Markups and Productivity of Heterogeneous Producers

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Abstract

This paper tests important empirical predictions from international trade models linking trade behavior and firms' markups using firm-level panel data for U.S. manufacturing firms from 1964-2011, producing the following results: firms of higher productivity have lower rates of exchange rate pass-through to export prices, i.e., they adjust their markups by a higher magnitude. However, firms of higher productivity also have less volatile markups, i.e, they adjust their markups less frequently than do firms of lower productivity. Such heterogeneous and complex firm behavior may be the reason why we are unable to explain the lack of response of aggregate prices to exchange rate movements.

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1 Introduction

One of the chief puzzles in international macroeconomics is why large movements in nominal and real exchange rates have little impact on the prices of internationally traded goods. Exchange rate pass-through[1], which is a measure of how responsive international prices are to changes in exchange rates, have been estimated by various studies and have been found to be quite low or incomplete (e.g.,Goldberg and Knetter (1996), Campa and Goldberg (2005))[2]. The causes of incomplete pass-through have been attributed to the presence of local costs (Corsetti and Dedola (2005)), price rigidity (Devereux and Engel (2002)), and product differentiation in quality (Yu et al. (2013)).

With respect to the response of markups to exchange rate movements, Goldberg and Knetter (1996) show that destination-specific changes in markups due to third-degree price discrimination are significant in explaining the lack of response of prices to exchange rate changes, and Hellerstein (2008) finds that in the beer industry, markup adjustments explain roughly half of the incomplete transmission of exchange rate changes into prices. However, there have been very few empirical studies using firm-level heterogeneity in markup adjustments as an explanation for the lack of response of aggregate prices to exchange rate movements.

Firms are heterogeneous with respect to their levels of productivity. This has been documented empirically. Bernard and Jensen (1999) find that U.S. exporters are more productive than non-exporters in the same industry. Firms of higher productivity have lower marginal cost of production and hence set lower prices and are also able to set higher markups. The question of interest here is whether the markup of a very productive firm or that of a low-productivity firm will be more responsive when faced with an exogenous exchange rate shock. The answer to this question has broad implications for the effects of exchange rate changes on prices and trade flows, and for theoretical modeling choices.

This paper links firm-level heterogeneity to responses to exchange rate changes. I find that firms of higher productivity have lower rates of exchange rate pass-through to export prices, i.e., they adjust their markups by a higher magnitude. However, firms of higher productivity also have less volatile markups, i.e, they adjust their markups less frequently than do firms of lower productivity. I document these results using Compustat firm-level unbalanced panel data for around 4000 U.S. manufacturing firms from 1964 to 2011.

Recent theoretical models of international trade have introduced firm heterogeneity at the core of the

[1]Exchange rate pass-through to import (export) price = percentage change in import (export) price / percentage change in exchange rate. An exchange rate pass-through that is equal to one implies complete pass-through. As the importer's currency depreciates, as a result of incomplete pass-through, the markup decreases to accommodate for the less than full increase in import price.

[2]For example, Campa and Goldberg (2005) find that in the U.S., pass-through rate is 25 percent in the short run and 40 percent in the long run.

analysis (e.g. Melitz (2003), Bernard et al. (2003)). Newer theoretical models of heterogeneous firms assume preferences that imply endogenous markups. Bernard et al. (2003) assume Bertrand oligopolistic price competition, Atkeson and Burstein (2008) assume Cournot oligopolistic quantity competition, Melitz and Ottaviano (2008) assume a quasilinear-quadratic utility function that generates a linear demand system with endogenous markups and Rodriguez-Lopez (2011) assumes a translog expenditure function that generates a demand system with endogenous markups. Although these models agree on the positive relationship between productivity and markups, different assumptions in preferences can have opposite implications regarding the responsiveness of heterogeneous firms' markups to exogenous shocks. For example, in response to exchange rate shocks, a model with the quasilinear-quadratic preferences of Melitz and Ottaviano (2008) predicts that markups of more productive firms are more responsive, while a model with the translog preferences of Bergin and Feenstra (2000) predicts the opposite (see Rodriguez-Lopez (2011)).

Using French firm-level data, Berman et al. (2012) find that high-productivity firms have lower pass-through rates of exchange rate changes to prices, which they suggest is evidence that more productive firms have more responsive markups (i.e., they prefer to absorb a shock in their markups rather than changing prices), thus supporting the theoretical model of Melitz and Ottaviano (2008). I explore this question empirically following a different approach.

