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Price Adjustment to Exchange Rates and Forward-looking Exporters: Evidence from USA–China Trade

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Abstract

This paper shows that the pricing behavior of exporting firms exhibits a "forward-looking" nature with sticky prices. As a result, the expectations of future exchange rates affect current prices at both the product level and firm level. We find evidence by employing both highly disaggregated Harmonized System (HS) 10-digit product-level import data of the USA and firm–product level customs data on China's exports to the USA. These findings provide evidence for a previously unexplored micro-level forward-looking nature of trade price adjustment as response to future exchange rates, and suggest a potentially important factor in helping explain incomplete exchange rate pass-through.

1. Introduction

Price responses to exchange rate movements are one of the central topics in international economics (see the comprehensive literature review by Burstein and Gopinath (2014)). Previous studies have documented the well-known phenomenon of incomplete exchange rate pass-through into import prices.[1] Consequently, many studies have endeavored to provide potential explanations for the low exchange rate pass-through coefficients. Various macroeconomic variables, including the stability of monetary policy, exchange rate volatility and currency choice, have been found to affect the aggregate price response to exchange rate changes.[2] Devereux and Yetman (2010) develop a framework to incorporate slow price adjustment in explaining exchange rate pass-through. Yet, the micro-level evidence for determinants of exchange rate pass-through remains understudied, though the more recent development of the literature has witnessed emerging studies that examine micro-level, especially firm-level, responses to exchange rate fluctuations based on disaggregated trade data (e.g. Berman et al., 2012; Amiti et al., 2014; Chatterjee et al., 2013). A recent example of the micro evidence in pass-through determination is Auer and Schoenle (2016) who use US import price micro data to study firm-level pricing behavior and provide new evidence on the role of firm-level market shares and price complementarities in determining exchange rate pass-through.[3]

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This paper fills a gap in the literature by exploring firms' forward-looking behavior in the presence of sticky prices to provide micro-level evidence that shows how firms adjust trade prices in response to not only current but also future expected exchange rate movements.[4]

The paper first uses a parsimonious framework with price rigidity to explore the firm's pricing behavior in response to expectations of future exchange rate movements. In this parsimonious model, we show that exporting firms (sellers) take anticipated future exchange rate changes into consideration when they cannot adjust prices frequently. Thus, at the micro-level, an individual firm's pricing decision responds to expected future exchange rate fluctuations. Consequently, from the perspective of importing countries, the observed prices of imported products reflect both current (and past) and future exchange rate fluctuations. This provides the channel by which expected future exchange rate fluctuations "pass through" into current prices at the product level.

Empirically the paper confirms the testable predictions of our simple yet intuitive model that prices positively respond to future expected exchange rate fluctuations, at both the product level and the firm level. In the main tests we use US imports from China (at the Harmonized System (HS) 10-digit product level) and China's exports to the USA (at the firm–product level) to estimate exchange rate pass-through, from both import and export perspectives. We use various forward exchange rates between US dollars (USD) and Chinese Yuan (Renminbi, in short, RMB) as proxies for the market's expectation of future exchange rate movements and compute annualized forward premiums. In our context, the forward premium between USD and RMB is a well-performed indicator for the future exchange rate movements, and forward exchange rates are also highly correlated to professional forecast of exchange rates (see data description in section 4 for more details).

We restrict our main tests using trade data between the USA and China because the reform of China's exchange rate provides an ideal setting to test the role of forward expectations of exchange rates in determining prices.[5] First, the exchange rate reform was preceded by widespread expectation of future appreciation of RMB and the anticipation was subsequently supported by the realized appreciation. This distinguishes China from many cases in which floating exchange rates are characterized by random walk expectations, given the fact that China had clear and substantial movements in her forward premiums based on fundamentals over time. Unlike most non-credible fixed exchange rate regimes, the market's expectations of RMB appreciation were not driven by financial crisis or economy uncertainty. Second, since China had implemented capital control during the sample period, the link between forward premiums and interest rate differentials is broken down. Thus, the forward premium change had little correlation with domestic financial conditions relative to its impact on traded goods competitiveness that alleviates the concern resulting from interest rate movement.

We find that at detailed product level not only current (and past) exchange rate fluctuations but also anticipated future exchange rate changes effectively pass through into import prices. The price response to expected future exchange rate changes accounts for approximately one-third of the total "pass-through" coefficient. In other words, using only past and current exchange rates to compute the pass-through elasticity, a typical practice in the literature, would overlook a significant proportion of the price responses to exchange rate fluctuations. In this sense, when accounting for price responses to future exchange rate fluctuations, we find larger pass-through coefficients on import prices, which serves as an explanation for incomplete exchange rate pass-through into import prices. From exporters' perspective, our finding is supported by firm(–product)-level data when using exports of China to the USA: exporting firms indeed adjust their prices in response to expected future exchange rate movements.

We also conduct some further tests to address heterogeneity across product and robustness across country as well as under different trade regimes. For example, we distinguish exchange rate pass-through by product heterogeneity using the Rauch's product classification (Rauch, 1999) and find that future exchange rate changes influence current prices more significantly for heterogeneous than for homogeneous products. In robustness, we extend our sample to cover the major trade partners of the USA. This cross-country analysis explores price adjustment to exchange rate movements in a more comprehensive setting by incorporating cross-country variation and controlling for country and product fixed effects. In addition, we use firms operating under different trade regimes, including both ordinary trade and processing trade, to check the robustness of our results. For both types of trade regimes, future exchange rate changes can effectively pass through into current prices.

This paper relates to several branches of the literature. First, our paper is closely related with the emerging studies that explore micro-level evidence to study firms' responses to exchange rate movements (e.g. Amiti et al., 2014; Berman et al., 2012; Chatterjee et al., 2013).[6] Our paper contributes to this literature in two ways: (i) at the product level, this paper verifies that expectations of future exchange rate movements would pass through into the current prices of imported goods; (ii) at a more micro-level using firm–product export data, this paper confirms that exporting firms' pricing behavior indeed responds to future exchange rate fluctuations. To sum up, our paper reveals a previously overlooked micro-level pass-through effect of future exchange rates, and suggests a potentially important factor in helping explain incomplete exchange rate pass-through.

Second, this paper is inspired by the theoretical framework on sticky prices in international macroeconomics, e.g. Fuhrer and Moore (1995a,b), Fuhrer (1997), Chari et al. (2000) and Calvo (1983). Our model builds upon the sticky price models (Chari et al., 2000; Calvo, 1983, among others) that show the "backward and forward looking" effects of macroeconomic shocks (such as money supply shocks) on firms' pricing behavior. Our paper links the "forward-looking" nature of exporting firms to exchange rate fluctuations with micro-level empirical evidence.

