$$Y^m = C^m + (P^m)^{-\nu} (P^*)^{\nu} \zeta Y^*$$

13. For Y^s, use equilibirum in non-tradeables $Y^s = C^s$

14. Iterate over equations for Y^m, P^m, u and Y^s

5.3 Solution Algorithm–First Stage

In this appendix, I explain the algorithm used to solve for the equilibrium in the first stage. In summary, I choose purchase obligation quantities using an iterated method.

1. Solve equilibrium in second stage assuming $\bar{m}_i^m = 0$ for all firms. This pins down $A^m(q, 0, 0)$.

2. Solve for $\bar{m}_i^m$ using equations (2.16) and (2.17) for $A^m(q, 0, 0)$.

3. Update second stage using new PO quantities $\bar{m}_i^m$. In particular, find $A^m(q, \bar{m}_i^m, \bar{m}_{-i}^m)$

4. Repeat stages 2 and 4 until the PO quantity vector converges.

Chapter 3

New Keynesian Open Economics

1. Introduction

Over the last decades we have seen interesting progress in the New Keynesian Economics. Under nominal rigidities, aggregate shocks can have real effects in output and consumption. Moreover, heterogeneity plays an important role in the transmission of aggregate shocks and policies. In this Chapter I survey recent papers and provide a styled example of a standard NK model. This Chapter builds on Galí and Monacelli (2005) and studies the effect of two policy changes: a nominal exchange depreciation and a wealth transfer across households. For the first policy, as firms face nominal rigidities to adjust their prices, the depreciation increases domestic output through exports. Local consumers benefit from this gains. For the second shock, the wealth transfer reduces incentives to work of the beneficiaries of the transfer and firms have to scale down production.

The rest of the Chapter is organized as follows. Section 2 reviews recent literature in New Keynesian Economics. I will follow previous reviews by Lane (2001), Sarno (2001) and Galí (2018). Section 3 describes the model. In Section 4, I explain the effects of the policy changes and the role of heterogeneity in the model. Section 5 concludes.

2. Related Literature

2.1 Exchange Rate Dynamics Redux

Obstfeld and Rogoff (1995) [OR] is considered the paper that started this new literature. The authors note the inadequacy of the standard Mundell-Fleming model to address correctly the effects of monetary policy. Their argument has a Lucas Critique flavor: consumer and firm behavior is not derived from the model and could not remain constant after the policy. Therefore they create a general equilibrium model to study the effects on monetary shocks to real variables.

They work with a two-country model, each populated by a representative farmer-consumer choosing consumption, varieties supply and money demand. The final consumption bundle is constructed using a CES aggregator over said varieties, with the same elasticity for domestic and foreign commodities. These agents will have CRRA preferences over the final good consumption, money holdings and labor used to produce varieties. Moreover, these differentiated goods will be sold in a monopolistic competition fashion. Also, they will ordered according to its labor requirements and therefore each country will produce and export a fraction of the variety set, similar to Dornbusch et al. (1977). No trade costs will be considered in their analysis, therefore the law of one price will hold for each good and the real exchange will be constant. Agents will be infinitely lived and will have a access to a international risk-free real bond to smooth consumption over time. Each farmer will set one period in advance its prices, creating a nominal rigidity in price setting. The authors close the model by introducing a government in each country with no real expenditures that only prints money and transfers this income to agents.

Their objective is to study the effect of an unanticipated permanent increase in the monetary supply in the domestic country. To do so, they compute the stationary equilibrium and solve for a log-linear approximation around said equilibrium. The total effect will be composed by an impact effect and a long-run effect. Their results show that domestic output and consumption will increase. Current account will show a surplus due to an increase in exports (nominal depreciation after the monetary expansion). On the other hand, foreign consumption will also rise given by a decline in the world's interest rate and the fact that the domestic varieties became cheaper. The effect in foreign output will be indeterminate because of the opposing effects that relative prices and consumption have on labor.

Due to the existence of nominal rigidities, the long run equilibrium displays non-neutrality of money. Sticky prices will allow the domestic country to accumulate foreign assets (current account surplus) that will permanently improve consumption in the steady state due to the income coming from this assets. Moreover, this wealth effect reduces home labor and output improving terms of trade (permanent). In terms of welfare, the expansionary monetary supply can reduce the inefficiency produced from the monopolistic competition.

2.2 Extensions

Pricing

The assumption on price rigidities has also been extended departing from one-step-ahead pricing. In particular, many papers follow Calvo (1983) assuming that firms are able to adjust prices with certain probability and therefore will set prices for all future periods, taking into account this constraint. This realizations will be independent across firms implying that a fixed fraction of firms adjusts its prices every period.

Consumption Bundle

Warnock (2003) includes home bias to the previous model assuming domestic varieties have a bigger weight in the domestic final bundle. This assumption will boost the domestic effect on consumption and output coming from a permanent expansionary monetary shock. Moreover, the welfare effects will be greater for the domestic country.

An interesting simplification of OR is analyzed in Corsetti and Pesenti (2001). The authors include a Cobb-Douglas aggregator in consumption of domestic and foreign goods to solve the model in closed form. This assumption implies that total expenditures on local and foreign goods are constant. As a consequence, economies will keep their current account balance and the long-run effect in OR (asset accumulation) will will not be present under this setting. The authors find that a monetary expansion in the domestic country could help increase output by reducing the inefficiency from the monopolistic competition but also will have a negative impact due to a reduction in the terms of trade. The key assumption will be that the home country will not accumulate foreign assets due to the Cobb-Douglas specification in consumption. Adding physical capital could reincorporate OR's long-run prediction.

In line with this argument, Tille (2001) builds a model featuring different elasticities of substitution for varieties within and across countries. In Corsetti and Pesenti (2001) the monetary expansion might hurt the local economy through terms of trade, however it can be beneficial to the home country when there is more substitutability across than within (beggar-thy-neighbor).

Capital Accumulation

Chari et al. (2002) develop a general equilibrium model featuring sticky prices and capital accumulation (in the spirit of OR) to explain the persistence and volatility of real exchange rates. A key addition is to include capital accumulation to match the volatility of consumption and output. They can match the volatility but their persistence is not quite high enough. These properties of the exchange rates can be explained by monetary shocks, but the model must also include separable preferences in leisure, high risk aversion and price stickiness. The model falls short in addressing the consumption-real exchange anomaly. The correlation between real exchange rates and relative consumption is higher than in the data. Complete asset markets might be the assumption generating this puzzle. The authors unsuccessfully solve this issue by adding incomplete markets using uncontingent bonds and habit persistence in consumption.

Pricing to Market

Betts and Devereux (2000) and Betts and Devereux (2001) also document the role of the currency of invoicing of exports in the international transmission of monetary shocks. Specifically, they find that the propagation of monetary shocks has different properties when the exports are priced in the purchasing market's currency. If the invoice is set in the domestic currency, a monetary expansion depreciates the currency and worsen the terms of trade, improving exports. The foreign country will replace production with imports, reducing its output. However, if the invoice is set in the foreign currency, the nominal depreciation improves the terms of trade and both countries experience an output increase.

2.3 Heterogeneity in Consumers

The Great Recession showed that the current macroeconomic models had several issues regarding the transmission of shocks . In particular a financial block was missing. Therefore, a new literature emerged, trying to apply the lessons of the past crisis. One of the main assumptions that was criticized was the representative agent. In this case, financial frictions might have deep consequences in the way agents react to shocks. In general, this new literature assumes uninsured idiosyncratic shocks[1], incomplete markets and borrowing constraints. This will generate a time-varying heterogeneity on marginal propensity to consume

[1] Mainly to labor income

out of shocks. Several papers addressed this issues.