Instead of simply looking at whether higher productivity firms have higher or lower pass-through rates, I also compute the volatility of markup adjustments and investigate whether firms of higher productivity have more volatile markups or not. Empirically, I find that smaller and less productive firms adjust their markups more frequently in response to exchange rate movements in order to remain competitive. In other words, even though less productive firms have a lower markup elasticity, they have more volatile markups in order to save their market share from more productive firms.

This suggests that the price adjustment costs (or menu costs) of more productive firms are smaller since they adjust their prices more frequently and by smaller amounts. Therefore, it appears that the lump-sum component of menu costs that all firms have to pay irrespective of their size, is important for explaining the heterogeneous markup adjustment behavior of firms and consequently the aggregate pricing behavior. Larger and more productive firms account for a higher share of aggregate exports and also absorb more of the exchange rate changes in their markups. Therefore, aggregate prices do not change very much. At the same time, smaller and less productive firms, which are more in number, adjust their markups much more frequently, another reason why exchange rate movements do not show up much in aggregate prices in the short-run. This paper is complementary to existing studies on incomplete exchange rate pass-through and heterogeneous firm behavior.

The rest of the paper is organized as follows. Section 2 presents related literature. Section 3 introduces the empirical strategy, presents the data and empirical findings, and also discusses the implications of the findings. Section 4 concludes.

2 Related Literature

Empirical studies on the magnitude of price adjustments find that price changes are quite large but many small price changes also occur. Nakamura and Steinsson (2008) use U.S. microdata from the Bureau of Labor Statistics to find that the median magnitude of finished-goods producer prices is 7.7 percent, while Klenow and Kryvtsov (2005) find that the median of regular consumer price changes is 10 percent , which can be considered as pretty large. However, Klenow and Kryvtsov (2005) also find that there are many small price changes that occur. Since large firms are the ones making small price changes, as reported using Compustat data, this finding is not surprising.

The theoretical literature has also tried to accommodate the fact that small price changes do exist. Midrigan (2011) models both large and small price changes by assuming economies of scope in price adjustment, while Caballero and Engel (1999) assume that the cost of changing prices is stochastic, such that when the cost is low, firms might make frequent price changes. These firms would be the more productive firms, as suggested by this paper.

As far as the frequency of price adjustments is concerned, Nakamura and Steinsson (2008) document that the median duration of regular price changes is 8-11 months. Klenow and Malin (2010) survey various studies and data sources to conclude that price changes occur at least once a year but the degree of price stickiness differs across countries. More specifically, producer prices have a median duration of 12 months in the Euro area, 6-8 months in the U.S., and are even less stickier in high-inflation developing countries like Brazil, Chile and Mexico.

Gopinath and Itskhoki (2008) using BLS microdata run cost pass-through regressions and find evidence that firms that adjust prices infrequently also pass-through a lower amount even after several periods and multiple rounds of price adjustment, as compared to high frequency adjusters. They take this evidence to imply that firms that infrequently adjust prices are typically not as far from their desired price, while firms that have high pass-through drift farther away from their optimal price and, therefore make more frequent adjustments.

In this paper, more productive firms are high frequency adjusters, not because they drift away from their optimal price, but because the menu costs they face are lower and therefore, it is easier for them to adjust their prices more frequently. However, despite being high frequency adjusters, they do not pass-through a higher amount, as observed by Gopinath and Itskhoki (2008). The fact that more productive firms have lower rates of pass-through has also been observed by Berman et al. (2012).

Using New Zealand survey data, Buckle and Carlson (2000) show that large firms change prices more frequently than small firms. In fact, they report a perfect rank-order correlation between firm size and the average frequency of price changes. In their paper, size is defined by the number of employees. Since firm size and productivity are positively related, this can be taken as evidence that more productive firms do change prices more frequently.

On the subject of the significance of menu costs, theoretically, menu costs of price adjustment are a popular explanation for price stickiness in markets characterized by monopolistic competition. Ball et al. (1988) find that menu costs cause prices to adjust infrequently. So the higher the menu cost, the higher is the infrequency of price adjustment. This supports the claim that more productive firm have lower menu costs, since they are the ones to adjust prices more frequently.