Our paper is also related to a literature that identifies the effect of RMB appreciation based on USA–China trade. For example, Auer (2015) quantifies the effect of RMB appreciation on the price decision of US domestic producers and on aggregate US producer price inflation. By solving the endogeneity issue, Auer and Fischer (2010) offer better estimates on the effect of import competition from China and other low-wage countries on US inflation level. Tang and Zhang (2012) also explore exporters' responses with the background of China's exchange rate reform.

Lastly, this paper is related to a large body of literature seeking various explanations for the incomplete exchange rate pass-through elasticity.[7] These studies explore the disconnect between exchange rates and prices from either the macro (aggregate level) or micro perspective (disaggregate level). Among these studies, our paper is closely related to those exploring the role of price rigidity (Choudhri and Hakura, 2015; Devereux et al., 2004) and frequency of price adjustment (Gopinath and Itskhoki, 2010) in determining the "incomplete" pass-through coefficients. But we focus on micro evidence of firms' forward-looking behavior.

The remainder of the paper is organized as follows. Section 2 presents a simple model that incorporates forward-looking behavior into firms' pricing decisions. Section

3 introduces the context of China's exchange rate reform and section 4 describes the data and measurement issues. Section 5 presents the econometric specifications. Sections 6 and 7 report empirical results from the perspectives of product-level imports of the USA and of firm–product-level exports of China to the USA, respectively. When we examine the exports of China, we also include the analysis using firm-level price index. Section 8 concludes.

2. Exporter's Pricing Decision with Price Rigidity

We use a parsimonious model in line with Chari et al. (2000) and Calvo (1983) to describe an incumbent exporting firm's pricing decision under price rigidity. By assumption, $1 - \beta$ proportion of firms can adjust prices in every period. In other words, the sticky price parameter is β; if there is no price rigidity, we have $\beta = 0$. We also assume that exporting firms use local currency pricing (e.g. Chinese exporters use the US dollar to denote their selling prices).[8] e_t is the current exchange rate of the domestic currency with a foreign currency and, thus, an increase in e_t denotes domestic currency appreciation.

Firms engage in monopolistic competition within a sector. The foreign demand equation follows $Q_i = o p_i^{-\rho} P_t^{\rho-\eta}$, where p_i is the price charged by a representative firm i, P_t denotes the aggregate price level at time t, ρ and η ($\rho > \eta > 1$) represent the elasticities of substitution of varieties within the sector and across sectors, respectively, and o is a constant.

The optimal price $\overline{p_t}$, chosen by an incumbent firm i in period t to maximize profits, is denominated in the currency of the buyer (i.e. the destination country's currency) and solves the following optimization problem (where the subscript i is suppressed without loss of generality):

$$\max_{\overline{p_t}} E_t \left\{ \sum_{j=0}^{n} \beta^j e_{t+j}^{-1} (\overline{p_t} - c_{t+j}) \left[o \overline{p_t}^{-\rho} P_{t+j}^{\rho-\eta} \right] \right\} \tag{1}$$

where c_{t+j} is the unit cost of production (also denominated in the destination country's currency) and j is the forward horizon (from 0 to a limited period n). Solving this optimization problem yields:

$$\overline{p_t} = \frac{\rho}{\rho - 1} E_t \frac{\sum_{j=0}^{n} \beta^j e_{t+j}^{-1} c_{t+j} P_{t+j}^{\rho-\eta}}{\sum_{j=0}^{n} \beta^j e_{t+j}^{-1} P_{t+j}^{\rho-\eta}}. \tag{2}$$

With the presence of sticky prices ($\beta > 0$), the optimal price set by firm i is a function of not only cost c_t and current exchange rate e_t but also expected future cost $E_t c_{t+j}$ and expected future bilateral exchange rate $E_t e_{t+j}$.[9] If there is no price rigidity ($\beta = 0$), the optimal price equals $\frac{\rho}{\rho-1} c_t$, which is the typical case of constant mark-up under monopolistic competition.

After log-linearizing the optimal price $\overline{p_t}$ around its steady state, we find that export price fluctuation $\tilde{p}_t$ (hereafter, $\tilde{x}$ denotes the change in x) depends on fluctuations of both current and future production costs, $\sum_{j=0}^{n} E_t \tilde{c}_{t+j}$, where $\tilde{c}_{t+j}$ is also denominated in the foreign currency:

$$\tilde{p}_t = (1-\beta)\sum_{j=0}^{n} E_t\beta^j \tilde{c}_{t+j}. \tag{3}$$

In this sense, price fluctuation depends on the production cost denominated in the destination country's currency. In a simple case in which a firm uses only domestic intermediate inputs, the production cost in terms of the foreign currency follows $c_t = e_t P_t v_d$, where v_d is an input bundle, P_t is the domestic aggregate price level. Thus, the cost fluctuation function follows $\tilde{c}_t = \tilde{P}_t + \tilde{v}_d + \tilde{e}_t$. Then, the fluctuation in the exporter's price denominated in the foreign currency generally follows $\tilde{p}_t = (1-\beta)\sum_{j=0}^{n} E_t\beta^j (\tilde{P}_{t+j} + \tilde{v}_d + \tilde{e}_{t+j})$. When we suppress the changes in intermediate input costs $\tilde{v}_d$ and in the domestic aggregate price level $\tilde{P}_{t+j}$,[10] then export price fluctuations depend on current and anticipated future exchange rate fluctuations, as follows:

$$\tilde{p}_t = (1-\beta)\sum_{j=0}^{n} E_t\beta^j \tilde{e}_{t+j}. \tag{4}$$

Proposition 1. *In the presence of sticky prices, firms adjust current export prices according to both current exchange rate fluctuations $\tilde{e}_t$ and expectations of future exchange rate fluctuations $E_t\tilde{e}_{t+j}$.*

Now we focus on price level within the sector. At the aggregate level, only a proportion of firms $(1-\beta)$ in the sector adjust prices, while the other proportion of firms (β) at the sector remains at the previous price level. Assuming that firms are producing and exporting a certain product h, the aggregate price level of the exported product h, P_t^h, follows $P_t^h = (1-\beta)\bar{p}_t + \beta P_{t-1}^h$. Then, the aggregate price fluctuations within the sector follow $\tilde{P}_t^h = (1-\beta)\tilde{\bar{p}}_t + \beta\tilde{P}_{t-1}^h$. Iterating it over time yields

$$\tilde{P}_t^h = (1-\beta)^2 \sum_{i=0}^{n} \beta^i \sum_{j=0}^{n} \beta^j E_t \tilde{e}_{t+j-i}. \tag{5}$$

Proposition 2. *Price fluctuations at the aggregate level (product level) reflect past, current and expected future exchange rate changes*, i.e. $\tilde{e}_{t-j}$, $\tilde{e}_t$ and $E_t\tilde{e}_{t+j}$.