For the general representative agent framework monetary shocks can improve output through substitution effect (real interest rate effect) and aggregate income (multiplier effect). Auclert (2019) shows that three additional channels can play a role in the transmission of monetary shocks. In general, the monetary policy will generate a redistribution of income because agent will have different exposures to the shock. Firstly, the earnings heterogeneity imply different income effects across the population. Secondly, the Fisher channel relates to the revaluation of nominal assets due to inflation. Lastly, as agents will have different exposure to the interest rate changes coming from their asset portfolio decision (mismatch between maturity of assets and liabilities). The aggregate effect on output will be correlated with the effect that each of these channels have on marginal propensities to consume. In particular, the expansion will be greater if those channels are highly correlated with consumption. This follows closely the standard Keynesian argument that a redistribution of income towards high MPC consumers will increase output.

Kaplan et al. (2018) continues the study of market incompleteness under a heterogeneous agent framework. The authors allow agents to invest in a liquid (bonds) and an illiquid asset (capital). This endogenously divides the population in two groups: hand-to-mouth and optimizers. The first group consists of agents that posses almost no liquid assets and therefore will have a high marginal propensity to consume out of transitory income shocks. The other group will have a stronger reaction coming from the intertemporal channel (changes in interest rate) and hence a lower MPC.

Following these lines, the authors are able to divide the total effect on consumption coming from monetary expansions into a direct effect and an indirect effect. Only optimizers will increase consumption after the interest rate cut (direct effect). However, the general equilibrium effect (indirect effect) coming from an increase in income will have a strong effect on consumption coming from hand-to-mouth agents.

It is important to note that the Ricardian Equivalence will fail to hold under these assumptions, hence it is of vital importance for aggregate output how the governments uses its income effect after the monetary expansion. Moreover, the indirect effect will be stronger in this setting, compared to the representative agent case. The authors conclude that the Federal Authority and the Government must coordinate their policies to take advantage of these effects on output and consumption.

Another set of papers capture the essence of the last papers but reduce the level of heterogeneity to keep the model tractable. Papers such as Galí et al. (2007) and Galí and Monacelli (2005) extend the RANK[2] model by assuming dividing the population into two groups, optimizers and a hand-to-mouth (with constant fractions). This model capture the essential components of the general HANK[3] model but fail to micro-found the reasons behind the heterogeneity in MPC. In particular, the model does not take into account the fact that consumer's present decisions might be conditional on being constraint in the future.

An interesting model is studied in Galí and Monacelli (2005). Following OR, they propose a two-country model without capital and featuring sticky prices and imperfect competition to analyze the propagation of monetary shocks. Specifically, they show the effects of technology shocks under three different monetary regimes: domestic inflation and CPI-based Taylor rule, and exchange rate peg. They rank these three policies in terms of terms of trade volatility they have after a technology shock and construct a welfare score based on the houshold's preferences to determine the relative success of each policy in terms of welfare effects. The domestic inflation Taylor rule seems to dominate the others because if offers the greater terms of trade volatility and therefore the lower volatility in inflation and output gap, hence higher welfare score.

[2]Representative Agent New Keynesian
[3]Heterogeneous Agent New Keynesian

A more recent paper by Debortoli and Galí (2018) tries to connect the more rich HANK literature review above and the tractability offered by the TANK[4] model. Their main finding is that a TANK model can reasonably approximate the effects of aggregate shocks on aggregate variables of a more complex HANK model, with out loosing tractability. However, questions about heterogeneity are harder to answer in this context than in a richer HANK model (wealth distribution for example).

HANK in Open Economy

Recent applications of these HANK models extend the results to open economy. Cugat (2019) uses Mexico's 1995 crisis as a natural experiment to study the propagation of foreign shocks in an economy with heterogeneous agents and nominal rigidities. All previous papers modeled the heterogeneity in terms of the degree of financial liquidity agents can hold. However, this paper adds a natural heterogeneity margin. Agents not only can access the international bond market or not, but they can receive labor income from a traded or a non-traded sector. The first section of the article documents this facts to later introduce a small open economy economy model to study the effect of foreign-driven crisis events. The model is an extension of Galí and Monacelli (2005) with the extended heterogeneity mentioned. The author finds that the effects of a "crisis shock" are amplified due to this heterogeneity: output and consumption are more responsive than in the representative agent case. This foreign shock is modeled as an increase in the interest rate, interpreted as a sudden stop in capital inflows, combined with an productivity shock in the tradeable sector.

The propagation channel works as follows. As some portion of the workers in the tradeable sector can not access the international bond market, they do not react to the interest rate change. Nevertheless, the productivity shock has a stronger impact in this fraction of the population because their income follows tradeable output after the foreign shock. Moreover,

[4] Two Agent New Keynesian

in the non-traded sector, the nominal rigities (prices) imply that output has to fall for market clearing due to the reduction in local demand. Hand-to-mouth agents in the non-traded sector will reduce consumption more than all other consumers and therefore the impact on this sector will be larger compared to the representative agent benchmark.

An important conclusion of the paper is that both heterogeneity margins have predictive power over consumption and output paths. Broadly speaking, the financial frictions allow the model to explain the changes observed in the traded sector and the income heterogeneity, variations in the non-traded sector.

de Ferra et al. (2020) follow a similar approach but take into consideration portfolio revaluation after the foreign shock to explain the propagation. In this model, agents hold different degrees of debt (in foreign currency). A capital inflow reversal will have heterogeneous effects over the value of this debt across consumers, depending on their leverage ratios. Moreover, these consumer will have different marginal propensities to consume hence creating different effects over individual consumption. The authors calibrate their model to match Hungary's data during the Great Recession. In particular, their leverage ratio is decreasing in wealth: poor households with a high marginal propensity to consume were more indebted in foreign currency. The aggregate effect on real variables gets amplified by this heterogeneity because high MPC agents substantially drive the changes in aggregate consumption.

Several recent papers extend the empirical evidence suggested by Auclert (2019) in open economy. Hong (2023) leverages consumer survey data for Peru to estimate the marginal propensity to consume (MPC) out of transitory income shocks in a developing economy for each income decile. The author finds that mean annual MPCs are three times as large as in the U.S. and this can be explained mainly by precautionary savings. To see this, the author constructs a HANK model that matches the heterogeneity present in Peru and the U.S. to show that Peruvian households have stronger precautionary savings motives and hence increase consumption by more after a positive income shock. On the other hand, Zhou (2022) leverages rich consumer survey data from Uruguay to study the role of consumer heterogeneity in the transmission of currency devaluation shocks. The paper shows that the presence of high and low MPCs consumers with heterogenous exchange rate exposure drives drives the aggregate consumption response. A key contribution is to link this effect with the redistribution channel present in Auclert (2019) but in open economy. For instance, these external shocks generate larger negative effects on aggregate consumption when the shock is concentrated among high MPC consumers.

On the other hand, other papers extend the canonical HANK model to open economy. For instance, Oskolkov (2023) studies the relationship between heterogeneity and nominal exchange policy in a HANK open economy where agents also can work in tradable or non-tradable sectors. In particular, the author shows how the economy reacts to a foreign interest increase under flexible and fixed exchange regimes. The results show that under a flexible exchange rate, the tradable sector benefits relative to the non-tradable, increasing consumption inequality. Under peg, the paper finds an even larger increase in consumption inequality because the non-tradable sector is more affected to the domestic interest hike to keep the exchange rate constant.

Camara (2022) shows empirically for Uruguay that poor households have almost no participation in the financial market and have larger tradeable expenditure shares. Next, the author buids a TANK model with non-homothetic preferences over consumption and hand-to-mouth agents to study the role these two margin plays in currency depreciations. In summary, the non-homoteticities exacerbate the decline in consumption for hand-to-mouth agents because they consumer more tradeables. The aggregate results of consumption are driven by this large decreaase in consumption by high MPC consumers.