Levy et al. (1997) provide direct empirical evidence on menu costs using store-level data. They find that the magnitude of menu costs found is large enough to be capable of having macroeconomic significance. They also suggest that managerial menu costs are very important. This includes the time and attention required by managers to gather relevant information to implement a price change. This is lump-sum and independent of firm size. Slade et al. (1998) also find that the estimated magnitude of fixed costs of price adjustment is substantially larger than that of variable costs. This evidence helps emphasize the importance of lump-sum menu costs in explaining price adjustment behavior by heterogeneous firms.

3 Empirical Analysis

3.1 Empirical Specification

First, to verify that firms of higher productivity do set higher markups and to determine whether firms of higher or lower productivity have higher pass-through rates to export prices, I run the following regression:

$$ln(\mu_{it}) = \alpha ln(TFP_{it}) + \beta ln(REER_t) + \gamma ln(REER_t) * \Phi_i + \Psi_i + u_{it}, \tag{1}$$

where, μ_{it} is the markup of firm i at time t, TFP_{it} is the firm-level total factor productivity at time t, and $REER_t$ is the real effective exchange rate between the U.S. and its major trading partners at time t (an increase in this index means appreciation). Φ_i is the relative TFP of each firm compared to its 4-digit SIC industry peers. I first rank the firms within each industry based on their average lifetime TFP and then map this ranking to the [0,2] range such that zero corresponds to the firm with lowest productivity, 1 corresponds to the firm with median productivity within each industry, and 2 corresponds to the firm with the highest productivity. This is done for ease of interpretation when distinguishing the effects of an exchange rate movement between a firm of lower productivity versus a firm of higher productivity. Firm fixed-effects are included in the regression. The effect of an exchange rate movement will be seen by $\beta + \gamma\Phi$ for firms of different productivity levels.

I expect α to be positive, since firms of higher productivity are expected to set higher markups. If there is incomplete exchange rate pass-through to export prices along with an appreciation of the exporter's currency, prices in the importer's currency will increase but less than the complete pass-through price, and exporters will achieve this by absorbing a part of the exchange rate movement in their markups. I expect β to be negative since an appreciation will cause markups to decrease. Now the question of interest is whether firms of higher or lower productivity will lower their markups more following an appreciation. In the theoretical framework of Rodriguez-Lopez (2011) more productive firms have higher pass-through in the exact translog expenditure case and lower pass-through in the quasilinear-quadratic utility case.

The empirical specification for the relationship between the volatility of markups and exchange rate movements is:

$$ln(Volatility_{it}^{\mu}) = \alpha ln(sale_{it}) + \beta ln(REER_t) + \gamma ln(REER_t) * \Phi_{it} + \Psi_i + u_{it}, \tag{2}$$

where $Volatility_{it}^{\mu}$ is the standard deviation of five-year rolling windows of firm-level markup adjustments computed as $\sigma(\triangle\mu_{it}) = \sqrt{\frac{1}{5}\sum_{\tau=t-2}^{t+2}(\mu_{i\tau} - \bar{\mu_{it}})^2}$, where $\bar{\mu_{it}}$ is the average from $t-2$ to $t+2$. $\triangle\mu_{it}$ is the percentage change in μ_{it} from period $t-1$ to t. The use of rolling standard deviations to compute volatility of micro-level variables such as sales growth and earnings can be found in Comin and Philippon (2006) and Cournède et al. (2015). Again, $\beta + \gamma\Phi$ will be able to tell us whether firms of higher or lower productivity have more volatile markups.

I also use another measure of volatility that is used in Cournède et al. (2015). I count the incidences of large adjustment in markups by every firm. I define a large change as being greater than the 75th percentile of the distribution of absolute percentage change in firm-level markups from one year to the next. Using this measure of markup volatility, I run a Poisson regression, where the log of the response variable $count_i$ follows a Poisson distribution and is modeled as a function of the predictor variable, which is Φ_i, the relative productivity of each firm.

$$P(count|\Phi, \beta) = \frac{\lambda^y e^{-\lambda}}{y!}, ln(E(count|\Phi)) = \alpha + \beta\Phi = \lambda. \tag{3}$$

I expect the coefficient on Φ_i to have the same sign as α in estimation (2).