3. Exchange Rate Reform in China

Our main tests are based on bilateral trade between China and the USA during the period from 2000 to 2008. The sample period features a change in the Chinese exchange rate regime. In July 2005, China officially announced and adopted a managed floating exchange rate regime to replace the previous peg to the US dollar. As a result, the spot rate between the USD and RMB has appreciated since July 2005. However, examining global forward markets reveals that the forward exchange rates moved substantially before the announcement of the reform in July 2005. As early as 2003, the 1-year forward and 6-month forward RMB/USD exchange rates had begun to appreciate. This shows that the market had anticipated the long-run future appreciation of the RMB. Since 2003, there had been widespread debate and discussions on

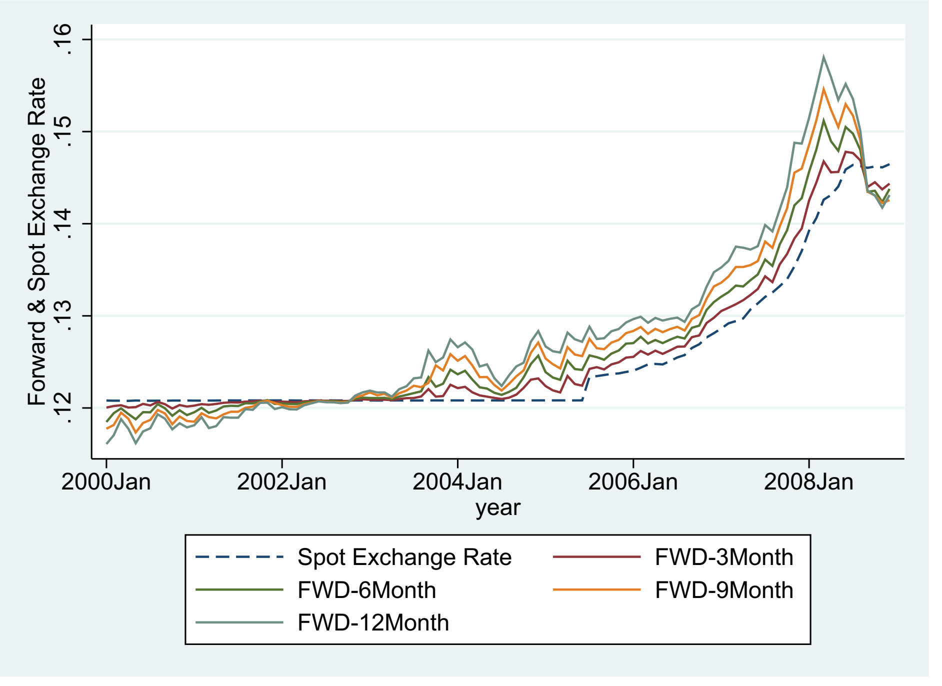

Figure 1. Monthly Forward & Spot Exchange Rates Between RMB and USD (Jan 2000–Dec 2008)

the necessity and feasibility of exchange rate reform, and the Chinese government faced increasing pressure to raise the value of the RMB.

Figure 1 displays the pattern of the monthly RMB/USD nominal exchange rates (spot rates) and forward exchange rates. Note that the nominal exchange rate (the dashed line) was flat before July 2005 and appreciated gradually thereafter. However, the forward exchange rates for the RMB (including the 3-, 6-, 9- and 12-month forward) appreciated as early as late 2003, especially for the 9-month and 12-month forward exchange rates. This represents a substantial increase in the expected value of the RMB during the period of exchange rate reform.

The reform of China's exchange rate represents a unique setting to explore firms' pricing behavior under the expectation of future exchange rate fluctuations. In general, because China had implemented capital control during this period, the link between forward premiums and interest rate differentials is broken down. Thus, the forward premiums on exchange rates had little correlation with domestic financial conditions.[11] Because of the trend in China's growth, the announcement of the exchange rate reform was preceded by widespread anticipation of future currency reform and the appreciation of the RMB. Therefore, unlike many cases in which floating exchange rates are characterized by random walk expectation, China had clear and substantial, albeit time-varying, movements in its forward premiums based on fundamentals. The expectation of RMB appreciation was subsequently supported by the realized appreciation after July 2015. Unlike most non-credible fixed exchange rate regimes, China's forward premiums during this period were not driven by the probability of a currency or other type of crisis.

In the previous literature, the choice of an invoicing currency is considered to influence pass-through elasticity, e.g. Gopinath et al. (2010), Devereux et al. (2004), Parsons and Sato (2006), Goldberg and Tille (2009) and Choudhri and Hakura (2015). If firms are flexible in switching invoice currency, it may weaken the accurateness of our estimation. However, our main econometric estimations are confined to bilateral trade between the USA and China. By restricting our data to USA–China bilateral trade in the main tests, we can better avoid the invoicing currency issue because the majority of trade transactions between the USA and China use the USD as the invoicing currency. When the USD is used as the invoicing currency, fluctuations in the exporting country's domestic currency (RMB) directly affect exporters' revenue and, thus, exporting firms will have an incentive to adjust export prices. In the later cross-country analysis, we extend our empirical tests to a larger sample with the major trading partner countries of the USA.

4. Data and Measurement

We compile three sources of data to conduct our empirical analysis, including exchange rate data, product-level import data of the USA and firm–product-level export data of China. We describe each as follows.

First, the data on exchange rates include both spot exchange rates and forward exchange rates that are obtained from Bloomberg. Forward exchange rates are non-deliverable forward (NDF) rates between USD and RMB in the foreign exchange market as a proxy for expected future exchange rates. Forward rates in our tests cover various maturities, namely, 3-, 6- and 12-month forwards, and indicate the trend in market expectations of exchange rate fluctuations. The forward rates with different maturities are highly correlated with each other.[12]

One might be concerned whether forward rates adopted in this paper serve as valid measurements for the expected future exchange rates (Fama, 1984), but our data shows that between RMB and USD the forward exchange rate FWD_t is a strong predictor of future realized spot exchange rate S_{t+1} (for example, see Figure 1 for strong co-movements between the two).[13] The correlation between forward rates FWD_t and realized future spot rates S_{t+1} ranges from 0.88 to 0.98.[14] The high correlation shows that forward rates have a strong prediction power on realized future exchange rates. The high correlation suggests that the forward exchange rate here is a valid measurement for the realized future spot exchange rate. Also, the forward premium ($\Delta fwd_t \equiv \log FWD_t - \log S_t$) between RMB and USD is positively correlated with realized future exchange rate movement ($\Delta exr_{t+1} \equiv \log S_{t+1} - \log S_t$), indicating that the forward premium is a well-performed indicator for the future realized exchange rate movements.[15]

It might be interesting to find alternative proxies for expected future exchange rates, for example, some professional forecast data of exchange rates. We thus collect the quarterly FXFC Foreign Exchange Forecast Index released by Bloomberg, which is based on the survey of forecasts of foreign exchange rates from 26 individual forecast providers. Bloomberg reports a very high correlation (above 0.94) between forward exchange rates and the FXFC Index of USD–RMB. This suggests that the forward rates are indeed an accurate proxy for expected future exchange rates.[16]

The second data source for examining the exchange rate pass-through into product prices is the product-level import data provided by the US Census Bureau.[17] This database documents imported products of the USA at detailed HS 10-digit level on a yearly basis. This sample includes import information for each HS10 product, such as import value (excluding tariff and other charges), import quantity and origin country, and spans from 2000 to 2008.[18] Then we calculate unit value import prices at HS10 product level using import value of each product divided by import quantity of that product. As the HS10 is a highly detailed product categorization scheme, the unit value is an accurate proxy for price in our estimations. Though this database records detailed product-level US import, it also has its limitations for estimating pass-through, e.g. annual basis, without invoicing currency information, and so on.