Guo et al. (2022) study the contribution of financial integration in the propagation and distributional consequences of external shocks for Canada. The authors construct and calibrate a HANK model and show that typically agents can be divided into two groups: one that participates in the international financial market, and the other that does not. Their results show that this heterogeneity in financial integration accounts for half of the inequalities in consumption responses.

Guntin et al. (2022) study the cross-sectional consumption response in large crisis. The authors use microdata from Spain, Italy, Peru and Mexico to show that high income household have large consumption-income elasticities. Accross the income distribution, these consumption-income elasticities are flat in European countries and increasing in income for emering economies. Due to spillovers to low-income households, there is a rise in inequality in these events. Finally, they construct a version of a HANK model and show that the permanent income hypothesis can explain a large magnitude of the empirical pattern.

Auclert et al. (2022) study how open economies react to exchange rate shocks and the role of consumer heterogeneity in the aggregate results. The authors extend the canonical open economy model by Galí and Monacelli (2005) incorporating consumer heterogeneity along the lines of the HANK papers cited above. The results of the paper show that when the sum of import and export elasticities is one, the consumer heterogeneity does not matter for explaining the aggregate change in consumption. However, when this sufficient statistic is lower than one, devaluations can be contractionary driven by high MPC agents drastically reducing demand. In their words, "heterogeneity sizes-up the real income channel". On the other hand, when the sum of elasticities is larger than one, the depreciation becomes expansionary and consumer heterogeneity generates a larger expansion. Finally, they argue that the relevant empirical case is when the sum of elasticities is less than one.

3. Model

In this section I will extend Galí and Monacelli (2005) to illustrate the main effects of a nominal exchange depreciation and an income transfer between agents.

Consumers. Households will choose consumption, labor supply and asset holdings. An international bond will be available only for a fraction $1-\psi$ of the population called Ricardian consumers. The remaining fraction (hand-to-mouth or constrained agents) will only be able to consume their labor income. In terms of consumption, agents will have to choose between two commodities, a local and foreign good (Armington trade setting). The problem for non-constrained agents:

$$\max_{C_t^O, C_{Ft}^O, C_{Ht}^O, N_t^O, D_{t+1}} \left\{ \mathbb{E}_0 \sum_{t=0}^{\infty} \frac{(C_t^O)^{1-\sigma} - 1}{1-\sigma} + \varphi_0 \frac{(N_t^O)^{1+\phi}}{1+\phi} \right\}$$

subject to:

$$C_t^O = \left[(1-\alpha)^{\frac{1}{\eta}} (C_{Ht}^O)^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} (C_{Ft}^O)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}$$

$$P_{Ht} C_{Ht}^O + E_t C_{Ft}^O + E_t D_{t+1} = W_t N_t^O + \omega_\pi^O \Pi_t + (1+i_t^*) D_t E_t + T_t^O$$

$$\lim_{T\to\infty} \frac{D_{T+1}}{\Pi_{s=0}^T (1+i_s^*)} = 0$$

$$D_{t+1} \leq \bar{D}_{t+1} - D_{t+1}^G$$

First Order Conditions imply:

$$
\begin{aligned}
C_{Ht}^{O} &= (1-\alpha)C_t^O \left(\frac{P_{Ht}}{P_t}\right)^{-\eta} \\
C_{Ft}^{O} &= \alpha C_t^O \left(\frac{E_t}{P_t}\right)^{-\eta} \\
N_t^O &= \left(\frac{W_t}{P_t\phi_0}(C_t^O)^{-\sigma}\right)^{\frac{1}{\phi}} \\
\left(\frac{C_t^O}{C_{t+1}^O}\right)^{-\sigma} &= \beta \frac{P_t}{P_{t+1}} \frac{E_{t+1}}{E_t}(1+i_{t+1}^*)
\end{aligned}
$$

The hand-to-mouth population will solve the following problem:

$$
\max_{C_t^{HM}, C_{Ft}^{HM}, C_{Ht}^{HM}, N_t^{HM}} \left\{ \mathbb{E}_0 \sum_{t=0}^{\infty} \frac{(C^{HM})_t^{1-\sigma}-1}{1-\sigma} + \varphi_0 \frac{(N_t^O)^{1+\phi}}{1+\phi} \right\}
$$

subject to:

$$
\begin{aligned}
&C_t^{HM} = \left[(1-\alpha)^{\frac{1}{\eta}}(C_{Ht}^{HM})^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}}(C_{Ft}^{HM})^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \\
&P_{Ht}C_{Ht}^{HM} + E_t C_{Ft}^{HM} = W_t N_t^{HM} + T_t^{HM}
\end{aligned}
$$

The solution is fully characterized by the system of equations:

$$\frac{C_{Ft}^{HM}}{C_{Ht}^{HM}}\frac{1-\alpha}{\alpha} = \left(\frac{E_t}{P_{Ht}}\right)^{-\eta}$$

$$(C_t^{HM})^{\frac{1}{\eta}}(1-\alpha)^{\frac{1}{\eta}}(C_{Ht}^{HM})^{\frac{-1}{\eta}} = \frac{P_{Ht}}{P_t}$$

$$\left(N_t^{HM}\right)^{\phi}\phi_0 = \frac{W_t}{P_t}(C_t^H)^{-\sigma}$$

$$P_{Ht}C_{Ht}^{HM} + E_t C_{Ft}^{HM} = W_t N_t^{HM} + T_t^{HM}$$

Finally, notice that the Consumer Price Index will have the standard CES formula:

$$P_t = [(1-\alpha)P_{Ht}^{1-\eta} + \alpha E_t^{1-\eta}]^{\frac{1}{1-\eta}}$$

Firms. Intermediate producer j will set prices to maximize profits. Given their linear technology on labor $Y_{Ht}(j) = A_{Ht}N_t(j)$, their marginal cost will be common to all domestic producers:

$$MC_t = W_t A_{Ht}^{-1}$$

Cost minimization implies that the demand for labor is:

$$N_t(j) = Y_{Ht}(j)A_{Ht}^{-1} = \left(\frac{P_{Ht}(j)}{P_{Ht}}\right)^{-\varepsilon} Y_{Ht}A_{Ht}^{-1}$$

where $P_{Ht}(j)$ will be the price set by monopolist j. Following Calvo (1983), each period firms are able to adjust prices with probability $1-s_t$. This probability is independent across firms and time, although it might be time varying. Applying the law of large numbers, a fraction $1-s_t$ of the total measure of firms resets their prices each period. Let that price be the *flexible price*. Due to the perfect foresight feature of this model, firms able to set prices each period solving:

$$\max_{P_H(j)}\left\{[P_{Ht}(j)-MC_t]Y_{Ht}(j) \quad s.t.: \quad Y_{Ht}(j)=\left(\frac{P_{Ht}(j)}{P_{Ht}}\right)^{-\varepsilon}Y_{Ht}\right\}$$

Solution: $P_{Ht}(j)=P^f_{Ht}=\frac{\varepsilon}{\varepsilon-1}MC_t$ for all j.

The remainder set will be constrained to keep their prices at P_{H0}. Thus the Home good price will be:

$$\begin{aligned} P_{Ht} &= \left(\int P_{Ht}(j)^{1-\varepsilon}dj\right)^{\frac{1}{1-\varepsilon}} \\ &= \left[s_t P_{H0}^{1-\varepsilon}+(1-s_t)(P^f_{Ht})^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}} \end{aligned}$$

Rest of the World. I assume a small open economy model, where foreign consumers demand home goods with demand give by : $(P^*_{H,t})^{-\theta}P^*Y^*$, where θ is the export elasticity. I assume Law of one price holds and therefore $E_tP^*_{H,t}=P_{H,t}$ and normalize $P^*\equiv 1$. This implies that the external demand of home goods is $\left(\frac{P_{H,t}}{E_t}\right)^{-\theta}Y^*$.