3.2 Data

I use three different sources of data:

1. I use the CRSP/Compustat Merged (CCM) - Fundamentals Annual database for our firm-level analysis. Compustat is compiled by Standard and Poor from annual corporate reports of publicly traded companies. Compustat data contains annual and quarterly income statement, balance sheet, cash flow, pension, supplemental, and descriptive data items for active and inactive companies,

whereas the CRSP (The Center for Research in Security Prices) contains security-level historical descriptive information and market data on stocks. The CSRP data was used only to procure information on start and end date of firms in the Compustat database, in order to calculate age and exit variables for the analysis. All other firm-level information on sales, capital expenditures, capital stock, material cost, payroll, etc came from the Compustat database. A detailed description of the construction of firm-level variables for the estimation can be found in the Data Appendix. I keep only U.S manufacturing firms and use annual data from 1962 to 2011. This gives an unbalanced panel with 3917 distinct firms and the total number of firm-year observations is around 45,890.

Table 1 gives an overview of the type of firms in the Compustat sample. The most number of manufacturing firms are from the different Equipments sectors, while there are little to no firms in Apparel, Leather and Tobacco Products. Table 2 shows the composition of firms by age. The median age of firms is 9, in the sample as reported later in Table 4. We see that there are very few firms that were followed for entire duration of the sample. I use the entry and exit dates of the firms in the Compustat sample to proxy for the actual entry and exit of firms from the industry.

In the absence of export-related information, a valid concern might be about the representativeness of Compustat firms as firms engaging in international trade. Table 3 shows what fraction of total manufacturing employment is made by Compustat firms. The data on the total number of manufacturing firms and total employments come from the U.S. Census. As the evidence suggests, our sample represents very large firms, which are very likely to engage in some sort of international trade, such that exchange rate movements would affect them.

2. In order to deflate the nominal values from the Compustat database, I use the NBER-CES Manufacturing Industry Database, which has 4-digit SIC level deflators for capital stock, investment, materials and sales and proceed with instructions in the technical notes by Becker et al. (2013).

3. Since export destination-level information is unavailable, I cannot use bilateral exchange rates. Hence, I use the Real Narrow CPI-based Effective Exchange Rate database (Index: 2010 = 100) from the Bank of International Settlements, which is available from 1964. An increase in the real effective exchange rate (REER) means an appreciation. It is the trade-weighted effective exchange rate between U.S and 26 other economies, which include the major trading partners.[3] Figure 1 shows the evolution of the real effective exchange rate. There are two major periods of appreciation and three periods of depreciation within the duration of the sample.

Table 4 shows descriptive statistics of the key estimation variables. Markup is defined as the price-cost margin. In other words, an average markup of 1.43 implies that, on an average, firms in the Compustat

[3]However, it doesn't include China, Brazil and India, which are also major trading partners of the U.S.

Table 1: Industry Composition of Compustat firms, 1962-2011

2 digit SIC code	Industry name	Number of firms
20	Food and Kindred Products	141
21	Tobacco Products	5
22	Textile Mill Products	72
23	Apparel and Other Textile Products	0
24	Lumber and Wood Products	50
25	Furniture and Fixtures	35
26	Paper and Allied Products	52
27	Printing and Publishing	97
28	Chemical and Allied Products	453
29	Petroleum and Coal Products	46
30	Rubber and Misc. Plastic Products	136
31	Leather and Leather Products	0
32	Stone, Clay and Glass Products	44
33	Primary Metal Products	111
34	Fabricated Metal Products	113
35	Industrial Machinery and Equipment	636
36	Electronic Equipment	772
37	Transportation Equipment	252
38	Instruments	797
39	Misc. Manufacturing Industries	105
Total	Manufacturing Industry	3917