Lastly, the Chinese customs data (2000–2008) on firm–product-level exports to the USA are used to test exporting firms' pricing behavior under exchange rate fluctuations. The Chinese customs data is a transaction-level database that contains disaggregated records on each firm's export value, quantity, product category (HS8), destination country and trade regimes (processing trade or ordinary trade). It is the most comprehensive high-frequency trade database in China that captures the universe of all export transactions through Chinese Customs.[19] Because we can observe changes in the export value and quantity of all products exported by each firm, we are able to compute firm–product unit value export prices to investigate price responses to exchange rate movements. Since China adjusts HS8 product categories from time to time while the concordance of Chinese HS8 product over time is not available to us, we aggregate HS8 product-level information to the HS6 level for the concord of the product codes consistently over time as in Fan, Li and Yeaple (2015).

5. Estimation of Price Adjustment to Exchange Rate Fluctuation

Since the model has predictions at both product level (see Proposition 2) and firm level (see Proposition 1), we will use data to test the price responses to current and future exchange rate movements. In this section, we introduce our estimation approach of exchange rate pass-through elasticity.

Following the conventional practice in the exchange rate pass-through literature, the change in the logarithm of prices is calculated as the dependent variable and the change in the logarithm of spot exchange rates is the main explanatory variable. Beyond that, we add future exchange rate changes as another important explanatory variable. For example, in the product-level analysis, we regress the US import price on exchange rate changes, including both current and anticipated future exchange rates (see equation (8) in section 6). The aim of this analysis is to measure the pass-through of expected future exchange rate fluctuations into import prices at the product level. According to our model predictions, positive coefficients for both current and forward exchange rates are expected. In further tests, we check the pass-through elasticity of expected future exchange rates into import prices for homogeneous and heterogeneous products to capture the importance of product homogeneity. We also conduct the product-level analysis for US imports from other trading partners (based on major currencies) to examine the effect of expected future exchange rates across countries.

We next investigate the export price response to exchange rate changes, especially to anticipated future exchange rate movements, from each individual exporting firm's perspective. This exercise aims to seek a micro-foundation for the pass-through effect observed in the product-level analysis. In this exercise, we define disaggregated (firm–product) prices in two aspects: one is the export price charged by an exporting firm for each specific product, and the other is a constructed firm-level price index.

Now we use a simplified econometric model (with a representative product) to illustrate our estimation approach. Note that the product index will be suppressed in this section for simplicity. In the typical practice of the literature, the pass-through elasticity can be obtained from the following estimation:

$$\Delta p_t = \beta \Delta exr_t + \eta_t \tag{6}$$

where $\Delta p_t \equiv p_t - p_{t-1}$ is log price changes, Δexr_t is the realized exchange rate changes at time t and η_t is an error term. This is the simplified version of pass-through estimation, and more control variables can be added when necessary. Now, by incorporating the price response to the expected future exchange rate into the pass-through estimation, our approach follows

$$\Delta p_t = \beta_1 \Delta exr_t + \beta_2 \Delta fwd_t + \mu_t \tag{7}$$

where forward premium Δfwd_t is included as explanatory variable and μ_t is error term. We do not add other lagged terms to capture the past exchange rate fluctuations because 1-year difference already incorporates price adjustments to both past and current exchange rate changes when using yearly data.[20]

According to Proposition 2 of our model, we expect to see $\beta_1 > 0$ and $\beta_2 > 0$ because price changes at aggregate product level always reflect both current and expected future exchange rate changes. This suggests that not only current (and past exchange rates) but also expected future exchange rates can effectively pass through into import price changes. Including the term of expected exchange rate changes would improve the estimates of exchange rate pass-through elasticity ($\hat{\beta}$) in equation (7) since it would alleviate the omitted variable issue in the conventional estimation as in equation (6).

We acknowledge that it is a challenge to solve the endogeneity issue of the spot exchange rate in the pass-through estimation empirically (although it could be addressed with theoretical framework and simulation, e.g. Devereux et al. (2004)). To our knowledge, previous empirical studies of pass-through estimation rarely tackle the endogeneity issue of spot exchange rate.[21] Now adding forward premium Δfwd into exchange rate pass-through estimation further brings on new complications.

The potential endogeneity in pass-through estimation with both spot and forward exchange rate fluctuation is more likely caused by omitted variables but less likely caused by simultaneity and measurement error since the standard exchange rate pass-through estimation specification is well-defined in the literature and uses nominal exchange rates rather than real exchange rates. The concern of potential omitted variables might primarily come from financial or other macroeconomic conditions and invoicing currency choice. For example, the macroeconomics condition may affect price level, and also interacts with exchange rate movement in an open economy. Exporters may also have incentive to switch invoice currency when anticipating appreciation.[22]

Fortunately, the potential endogeneity concerns may be alleviated, to a large extent, under the China–USA trade context, because China adopts a strict capital control policy during the sample period, which cuts down the linkage between exchange rate fluctuations and interest rate differentials. Also, the majority of Chinese exporters use the USD as an invoicing currency and are unable to switch it with flexibility.[23] However, there is still a concern of a potential endogeneity issue coming along with future exchange rate expectations. To fully eliminate the endogeneity issue for both spot and future exchange rates, an improved econometric estimation with valid instruments is desirable and would be fruitful as an important direction for future study. On this regard, Auer and Fischer (2010) offers an inspiring hint on solving the related endogeneity issue under a different context when studying the effect of import competition from low-wage countries on US prices where the weighted growth rate of low-wage countries' industrial output interacted with US sectoral labor intensity serve as an instrument for trade flows.

6. Exchange Rate Pass-through into US Import Price

The two propositions in our model will guide our empirical analysis. We start with Proposition 2 to test the price responses to current and future exchange rate movements at the product level. In this section we will use highly detailed HS10 product-level import data from the US Census Bureau to estimate exchange rate pass-through into import prices. In the first two parts of the product-level analysis, we use imports of the USA from China, covering all goods, differentiated goods and homogeneous goods (by product heterogeneity). In the last part, to examine the heterogeneity of the current and expected exchange rate pass-through elasticities across countries, we conduct the product-level analysis for US imports from other major trading partners.