Government. The Monetary Authority will control the exchange rate and the Fiscal Authority will follow a deterministic path of expenditures G_{Ht}, G_{Ft} and taxes for both agents T^{HM}_t, T^O_t. Additionally, the government can access the international asset market, under a borrowing constraint $\bar{D}^G$. Balanced budget implies:

$$P_{Ht}G_{Ht} + E_t G_{Ft} + D^G_{t+1} = \psi T^{HM}_t + (1-\psi)T^O_t + D^G_t(1 + i^*_{t+1})$$
$$D^G_{t+1} \leq -\bar{D}^G$$

4. Impulse Response

4.1 Nominal Devaluation

The objective of this section is to study the effect of a 10% nominal depreciation coming from a unexpected increase in foreign interest rate. I normalize this shock to generate a 10% devaluation on impact using the Uncovered Parity Equation.[5] Regarding the calibration, I take the parameters from the literature. The following table summarizes the calibration:

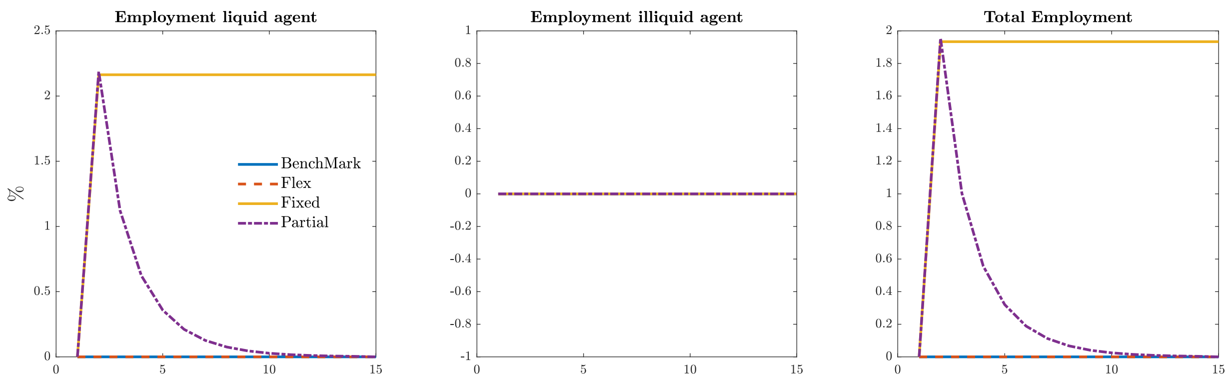
Table 3.1: Calibration - TANK model

Parameter	Value	Definition	Source
σ	1	risk aversion	Galí and Monacelli (2005)
η, θ	4	elasticity across countries	Auclert et al. (2022)
ϵ	6	elasticity across home varieties	Galí and Monacelli (2005)
ϕ	2	inverse of Frisch elasticity	Auclert et al. (2022)
α	0.4	foreign bias in consumption	Auclert et al. (2022)
β	0.95	5% annual interest rate $\beta(1+i^*) = 1$	Steady State
ψ	0.1	fraction of constrained consumers	Benchmark
A_H	10	Home Productivity	Benchmark
G_H, G_F, T^{HM} , T^O	0	Government Policy	Benchmark
Y^*	1	Foreign Output	Benchmark
$\bar{D}$	100	Borrowing constrain	Benchmark

[5]See Appendix for the algorithm used to solve for the Impulse Response.

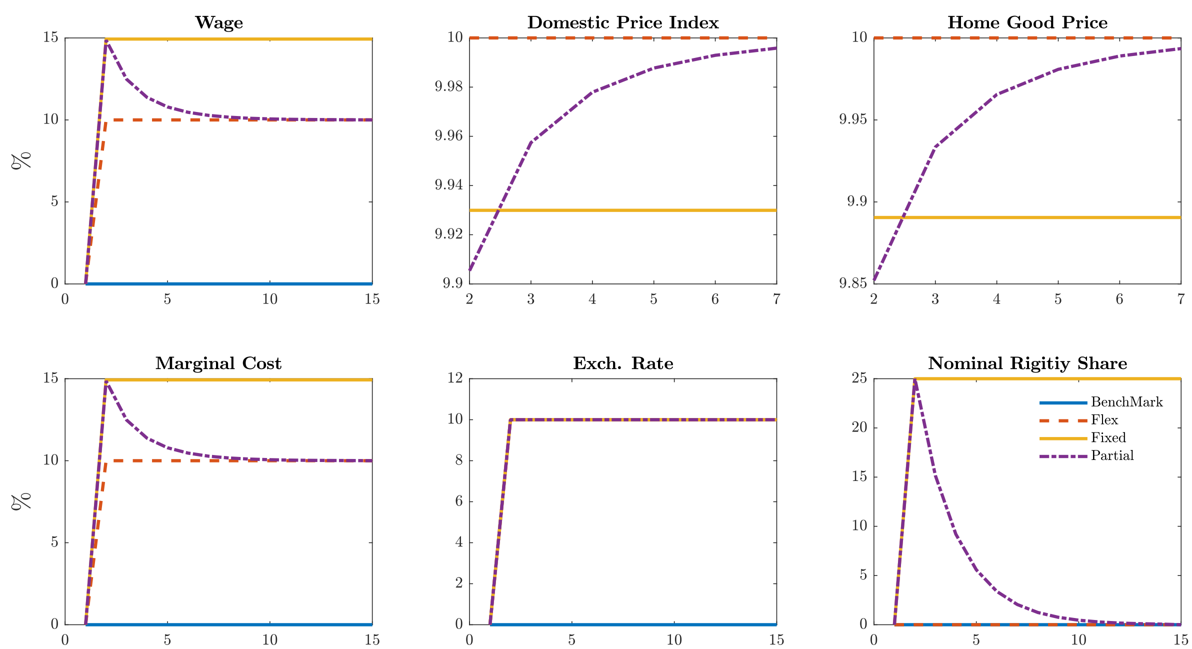
Results. The graphs show the percentage deviations from the steady state. I will consider four cases: (i) Benchmark: the exchange rate is fixed at the initial level (no shock); (ii) Flexible: all producers can adjust their prices ($s_t = 0$ for all t). (iii) Fixed: a share of all producers must keep their initial prices ($s_t = 0.25$ for all t); (iv) Partial: only a fraction of firms can adjust their prices ($s_t = 0.25e^{-t}$).