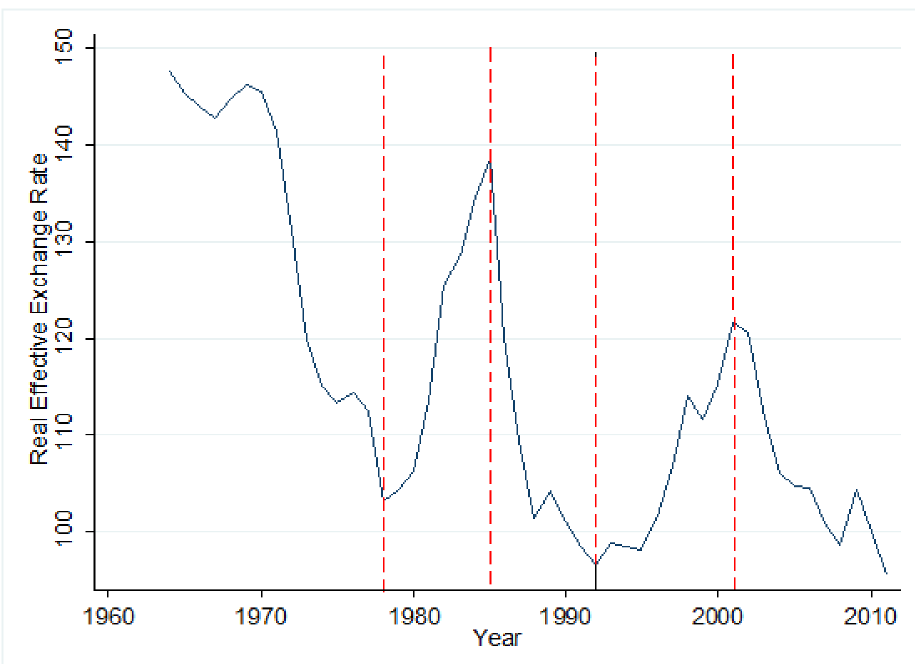
Table 2: Firm composition by age, 1962-2011

Age	Number of firms
60	3
50	4
40	140
30	399
20	930
10	1988

Table 3: The representativeness of the Compustat sample

Year	Total number of firms	Number of Compustat firms	Percentage share of employment
1980	270322	1273	48.46
1990	298052	1536	40.87
2000	291743	1678	45.03
2010	241097	1046	56.90

Figure 1: REER between U.S. and 26 other countries, 1964-2011, Index: 2010 = 100, increase = appreciation



sample charge a markup of 43 percent.

Table 4: Descriptive Statistics of Compustat firms, 1964-2011, N = 45890

variable	**mean**	**median**	**std. dev.**
markup	1.43	1.15	0.99
ln(markup)	0.21	0.14	0.50
ln(Total Factor Productivity)	1.62	1.55	1.18
REER (Index: 2010=100)	112.19	109.21	13.48
ln(REER)	4.71	4.69	0.11
sale (in million$)	1272.14	112.07	6825.11
ln(sale)	4.85	4.72	2.03
employees (in thousands)	7.56	1.07	29.41
age	12.02	9.00	10.23

3.3 Firm-level Variables

3.3.1 Firm-level Total Factor Productivity

The straightforward way to compute Total Factor Productivity (TFP) is to find the residuals from estimating a Cobb-Douglas production function via Ordinary Least Squares (OLS). However, there are several more evolved ways to do this.[4] I will be using the Levinsohn and Petrin (2003) approach.

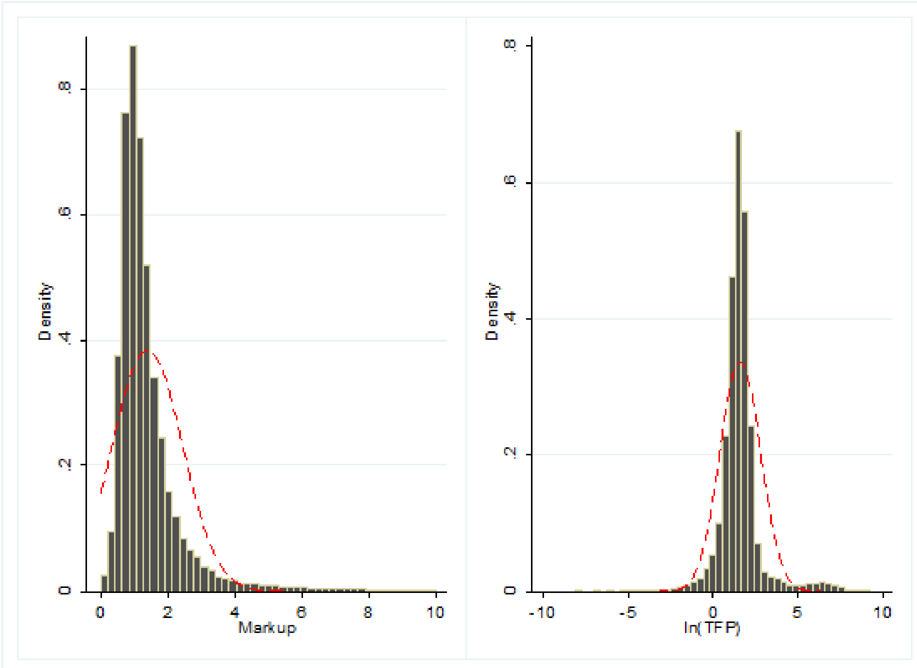
In estimating the parameters of a production function, there could be potential correlation between input choices and firm-specific productivity shocks that are unobserved by the econometrician but observed by the firm. This will lead to biased estimates of the input co-efficients. To solve this endogeneity problem, Levinsohn-Petrin used intermediate inputs to proxy for an unobserved time-varying productivity shock. More precisely, assuming a Cobb-Douglas specification in logarithm terms, we have:

$$y_{it} = \beta_0 + \beta_l l_{it} + \beta_k k_{it} + \beta_i i_{it} + \omega_{it} + \eta_{it}, \tag{4}$$

where ω_{it} is the productivity observed by firm i, which can be used to potentially make input choices, and η_{it} is the productivity unobserved by both the firm and the econometrician. Capital stock k_{it} is the state variable, labor l_{it} is a freely variable input and i_{it} is any intermediate input such as materials or energy.

[4]The four most popular methods are the Olley and Pakes (1996) approach, the Levinsohn and Petrin (2003) approach, the Blundell and Bond (2000) system-GMM approach, and the apparent labor productivity.

Figure 2: Markup and TFP distribution of Compustat firms, 1962-2011, dashed line = normal density.



In order to solve the endogeneity issue, we write the intermediate input demand as $i_{it} = i(\omega_{it}, k_{it})$. We need to assume that i_{it} is monotonic, i.e, it is increasing in productivity given the state variables. This allows us to invert i_{it} to obtain $\omega_{it} = \omega(i_{it}, k_{it})$.

Now we re-write (4) as

$$y_{it} = \beta_l l_{it} + \phi(i_{it}, k_{it}) + \eta_{it}, \tag{5}$$

where $\phi(i_{it}, k_{it}) = \beta_0 + \beta_k k_{it} + \beta_i i_{it} + \omega(i_{it}, k_{it})$. I take ϕ as a third-order polynomial and run OLS to obtain $\hat{\beta}_l$. This is done as prescribed in Petrin et al. (2004).

3.3.2 Firm-level Markups

I follow the method prescribed by De Loecker and Warzynski (2012) to estimate markups at the firm-level. They rely on standard cost minimization conditions. Consider the following cost-minimization problem: $Min\ P^l_{it} L_{it} + r_{it} K_{it}$ subject to $Y_{it} = Y_{it}(L_{it}, K_{it})$, where P^l_{it} and r_{it} are the prices of labor input and capital respectively. The corresponding Lagrangean is: $\mathcal{L} = P^l_{it} L_{it} + r_{it} K_{it} + \lambda_{it}(Y_{it} - Y_{it}(L_{it}, K_{it}))$. The first-order condition with respect to labor input is $\frac{d\mathcal{L}}{dL_{it}} = P^l_{it} - \lambda_{it} \frac{dY_{it}}{L_i t}$, where λ_{it} can be thought of the marginal cost as $\frac{d\mathcal{L}}{dY_{it}} = \lambda_{it}$. Re-writing the first-order condition yields

$$\frac{dY_{it}}{dL_{it}} \frac{L_{it}}{Y_{it}} = \frac{1}{\lambda_{it}} \frac{P^l_{it} L_{it}}{Y_{it}}$$

This generates the price-marginal cost fraction[5], which they define as the markup:

$$\mu_{it} = \theta^l_{it}/\alpha^l_{it} \tag{6}$$

where θ^l_{it} is the output elasticity of L_{it} and α^l_{it} is the share of expenditures on L_{it} in total sales.

While α^l_{it} is observed in the data, θ^l_{it} is not, and therefore has to be estimated. For labor input, it is in fact equal to $\hat{\beta}_l$ from the Levinsohn-Petrin Cobb-Douglas production function estimation in Section 3.3.1 [6]. Note that I am only able to obtain firm-level markups since I do not have firm-product level information in the dataset. Figure 2 shows the distribution of firm-level markups and firm-level log TFP in the Compustat sample.