US Import Prices and Expectation of Future Exchange Rates

Using highly disaggregated data on imports of the USA from China, we estimate the elasticity of the pass-through of current and expected future exchange rates into HS10 product import prices. The baseline specification is as follows:

$$\Delta p_{ht} = \beta_1 \Delta exr_t + \beta_2 \Delta fwd_t + \beta_3 \pi_t + F_h + \varepsilon_{ht}. \tag{8}$$

To be consistent with the annual US import data, we will use yearly difference estimation starting from this section (i.e. the time subscript t is year hereafter). The log price difference (Δp_{ht}) for product h (defined at the HS10 level) in year t is the dependent variable; current exchange rate changes Δexr_t and forward exchange rate fluctuations Δfwd_t are the main explanatory variables. To control for the inflation rate π_t, we use the exporting country's domestic consumer price index (CPI)-based inflation index. Product fixed effects F_h are also included in the regression to capture the time-invariant product heterogeneity in exchange rate pass-through elasticity.[24] Thus, standard errors are also clustered at the product level.

As the import data are annual data, both price changes and current exchange rate fluctuations are calculated on a yearly basis. For the dependent variable Δp_{ht}, i.e. product-level price changes, we include both unweighted and weighted (by quantity) average unit values as the price for each product. We adopt the weighted unit value price because there may be multiple transaction records of a single HS10 product in the original data even for the same trading partner country of the USA. For the main independent variable, forward rate fluctuations forward premium Δfwd_t, we employ two measures: an annualized forward premium $\Delta fwd1$ based on forward exchange rates with 3-month maturity and an annualized forward premium $\Delta fwd2$ based on forward rates with 12-month maturity.[25] Current exchange rate fluctuations Δexr_t are also included in the regression to capture the price response to the realized exchange rate movements, following the standard estimation of pass-through elasticity in the literature.

Table 1 reports the baseline results. The left panel presents the results of unweighted price regressions and the right panel presents the weighted results. We find that the current exchange rate pass-through coefficients are quite stable across

Table 1. Exchange Rate Pass-through to Import Price: US Imports from China

	Dependent variable: Δp_{ht}					
	Unweighted price			*Weighted price*		
	(1)	(2)	(3)	(4)	(5)	(6)
Δexr	0.426**	0.475**	0.445**	0.426**	0.473**	0.444**
	(0.185)	(0.187)	(0.187)	(0.185)	(0.187)	(0.187)
$\Delta fwd1$		0.328*			0.326*	
		(0.191)			(0.191)	
$\Delta fwd2$			0.249			0.248
			(0.220)			(0.220)
Inflation	1.957***	1.709***	1.746***	1.955***	1.709***	1.745***
	(0.292)	(0.339)	(0.369)	(0.292)	(0.339)	(0.369)
Product fixed effects	Yes	yes	Yes	yes	yes	yes
Observations	74,606	74,606	74,606	74,606	74,606	74,606
Adjusted R^2	0.053	0.053	0.053	0.053	0.053	0.053

Notes: $*p < 0.10$; $**p < 0.05$; $***p < 0.01$. Robust standard errors clustered by product in parentheses. Prices and exchange rates are in logarithm. A constant term is included in all regressions. The R^2 reported is the overall R^2 value. Columns (1)–(3) use unweighted prices and columns (4)–(6) use weighted prices. The unweighted price is computed as unit value price by dividing value by quantity; the weighted price is weighted unit value prices weighted by the quantity of each individual transaction within the same product. The explanatory variable Δfwd (forward premium) is computed as annualized forward premium based on different maturity: $\Delta fwd1$ (the annualized forward premium is computed based on 3-month maturity), and $\Delta fwd2$ (the annualized forward premium is computed based on 12-month maturity).

different specifications, ranging from approximately 0.4 to 0.5 for both the weighted import price and the unweighted import price. Annualized 3-month forward exchange rate changes have a pass-through elasticity of approximately 0.3 into import prices and 1-year forward changes also obtain positive coefficients of approximately 0.25. Thus, expected future exchange rates, especially the annualized forward premium with short-run expectation (under 3-month maturity) $\Delta fwd1$, significantly pass through into price changes of imported products. This is consistent with the intuition that producers' forward-looking behavior would more rely on the short-term expectation than the long-term one. In other words, it is relatively more difficult for firms to foresee exchange rate movements with a longer horizon than a short-run horizon.

If we regard the pass-through of exchange rates into prices as a combination of both current and expected future exchange rate changes, the current price adjustment to future changes adds approximately 0.3 to the conventional pass-through coefficients. Summing the coefficients for $\Delta fwd1$ and Δexr, we obtain a larger coefficient for the pass-through elasticity. By accounting for the price responses to expected future exchange rate fluctuations, we find larger pass-through coefficients into import prices. This provides a potential explanation for the incomplete exchange rate pass-through observed in previous studies.

Also note that after including forward expectations, the conventional exchange rate pass-through coefficients become larger in Table 1, i.e. we can compare pass-through coefficients for current exchange rates Δexr in regressions that include forward exchange rates (see columns (2)–(3) and (5)–(6)) with those in regressions without expected exchange rates (see columns (1) and (4)). This indicates that the pass-through of realized exchange rate fluctuations might be strengthened after controlling

Table 2. Exchange Rate Pass-through during Fixed Exchange Rate Period

	Dependent variable: Δp_{ht}					
	Unweighted price			Weighted price		
	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta fwd1$	1.320***			1.305***		
	(0.459)			(0.458)		
$\Delta fwd2$		1.231**			1.213**	
		(0.536)			(0.534)	
$\Delta fwd3$			1.136*			1.114
			(0.685)			(0.683)
Inflation	yes	yes	yes	yes	yes	yes
Observations	38,546	38,546	38,546	38,546	38,546	38,546
Adjusted R^2	0.216	0.216	0.216	0.216	0.216	0.216

Notes: $^*p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$. Robust standard errors clustered by product in parentheses. Prices and exchange rates are in logarithms. A constant term is included in all regressions. The R^2 reported is the overall R^2 value. Fixed exchange rate period with expected exchange rate changes lasts from 2003 to 2006. Columns (1)–(3) use unweighted prices and columns (4)–(6) use weighted prices. Unweighted price is computed as unit value price by dividing value by quantity; weighted price is weighted unit value prices weighted by the quantity of each individual transaction within the same product. The explanatory variable Δfwd (forward premium) is computed as annualized forward premium based on different maturity: $\Delta fwd1$ (the annualized forward premium is computed based on 3-month maturity), $\Delta fwd2$ (the annualized forward premium is computed based on 6-month maturity), and $\Delta fwd3$ (the annualized forward premium is computed based on 12-month maturity).

for price responses to changes in expectations of future exchange rates, while ignoring expected exchange rate movements may bring the estimation bias of pass-through elasticity owing to the potential omitted variable problem. To further employ the unique feature of Chinese data, we also conduct an auxiliary test that captures the fixed exchange rate period with only expected exchange rate movements during 2003–2006 (a subset of the whole sample period). The results (see Table 2) show that the price adjustments indeed significantly respond to forward premium variations.