Figure 3.1: Impulse Response - Employment



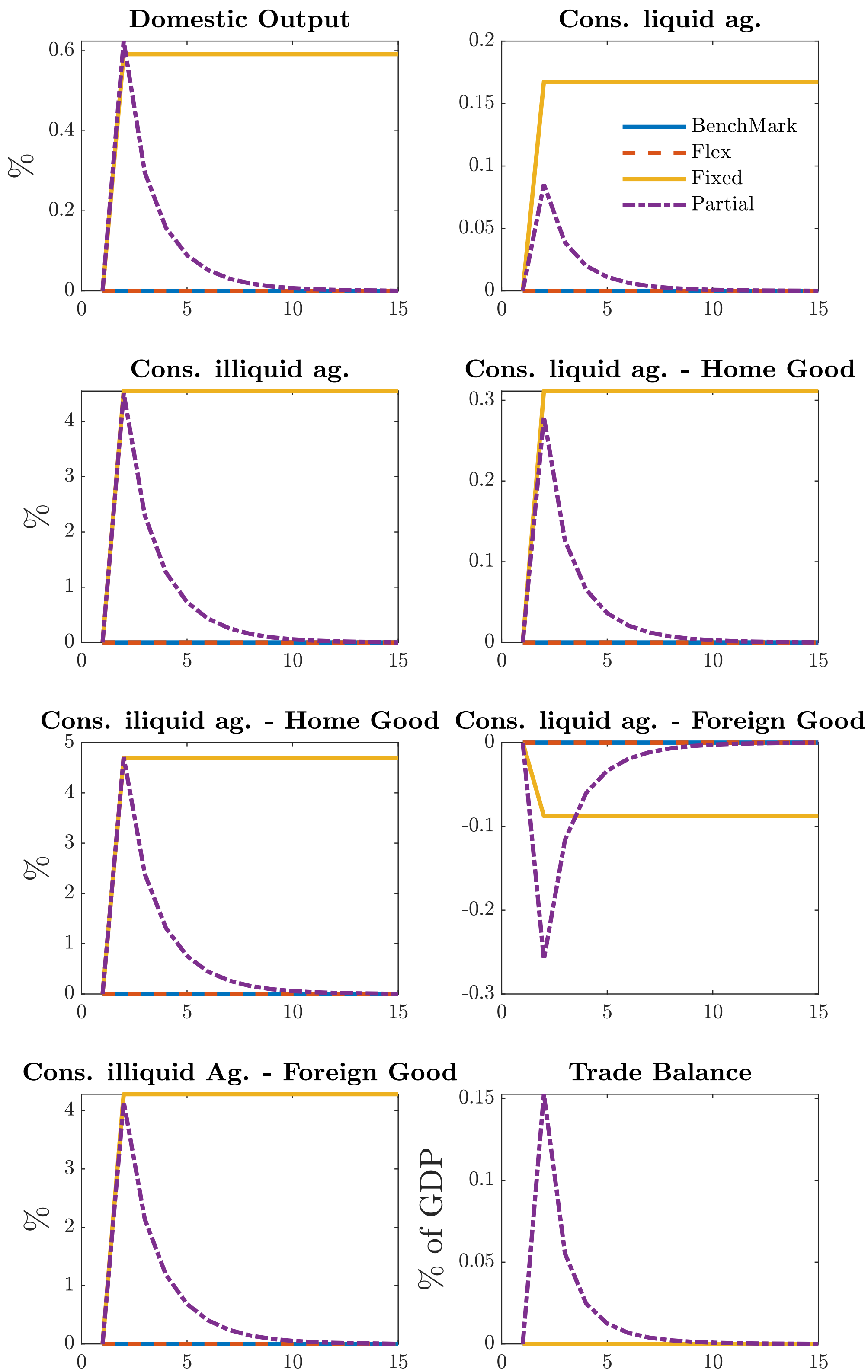
Notes. This figure shows results for a 10% devaluation on employment. Each period is one year in the model.

Figure 3.2: Impulse Response - Prices



Notes. This figure shows results for a 10% devaluation on prices. Each period is one year in the model.

Figure 3.3: Impulse Response - Goods



Notes. This figure shows results for a 10% devaluation on consumption and output. Each period is one year in the model.

For the flexible-price scenario, the only effect is a permanent change in prices and wages. There is no real effect of the devaluation because all producers instantly adjust their prices after the devaluation. For the other two case however, it has real effects.

The fixed prices case, where a large share of producers must keep their original prices, features a substantial increase in output. Foreigners will demand more local goods after the devaluation because their currency has a higher purchasing power. Moreover, local consumers will increase their demand for the domestic product due a substitution effect: will avoid foreign goods due to their price increase (in domestic currency). Local producers will increase labor demand and wages will surge. There is an heterogeneous response from consumers/workers: hand-to-mouth consumers will not change their labor supply and ricardian agents will desire to work more. Overall, labor supply increases in order to produce more goods.

Moreover, the devaluation transfers utility from optimizers to the hand to mouth consumers. In this scenario, constrained consumers benefit from the devaluation because the domestic wage increase and they are able to consume more. In term of the composition of consumption, both fractions of the population substitute foreign consumption with domestic consumption due to the change in relative prices.

In the partial case, where only a fraction of firms are constrained to keep their original prices, we see that initially all variables behave similarly as in the fixed-price case. Demand for the local good increases due to the redistribution of consumption from local consumers and the increase in exports. Local producers will demand more labor and therefore wages will increase. Ricardian consumers will supply more labor.

Overtime, producers will increase prices, reduce production and labor demand. This effect will have a negative effect on wages and both consumers will react differently. Ricardian workers will reduce their labor supply but hand-to-mouth consumers will decide to keep constant labor supply. However, the devaluation will have no permanent effects on real quantities. Only prices change permanently as the economy converges to the new steady state with higher prices but constant real quantities.

It is important to notice that the heterogeneity in consumers imply different marginal propensities to consume, and therefore different marginal utilities of labor supply. This explains why they react differently to changes in wages. In the benchmark calibration $\sigma = 1$ and no taxes/transfers implies that hand-to-mouth agents do not change their labor supply when real wages increase. On the other hand, ricardian households work more. The economy expands due to an increase in exports and both hand-to-mouth and optimizers increase consumption.