3.4 Empirical Results

Result I: Magnitude of markup adjustment: Firms of higher productivity adjust their markups by a higher magnitude and have lower rates of exchange rate pass-through.

By running an estimation on equation (1), I find that a 10 percent increase in productivity of firms will lead to a 0.33 percent increase in firm markups. Following a 10 percent appreciation in the exporter's currency, the firms of lowest productivity will decrease their markups by 2.5 percent, firms of median productivity will decrease their markups by 4.06 percent and firms of the highest productivity will decrease their markups by 5.61 percent. In other words, firms of lowest productivity in the sample have an exchange rate pass-through of 75 percent, while firms of highest productivity have the lowest rates of exchange pass-through at 43.9 percent. The results[7] are quite similar when including lagged values of $ln(TFP)$ or lagged value of $ln(REER)$ instead and can be found in Table 5.

This result can be understood easily with the help of a hypothetical numerical example as follows. Consider two countries, where the dollar is the exporter's currency and the pound is the importer's currency. Suppose that the pound depreciates by 50 percent. With complete pass-through to import prices, the price of the good that was originally priced at £10 should increase to £15. However, as the empirical evidence suggests, pass-through is incomplete. Let us consider the pass-through rates as in Estimation 5. Th following table shows the different adjustments firms of low and high productivity levels would make in this sceario.

[5] Markup is identified as the difference between a firm's variable input cost share and revenue share, where the cost share is not observed but by optimality conditions has to equal the output elasticity of the relevant input.

[6] Under a translog production function, it would be given by $\hat{\beta}_l + 2\hat{\beta}_{ll} l_{it} + \hat{\beta}_{lk} k_{it}$. Under Cobb-Douglas, the estimated output elasticity of labor is constant within each industry and markups vary across firms because of the difference in revenue share. Under translog, markup variation comes both from the variation in the estimated output elasticity and the revenue share.

[7] These results are also robust to a different and less complicated measure of productivity, the apparent labor productivity (value-added per worker).

Table 5: Estimation (1) results

$ln(\mu_{it})$	(1)	(2)	(3)
$ln(TFP_{it})$	0.0334***		
	(0.00578)		
$ln(REER_t)$	-0.251***	-0.272***	
	(0.0529)	(0.0550)	
$ln(REER_t) * \Phi_i$	-0.155***	-0.149**	
	(0.0451)	(0.0469)	
$ln(TFP_{t-1})$		0.0229***	0.0216***
		(0.00629)	(0.00630)
$ln(REER_{t-1})$			-0.302***
			(0.0540)
$ln(REER_{t-1}) * \Phi_i$			-0.159***
			(0.0453)
Intercept	2.123***	2.211***	2.407***
	(0.119)	(0.122)	(0.118)
Number of observations	45890	42958	42697
Number of firms	3843	3653	3653
Firm fixed effects	Yes	Yes	Yes

Robust standard errors (clustered by firms) in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 6: Estimation (2) results

	$ln(volatility_{it})$
$ln(REER_t)$	0.642***
	(0.0756)
$ln(REER_t) * \Phi_i$	-0.277***
	(0.0615)
$ln(sale_{it})$	-0.0187***
	(0.00455)
Intercept	0.919***
	(0.164)
Number of observations	31114
Number of firms	2662
Firm fixed effects	Yes

Robust standard errors (clustered by firms) in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Exporter = United States, Importer = United Kingdom.

		low Φ		**high Φ**	
time	ER	price in £	price in \$	price in £	price in \$
t = 0	\$1 = £1	£10	\$10	£10	\$10
t = 1	\$1 = £1.50	£13.75	\$9.16	£12.25	\$8.16
		ERPT = 75%		ERPT = 45%	
		%△ ER = 50%		%△ ER = 50%	
		%△ price = 37.5%		%△ price = 22.5%	
		%△ markup = 12.5%		%△ markup = 27.5%	

Result II: Frequency of markup adjustment: Firms of higher productivity adjust their markups less frequently.

By running an estimation on equation (2), I find that as firm size increases, markup volatility decreases. Table 6 reports these results. For the firms of lowest productivity, a 10 percent appreciation of dollar will cause markup volatility to increase by 6.42 percent, for median productivity firms, markup volatility increases by 3.65 percent and for firms of highest productivity, markup volatility increases by only 0.88 percent. Therefore, firms of lower productivity have more volatile markups, i.e, they adjust their markups more frequently than do firms of higher productivity in order to remain in competition.