Import Price Adjustment by Product Heterogeneity

Pricing decisions of firms are affected by the nature of the products that they sell. That is to say, firms' pricing power varies across products, perhaps because firms selling different products may face different demand elasticities, which leads to various scope of price adjustment. Thus, it is important to examine how product heterogeneity relates to exchange rate pass-through. We conjecture that the exchange rate pass-through, especially for future exchange rates, would vary by product heterogeneity: products that are heterogeneous would respond in a more pronounced way than those that are not.

Using the dataset on imports of the USA from China, we assess the pass-through effect of exchange rates for two subsamples: one with heterogeneous and one with homogeneous products. According to Rauch's product classification (Rauch, 1999), products are categorized into "homogeneous", "reference-priced" and "differentiated" where we denote "differentiated" goods as "heterogeneous" products. In Table 3, we list the summary statistics of the number of products imported by the USA from China at the HS 10-digit level in different years in our sample. The heterogeneous products

Table 3. Summary Statistics: Number of HS10 Products the USA Imported from China (by Rauch Index)

Year	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*
Heterogeneous	5,663	5,629	5,656	5,743	5,882	6,128	6,221	5,765	5,740
Reference-priced	1,635	1,684	1,670	1,769	1,904	2,042	2,141	1,934	1,888
Homogeneous	295	305	287	300	309	339	366	330	326

Notes: The categorizing of homogeneous, heterogeneous and reference-priced goods are based on Rauch's product classification (Rauch, 1999). "Hterogeneous goods" refer to "differentiated goods" (those not having a reference price or those whose price is not quoted on organized markets). "Homogeneous goods" are sold on organized exchanges. "Reference-priced goods" are products not sold on organized exchanges but whose benchmark prices exist.

account for 70% of total number of HS10 products that the USA imports from China, reference-priced products account for less than 30% of the total and homogeneous products represent only a small fraction. In the following regression analysis, we include both "homogeneous" and "reference-priced" products into a single group labeled "homogeneous" that would be compared with heterogeneous products.

Table 4 presents the differences in exchange rate pass-through into import prices resulting from the product heterogeneity. The left panel reports the results for the sub-sample of heterogeneous goods and the right panel reports the results for the homogeneous products. The pass-through coefficients of heterogeneous products, for both current and forward exchange rate changes, are larger and more significant than those

Table 4. Homogeneous Products and Heterogenous Products

	Dependent variable: Δp_{ht}					
	Heterogeneous			*Homogeneous*		
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
Δexr	0.479*	0.597**	0.537**	0.440	0.473	0.468
	(0.255)	(0.257)	(0.257)	(0.404)	(0.406)	(0.407)
$\Delta fwd1$		0.811***			0.208	
		(0.255)			(0.435)	
$\Delta fwd2$			0.777***			0.328
			(0.290)			(0.493)
Inflation	1.464***	0.819*	0.776	2.392***	2.233***	2.110***
	(0.399)	(0.460)	(0.499)	(0.626)	(0.741)	(0.806)
Product fixed effects	yes	yes	yes	yes	yes	yes
Observations	36,788	36,788	36,788	14,581	14,581	14,581
Adjusted R^2	0.113	0.114	0.114	0.177	0.177	0.177

Notes: $*p < 0.10$; $**p < 0.05$; $***p < 0.01$. Robust standard errors in parentheses. Robust standard errors clustered by product. Prices and exchange rates are in logarithms. A constant term is included in all regressions. Products are labeled as "heterogeneous" if they belong to "differentiated" goods according to the Rauch index and labeled as "homogeneous" if they belong to "homogeneous" and "reference-priced" goods. The explanatory variable Δfwd (forward premium) is computed as annualized forward premium based on different maturity: $\Delta fwd1$ (the annualized forward premium is computed based on 3-month maturity) and $\Delta fwd2$ (the annualized forward premium is computed based on 12-month maturity). The R^2 reported is the overall R^2 value.

of homogeneous products. This suggests that exchange rate fluctuations are more likely to be reflected in the prices of heterogeneous products.

A potential explanation for this pattern is as follows: producers of heterogeneous products enjoy greater pricing power owing to a larger scope of quality differentiation;[26] however, there is typically a universal market price in USD for the "homogeneous" and "reference-priced" products. When firms export "homogeneous" and "reference-priced" products, they may have little flexibility in adjusting their prices owing to the universal price denominated in USD in the world market. For bilateral trade between the USA and China, firms exporting homogeneous products have little room to change their prices when they forecast exchange rate movements, while exporters of heterogeneous products have greater pricing power and larger scope of price adjustment. They could adjust price with more flexibility when current and future exchange rates fluctuate.

Also, since homogeneous goods have internationalized the trade market with standardized prices, it is easier for producers to hedge exchange rate risk using future derivatives. As a result, homogeneous goods' producers tend to be less sensitive to future exchange rate shocks (as their risks have been already covered by future or forward contracts), and also present "inertia" in adjusting current prices in a "spot contract" as a response to forward rate fluctuations. Thus, we observe larger and more significant coefficients of Δexr and Δfwd for heterogeneous products than those for homogeneous products.[27]

In addition, the test using heterogeneous goods preserves two key features of the baseline result as in Table 1. First, the current price changes respond significantly to both current and forward exchange rate movements (see columns (2) and (3) in Table 4). Second, taking into account the expected future exchange rate changes also enlarges the conventional measure of the exchange rate pass-through elasticity, shown by the coefficients of Δexr, when comparing column (1) with columns (2)–(3).

Cross-country Evidence of Import Price Adjustment

So far, our analysis has been based on US imports from China and our sample period covers the time when the change in China's exchange rate regime occurred, i.e. China switched from a fixed exchange rate regime to a managed floating regime. This feature distinguishes China from other countries, especially those with a flexible exchange rate regime. In this subsection, we now extend the sample by including more countries, i.e. the major trading partners of the USA, and explore the variation in the pass-through coefficients of forward exchange rate fluctuations using a multi-country sample.

In addition to China, our test covers seven other major trading partners of the USA using data on US imports from the UK, South Korea, Japan, Germany, France, Canada and Australia. All seven countries have available bilateral forward exchange rates with the USA. We graph 3-, 6- and 12-month forward exchange rates and the current exchange rate for the major countries in Figure 2. Then we apply similar econometric specification as in the baseline estimation of equation (8) but with the country index as a subscript. The import price changes are regressed on exchange rate fluctuations, including both current and forward exchange rate movements. The results are reported in Table 5.