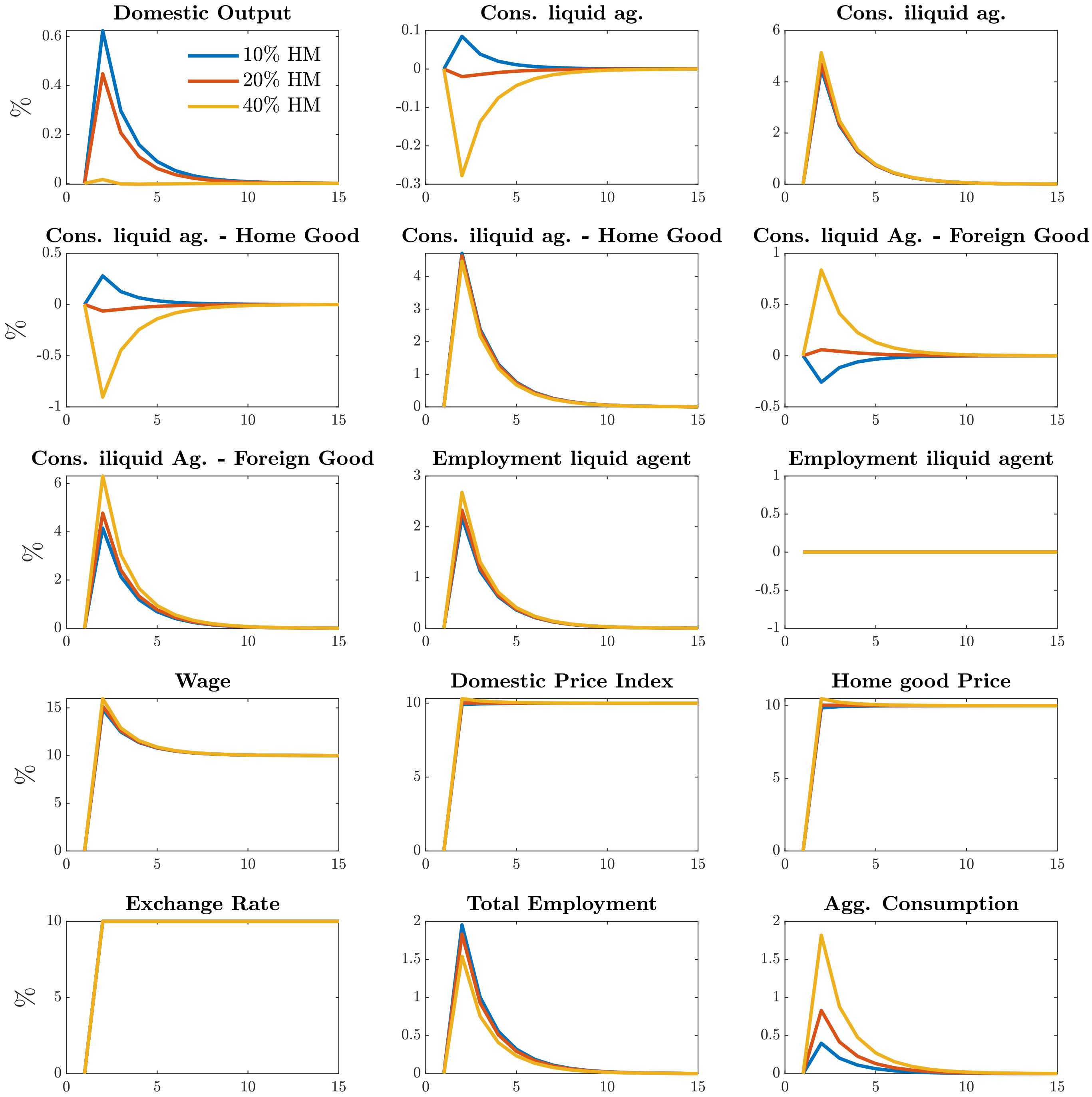
Role of Heterogeneity

In this section I will study how the fraction of constraint agents affect the results of the nominal devaluation for the partial fixed prices case. The following graph summarizes the deviation from steady state of all model variables for different values of ψ.

For prices, the share of hand-to-mouth does not have substantial effects. The main differences are in terms of quantities and employment. First, hand-to-mouth do not change their hours worked and always increase their consumption. This is because of the large increase in real wages. This is, however, transitory, as the economy converges back to the steady state as producers adjust their prices.

On the other hand, Ricardian face a consumption reduction if the share of hand-to-mouth is large enough. Remember that hand-to-mouth agents do not increase labor supply and hence the increase in demand from the rest of the world generates a rise in wages. Consequently, the foreign good becomes relative cheaper due to this large increase in wages that drive up the price of the domestic good. Therefore the Ricardian agent substitute away from home consumption and this drives down consumption of this group.

Figure 3.4: Sensitivity Analysis for the Share of Hand-to-Mouth - Devaluation



Notes. This figure compares the results for different shares of hand-to-mouth

4.2 Transfer

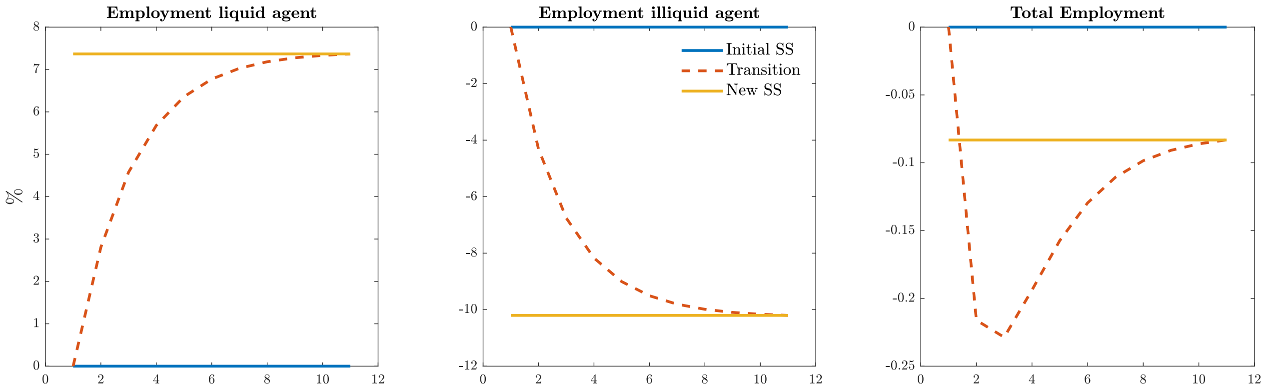
For the following counterfactual I will study the effect of a wealth transfer from optimizers to hand-to-mouth: the government will increase taxes to optimizers and transfer this income to constraint agents. This redistribution is budget deficit neutral. The size of the transfer is normalized to represent 30% of the hand-to-mouth agent's consumption after ten years.[6] The plots below show the results. The role of nominal rigidities is not extremely important in this case, therefore I will focus on the flexible price setting. For the calibration I will set $\psi = 0.4$ and will study its role in the next part below.

The main effect of the transfer is to reduce labor supply of the constrained agents but increase hours for optimizers. The tax/transfer acts a wealth redistribution between agents. Overall, the total labor supply is reduced and therefore wages and marginal costs increase. However, in my calibration this shock has a small impact on prices and wages because it mainly affects the composition of labor supply and not the aggregate level.

In terms of output and consumption, the counterfactual shows that domestic output is reduced in a small amount although the composition of consumption changes. After the shock hand-to- mouth agents consume more, but optimizers less. This exercise shows that fiscal policy can have macroeconomic implications due to employment and consumption changes between groups.

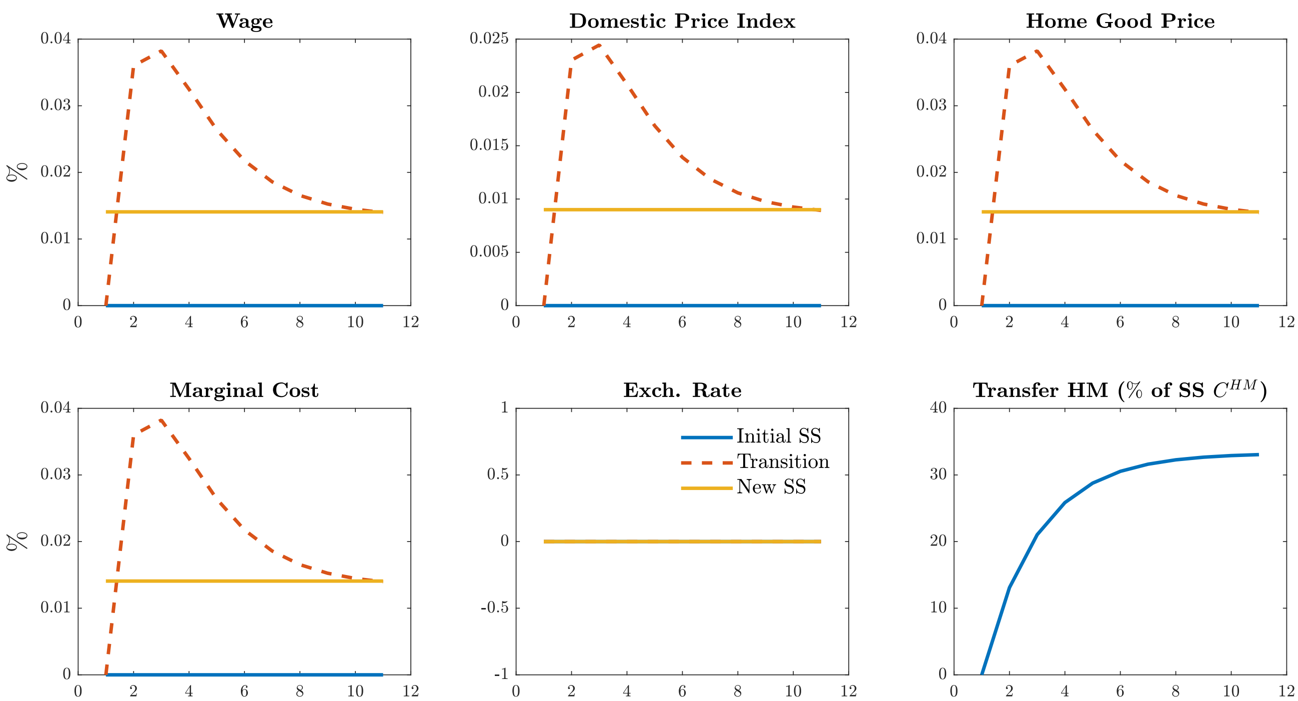
[6] Each period in the model is one year.