Table 7: Estimation (3) results

	Count of large markup changes
Φ	-0.287***
	(0.0258)
Intercept	-1.228***
	(0.0272)
Number of firms	3318

Robust standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

As a robustness check to this measure of volatility, I use another measure of volatility, which is the incidence of large markup changes as defined in Section 3.1. As we can see in Table 7, a 1 unit increase in productivity leads to a decrease in the count of large markup adjustments by 28.7 percent, which reinforces the previous result that firms of higher productivity do not adjust their markups as frequently as do firms of lower productivity.

3.5 Implications

I summarize the main findings from Section 3.4 as follows:

low Φ	**high Φ**
higher exchange rate pass-through	lower exchange rate pass-through
$\triangle$ markup by smaller amounts	$\triangle$ markup by greater amounts
$\triangle$ price by greater amounts	$\triangle$ price by smaller amounts
$\triangle$ markup more frequently	$\triangle$ markup less frequently
$\triangle$ price less frequently	$\triangle$ price more frequently

If firms of higher productivity are more comfortable in adjusting prices more frequently, this seems to suggest that the price adjustment cost (or menu cost) is lower for them. Menu costs can be characterized as $c = g(\phi) + f$, where one component constitutes the cost of changing catalogues and advertisement that varies with firm size or productivity, and one component which has to be incurred by all firms irrespective of their levels of productivity. The latter component is lump-sum and can be thought of to include managerial costs of implementing a price change. If menu costs as a whole are lower for more productive firms, then it is this fixed or lump-sum component of menu costs that is important for explaining the heterogeneous markup adjustment behavior of firms that we have observed in this paper. In the presence of such lump-sum menu costs, large firms will exhibit greater price flexibility (or lower markup flexibility) since the adjustment cost per unit of output will be lower for them. A theoretical model of heterogeneous firms such as Melitz and Ottaviano (2008), along with fixed price adjustments costs will be able to give us the cut-off productivity levels for firms that choose to incur menu costs and adjust their prices versus firms that choose to stick to their original price, following an exchange rate shock.

4 Conclusion

In this paper, I tested important empirical predictions from international trade models linking trade behavior and firms markups. My empirical exercise using firm-level panel data for U.S. manufacturing firms over 50 years produced the following results: firms of higher productivity have lower rates of exchange rate pass-through to export prices, however, firms of higher productivity also have less volatile markups, i.e, they adjust their markups less frequently than do firms of lower productivity. The higher magnitude of markup adjustment by more productive firms suggests that the markups of more productive firms are more responsive to exchange rate movements, however the higher frequency of markup adjustment by less productive firms suggests that the markups of less productive firms are more responsive to exchange rate movements. The former explanation supports the theoretical model of endogenous markups by Melitz and Ottaviano (2008). However, the magnitude of change is not enough to explain the lack of response of exchange movements on aggregate prices. The latter explanation suggests that the price adjustment costs faced by more productive firms are lower. This can be explored in a theoretical model of heterogeneous firms, endogenous markups and random price adjustment costs.

The availability of trade data on export information could improve our understanding of such firm-level behavior. This will be tackled in future work.

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A Data Appendix

The main data source for firm-level productivity and markup estimation is the CSRP/Compustat merged (CCM) fundamental annual database. I use annual data from 1962 to 2011 for only U.S. manufacturing firms (Standard Industrial Classification 2000-3999).

The key variables for estimating the firm-level productivity are output, capital input, material input, labor input and age of the firm, which are calculated as follows:

- Output = Net Sales/Deflator for shipments

- Capital Input is calculated using the Perpetual Inventory Method, where $K_t = K_{t-1} + I_{t-1} - d_{t-1}K_{t-1}$, where d_t is the industry-level rate of depreciation.
  Initial Capital Stock = Property, Plant and Equipment/New investments price index
  Investment = Capital Expenditures/New investments price index

- Material input = (Cost of goods sold + Administrative and Selling Expenses - Depreciation - Wages)/Deflator for total cost of materials, where Wages = average wage at the industry level * number of workers in the firm

- Labor input = number of workers

- Value-added = Real Sales - Real Material Input

All the deflators and industry-level variables mentioned above are from the NBER-CES Manufacturing Productivity Database.