In this multi-country analysis, we control for both country fixed effects and product fixed effects. According to Table 5, all types of forward exchange rates Δfwd have significant positive coefficients on import price adjustments.[28] Also, adding forward exchange rate fluctuations makes the pass-through coefficients of current exchange

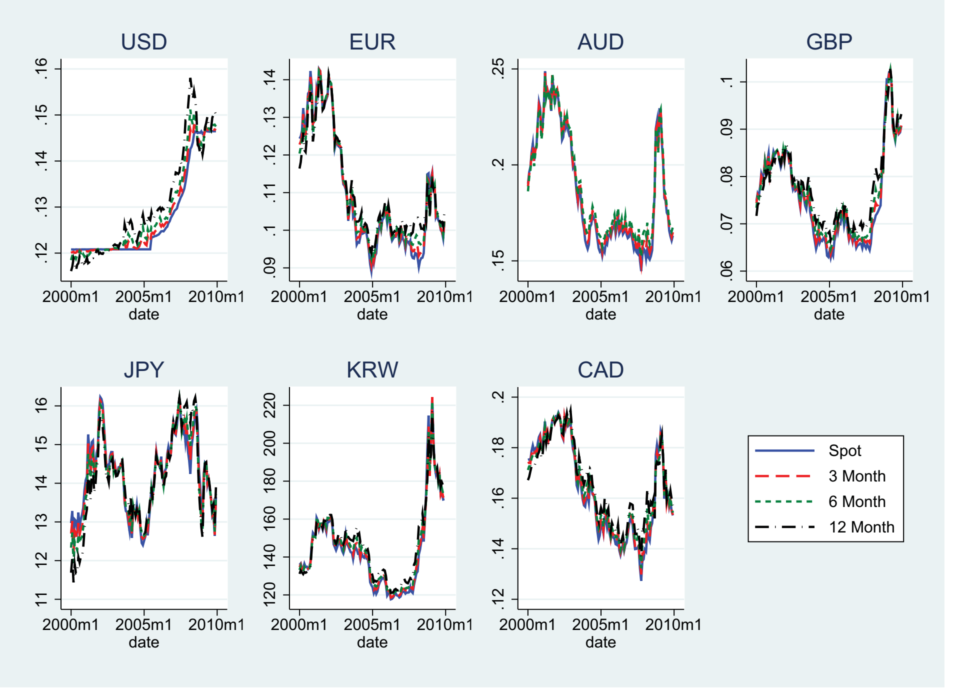

Figure 2. Movement of Exchange Rates across Countries

rates slightly larger than those without expected future exchange rate fluctuations. It reflects that current price adjustment at product level contains price response to the expected future exchange rate movements. By adding the effect of expected future exchange rate movements, the pass-through coefficients on spot exchange rate become more "complete" than without them (see the comparison between specification 1 vs 2–4 and specification 5 vs 6–8). This cross-country robustness analysis supports our main baseline result, which is based on a USA–China trade sample and confirms that future exchange rate fluctuations indeed "pass through" into current prices in a more comprehensive setting.

7. Micro Evidence from Exporting Firms

Now we turn to exporters' perspective to display direct evidence from Chinese exporting firms to justify that firms take expected future exchange rate movements into consideration when making decisions on current prices. Using customs data on Chinese exports to the USA, we are able to observe the prices that exporting firms charge for each product and the price movements with respect to exchange rates (including forward exchange rates). This exporting-firm analysis corroborates the previous product-level analysis since it presents micro-level evidence from the exporting firms' perspective and helps explain the pass-through effect at the product level observed from US imports. In this section, we report export price adjustment at both firm level and firm–product level where product h is defined at HS6 level owing to availability of Chinese customs data (see more discussions on data in section 4).

Table 5. Cross-country Test: US Imports from Major Trading Partners

	Dependent variable: Δp_{hct} (where c indexes country)							
	Unweighted price				Weighted price			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Δexr	0.245***	0.286***	0.279***	0.246***	0.246***	0.286***	0.279***	0.246***
	(0.028)	(0.029)	(0.028)	(0.029)	(0.028)	(0.029)	(0.028)	(0.029)
$\Delta fwd1$		0.747***				0.745***		
		(0.107)				(0.107)		
$\Delta fwd2$			0.729***				0.727***	
			(0.114)				(0.114)	
$\Delta fwd3$				0.844***				0.841***
				(0.121)				(0.121)
Inflation	1.537***	1.226***	1.197***	1.108***	1.535***	1.226***	1.196***	1.108***
	(0.144)	(0.159)	(0.165)	(0.17)	(0.144)	(0.159)	(0.165)	(0.170)
Country fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
Product fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
Observations	465,088	465,088	465,088	444,300	465,088	465,088	465,088	444,300
Adjusted R^2	0.021	0.021	0.021	0.023	0.021	0.021	0.021	0.023

Notes: $*p < 0.10$; $**p < 0.05$; $***p < 0.01$. Robust standard errors in parentheses. Robust standard errors clustered by product. Prices and exchange rates are in logarithms. A constant term is included in all regressions. Columns (1)–(4) use unweighted prices and columns (5)–(8) use weighted prices. Unweighted price is computed as unit value price by dividing value by quantity; weighted price is weighted unit value prices weighted by the quantity of each individual transaction within the same product. The explanatory variable Δfwd (forward premium) is computed as annualized forward premium based on different maturity: $\Delta fwd1$ (the annualized forward premium is computed based on 3-month maturity), $\Delta fwd2$ (the annualized forward premium is computed based on 6-month maturity), and $\Delta fwd3$ (the annualized forward premium is computed based on 12-month maturity). The R^2 reported is the overall R^2 value.

Exporters' Perspective (I): Price Adjustment at Firm Level

To capture exporters' price adjustments, we take the difference of the (log) export price of Chinese firm i between year t and $t-1$, Δp_{it}, as dependent variable.[29] The explanatory variables include the log annualized forward premium based on forward rates between RMB and USD with 3-month, 6-month and 12-month maturity, denoted by Δfwd_t, to reflect future exchange rate expectations.[30] We also control for the log realized exchange rate changes between t and $t-1$, Δexr_t. The domestic inflation rate π_t is added to control for price changes owing to inflation. The firm fixed effects F_i is also included to capture the time-invariant firm characteristics that may affect the change in its pricing behavior. We also conduct the regression without firm fixed effects under the belief that the time-invariant firm effect would be differenced out. Nevertheless, both ways yield qualitatively similar results. The robust standard errors are clustered at the firm level since the current focus is firm-level price response. The econometric specification is given by:

$$\Delta p_{it} = \beta_1 \Delta exr_t + \beta_2 \Delta fwd_t + \pi_t + F_i + \varepsilon_{it}. \tag{9}$$

If firms export multiple sub-categories of products within the main categories, it is natural to think of the price adjustments across sub-categories of products. For example, a multi-product exporter may adjust the prices of certain sub-categories but hold constant prices for other product categories in response to exchange rate fluctuations. Thus, the observed price adjustment at the firm level may be confounded by the adjustments across product sub-categories. To solve this issue we adopt two approaches. First, we examine the firm-level price adjustment by focusing on the major product (at the HS 6-digit level)[31] for each individual firm and single-product firms. Second, we construct a weighted average price index at firm level for each multi-product firm. We introduce each in turn.