Figure 3.5: Impulse Response - Employment



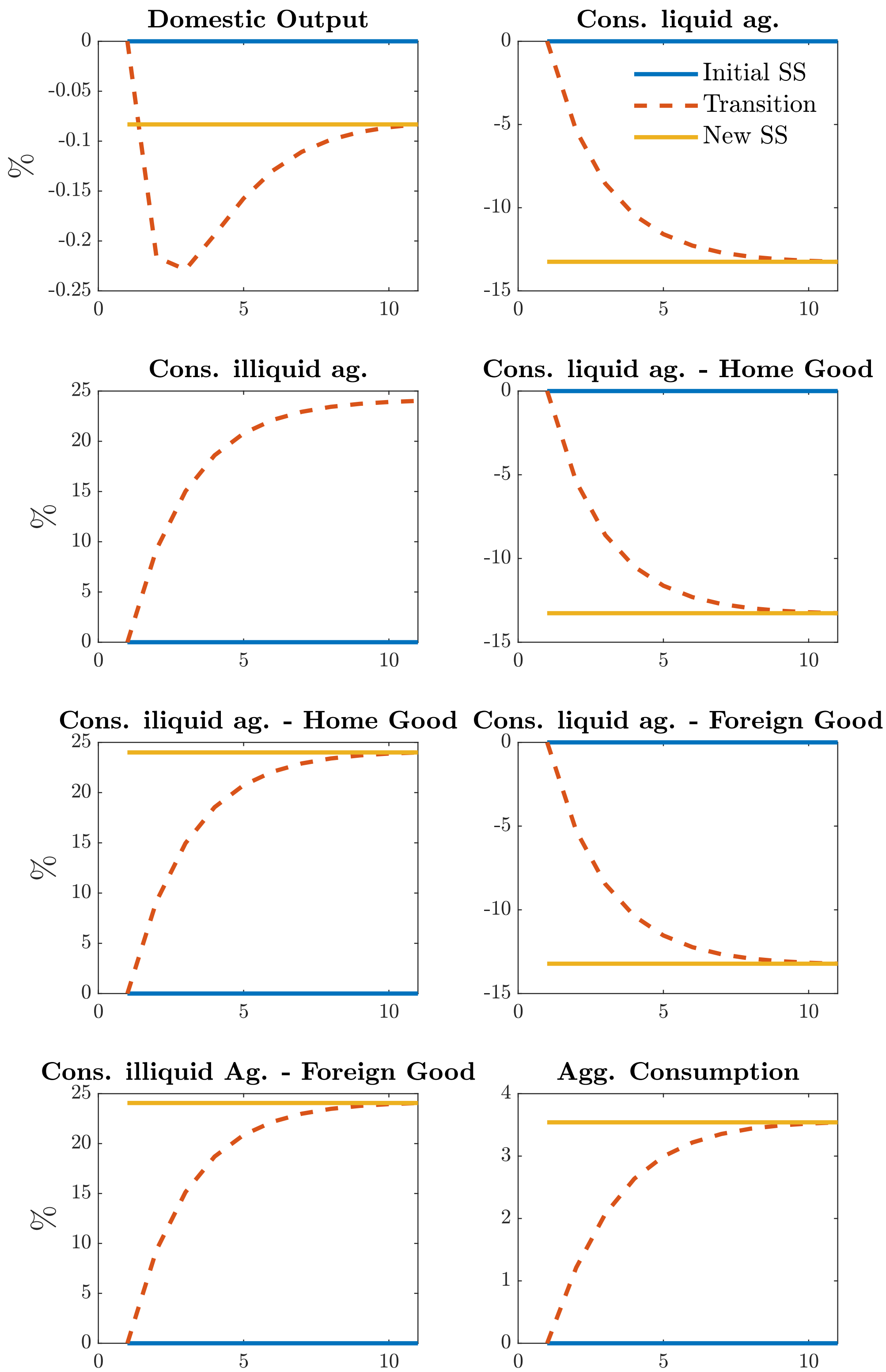
Notes. This figure shows results for a fiscal transfer on prices.

Figure 3.6: Impulse Response - Prices



Notes. This figure shows results for a fiscal transfer on employment.

Figure 3.7: Impulse Response - Goods



Notes. This figure shows results for a fiscal transfer on consumption and output.

Role of Heterogeneity

For this section I will describe the effects of the transfer shock under different consumer heterogeneity. In this case, the size of the transfer is to the hand-to-mouth is consistent with the previous section. However to reach budget deficit neutrality, the tax burden on optimizers will be increasing in ψ. The variables paths are summarized in the plots below.

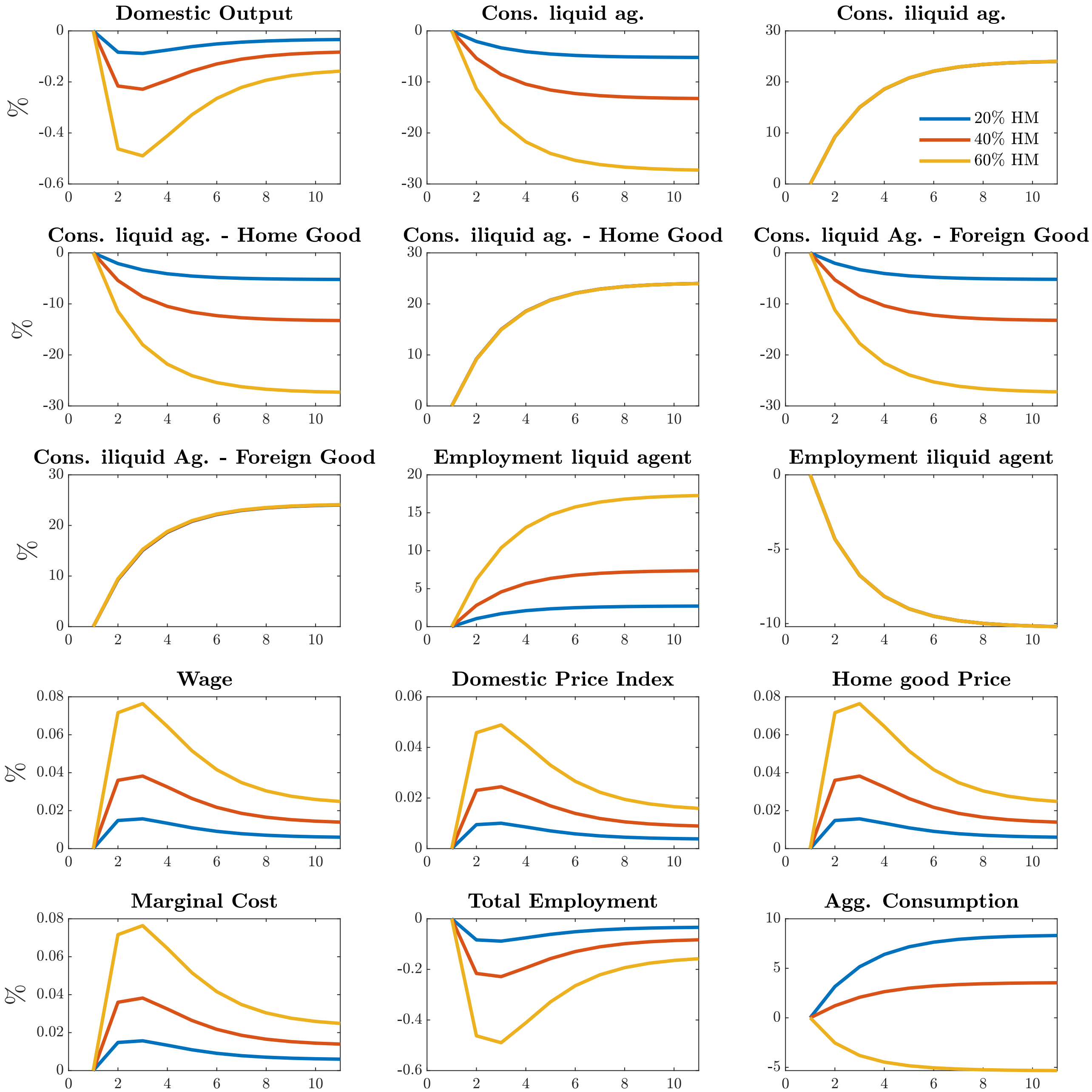
First, prices evolve quite similarly for different levels of ψ. Second, hand-to-mouth reduce their employment in similar levels. The increase in labor from the ricardian agents does not compensate this reduction and the economy experiences a stronger decrease in employment. Consequently, the impact on output is higher when the majority of people are constrained.

There is a reduction in consumption and income inequality from the transfer. Hand-to-mouth agents receive more income and consume more. For instance, when ψ is 40% optimizers reduce their consumption by 10% compared to hand-to-mouth that increase their consumption by 20% in ten years.

In terms of aggregate consumption, we see that the transfer increases total demand when the share of hand-to-mouth is small. This is because the tax on optimizers do not reduce their consumption greatly. On the other hand, when ψ is large, the decline in demand from optimizers drives down the aggregate consumption and is not compensated by hand-to-mouth response in consumption.

Overall, we have seen in this section that fiscal policy can have macroeconomic implications that differ according to the financial access of consumers. Governments should take into account this heterogeneity margin when employing transfers as the decline in income inequality is at expense of real activity.

Figure 3.8: Sensitivity Analysis for the Share of Hand-to-Mouth - Transfer



Notes. This figure compares the results for different shares of hand-to-mouth

5. Concluding Remarks

This chapter has reviewed the most important contributions to the New Keynesian Open Economy literature. Additionally, I have studied a simple model featuring the main characteristics. In my opinion, future research must take into account the fact that heterogeneity might also come from the firm side. One possible avenue would be to apply Eaton and Kortum (2002) features to see further understand how monetary and foreign exchange policies affect trade. I believe that monetary policy could be an important driver of specialization in exports. Developing countries could change their exchange rate to benefit from international trade. If those gains are invested appropriately (capital accumulation), the country might change their comparative advantages and shift it's exporting patters. Moreover, models with entry and exit (as in Hopenhayn (1992)) could be used to study the effect on firm decisions. In particular, I expect that nominal devaluations will change the concentration of firms exporting.

Furthermore, consumer heterogeneity might be important to understand the products each country exports and imports. I believe that even if consumers are alike but they differ in the access to international markets, the varieties exported and imported of each country could be correlated to the fraction of hand-to-mouth due to differences in marginal propensities to consume. An Eaton and Kortum (2002) model featuring consumer heterogeneity could shed light to this question.

6. Appendix

Algorithm to solve for the Impulse Response:

1. Set $t = 0$ and Guess C_t^O.

2. **Wage Algorithm**

   (a) Guess W_t

   (b) Solve for prices:

   - $P_{Ht}(j) \equiv P_{Ht}^f = \frac{\varepsilon}{\varepsilon-1}\frac{W_t}{A_{Ht}}\ \forall\ j$ if flexible price setter, if not P_{H0}
   - $P_{Ht} = \left[s_t P_{H0}^{1-\varepsilon} + (1-s_t)(P_{Ht}^f)^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}$
   - $P_t = \left[(1-\alpha)P_{Ht}^{1-\eta} + \alpha E_t^{1-\eta}\right]^{\frac{1}{1-\eta}}$

   (c) Solve for liquid agent's choices: C_{Ht}^O, C_{Ft}^O, N_t^O using FOCS and guess on C_t^O:

   - $(C_t^O)^{\frac{1}{\eta}}(1-\alpha)^{\frac{1}{\eta}}(C_{Ht}^O)^{\frac{-1}{\eta}} = \frac{P_{Ht}}{P_t} \rightarrow C_{Ht}^O = (1-\alpha)C_t^O\left(\frac{P_{Ht}}{P_t}\right)^{-\eta}$
   - $\frac{C_{Ft}^O}{C_{Ht}^O}\frac{1-\alpha}{\alpha} = \left(\frac{E_t}{P_{Ht}}\right)^{-\eta} \rightarrow C_{Ft}^O = \alpha C_t^O\left(\frac{E_t}{P_t}\right)^{-\eta}$
   - $\left(N_t^O\right)^{\phi}\phi_0 = \frac{W_t}{P_t}(C_t^O)^{-\sigma} \rightarrow N_t^O = \left(\frac{W_t}{P_t\phi_0}(C_t^O)^{-\sigma}\right)^{\frac{1}{\phi}}$

   (d) Solve for hand-to-mouth agent's choices: C_{Ht}^H, C_{Ft}^{HM}, N_t^{HM} and C_t^{HM} using FOCS:

   - $\frac{C_{Ft}^{HM}}{C_{Ht}^{HM}}\frac{1-\alpha}{\alpha} = \left(\frac{E_t}{P_{Ht}}\right)^{-\eta}$
   - $(C_t^{HM})^{\frac{1}{\eta}}(1-\alpha)^{\frac{1}{\eta}}(C_{Ht}^{HM})^{\frac{-1}{\eta}} = \frac{P_{Ht}}{P_t}$
   - $\left(N_t^{HM}\right)^{\phi}\phi_0 = \frac{W_t}{P_t}(C_t^H)^{-\sigma}$
   - $P_{Ht}C_{Ht}^{HM} + E_t C_{Ft}^{HM} = W_t N_t^{HM} + T_t^{HM}$

   (e) Solve for W_t using market clearing for goods and labor:

   - Labor Supply: $N_t^s = \psi N_t^{HM} + (1-\psi)N_t^O$

- Labor Demand: $N_t^d = \left[s_t P_{H0}^{-\varepsilon} + (1 - s_t)(P_{Ht}^f)^{-\varepsilon}\right] P_{Ht}^{\varepsilon} \frac{Y_{Ht}}{A_{Ht}}$
- where $Y_{Ht} = \psi C_{Ht}^{HM} + (1 - \psi) C_{Ht}^O + \left(\frac{P_{Ht}}{E_t}\right)^{-\theta} Y^* + G_{Ht}$

3. Set $t = t + 1$.

   (a) Solve for C_t^O and wages using Euler Equation and Wage algorithm using solution for previous period:

$$\left(\frac{C_{t-1}^O}{C_t^O}\right)^{-\sigma} = \beta \frac{P_{t-1}}{P_t}(1 + i_t^*) \frac{E_t}{E_{t-1}}$$

4. Solve for initial consumption C_0^O using the Economy's Intertemporal Budget Constraint:

$$\sum_{t=0}^{\infty} \frac{C_{Ft} + G_{Ft} - \frac{P_H t}{E_t} C_H^*}{\Pi_{s=0}^t (1 + i_s^*)} = 0$$

where:

- $C_{Ft} = \psi C_{Ft}^{HM} + (1 - \psi) C_{Ft}^O$
- $C_H^* = \left(\frac{P_{Ht}}{E_t}\right)^{-\sigma} Y_t^*$
- $T = \psi T_t^{HM} + (1 - \psi) T_t^O$

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