Firm-level analysis for major product and single product Table 6 reports regression results for firms with major products in columns (1)–(4) and firms with single products in columns (5)–(8). The top panel does not include product fixed effects, while the bottom panel does. We include product fixed effects in some specifications to capture the potential time-invariant product heterogeneity in exchange rate pass-through elasticity.[32] Note that here we consider product fixed effects instead of firm fixed effects because the dependent variable Δp_{it} in this exercise is in fact product-specific.

In Table 6, both the current exchange rate Δexr and the forward premium Δfwd show significantly positive effects on firm-level price changes. This means that the current export price set by a firm is positively affected by expectations of future exchange rate movements. Let us take columns (2) and (6) (based on 3-month forward rates) of Panel A in Table 6 as example. For firms with major products, the elasticity of future exchange rate fluctuations Δfwd is around 0.19 while that of current exchange rate Δexr is 0.72; for single product firms, the elasticity of Δfwd equals 0.41 and that of Δexr equals 0.47. It suggests that single-product exporters' responses are relatively more sensitive to future exchange rate changes, i.e. the ratio of β_2/β_1 tends to be larger for single-product exporters. One possible explanation is the following. Single-product firms, by definition, have only one product and must focus on that product. In order to maintain its market share, it is natural that the single-product firms pay more attention to stabilizing its price. As a result, single-product firms would tend to set the price in a more "stable" or "sticky" way. In other words, they are more likely to be sensitive to price volatility and thus put more weight in "future" than in "present" in order to keep the long-term profit. Also, multi-product exporters are facing more choices under exchange rate fluctuations, e.g. they could switch product mix to optimize profit.[33] Then the multi-product firms' incentive to maintain stable price is less than single-product exporters.

Comparing column (1) with columns (2)–(4), the realized exchange rate pass-through elasticity becomes larger when adding the expected future exchange rate movements Δfwd. All annualized forward premiums, include 3-, 6- and 12-month forward premiums, have significantly positive coefficients. It is worth noting that the largest coefficients of Δexr among all specifications appear when controlling for 12-month forward premiums, and the current exchange rate pass-through coefficients increase with the time interval of forward rates.

Weighted firm-level price adjustment To complement the above firm-level price analysis, we further construct a firm-level price index to analyze price adjustments to the expected exchange rate fluctuations for exporting firms, especially those multi-product firms. Firm i's export price change in time t, Δp_{it}, is an index calculated as weighted average unit value price change across all HS6 products (indexed by h) exported by firm i in time t and $t-1$, i.e. $\Delta p_{it}=\sum_h s_{ih,t-1}\Delta p_{iht}$, where $s_{ih,t-1}$ is the share

Table 6. Firm-level Export Price Adjustment and Forward Premiums

	Dependent variable: Δp_{it}							
	Firm with major product				Firm with single product			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Without firm fixed effects								
Δexr	0.688***	0.724***	0.739***	0.747***	0.412***	0.466***	0.485***	0.493***
	(0.069)	(0.069)	(0.069)	(0.070)	(0.121)	(0.120)	(0.120)	(0.121)
$\Delta fwd1$		0.194***				0.408***		
		(0.061)				(0.109)		
$\Delta fwd2$			0.279***				0.514***	
			(0.073)				(0.128)	
$\Delta fwd3$				0.353***				0.596***
				(0.082)				(0.143)
Inflation	0.975***	0.810***	0.731***	0.665***	1.018***	0.676***	0.572***	0.492**
	(0.110)	(0.119)	(0.125)	(0.130)	(0.182)	(0.198)	(0.209)	(0.217)
Observations	180,573	180,573	180,573	180,573	57,582	57,582	57,582	57,582
Adjusted R^2	0.006	0.006	0.006	0.006	0.004	0.004	0.004	0.004
Panel B: With firm fixed effects								
Δexr	0.748***	0.800***	0.817***	0.825***	0.400***	0.454***	0.472***	0.479***
	(0.071)	(0.071)	(0.071)	(0.072)	(0.127)	(0.126)	(0.126)	(0.126)
$\Delta fwd1$		0.262***				0.376***		
		(0.062)				(0.111)		
$\Delta fwd2$			0.360***				0.475***	
			(0.074)				(0.131)	
$\Delta fwd3$				0.440***				0.555***
				(0.083)				(0.146)
Inflation	0.983***	0.763***	0.673***	0.601***	1.036***	0.727***	0.630***	0.555**
	(0.111)	(0.120)	(0.126)	(0.132)	(0.188)	(0.204)	(0.214)	(0.223)
Observations	180,573	180,573	180,573	180,573	57,582	57,582	57,582	57,582
Adjusted R^2	0.037	0.037	0.037	0.037	0.069	0.069	0.069	0.069

Notes: *$p < 0.10$; **$p < 0.05$; ***$p < 0.01$. Robust standard errors in parentheses. Robust standard errors clustered by product. Prices and exchange rates are in logarithms. A constant term is included in all regressions. If a firm exports multiple products at HS6 level, we select the major product with the highest export value and label as "major product"; if a firm exports only one HS6 product, we label as "single product". The explanatory variable Δfwd (forward premium) is computed as annualized forward premium based on different maturity: $\Delta fwd1$ (the annualized forward premium is computed based on 3-month maturity), $\Delta fwd2$ (the annualized forward premium is computed based on 6-month maturity), and $\Delta fwd3$ (the annualized forward premium is computed based on 12-month maturity). The R^2 reported is the overall R^2 value.

of each HS6 product h in firm i's total export sales at time $t-1$, and Δp_{iht} is the log price change for firm i's product h from period $t-1$ to period t. Therefore, Δp_{it} is computed as a weighted average change in prices for all the individual products within firm i. This approach of computing firm-level price change index follows the construction of a Tornqvist index as in Smeets and Warzynski (2013).[34] Then the price change across products is aggregated at the firm level to analyze the price adjustment response to exchange rate fluctuations.

The results are reported in Table 7 with two panels, without and with firm fixed effects, respectively. To avoid the potential noise from processing trading firms, we analyze the two samples separately.[35] We first drop the transactions belonging to

Table 7. Firm-level Weighted Export Price Adjustment and Forward Premiums

	Dependent variable: Weighted firm-level price index Δpit							
	Subsample: Only ordinary transactions				*Full sample: All transactions*			
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*
Panel A: Without firm fixed effects								
Δexr	0.340***	0.352***	0.356***	0.358***	0.334***	0.352***	0.358***	0.359***
	(0.024)	(0.024)	(0.024)	(0.024)	(0.022)	(0.021)	(0.021)	(0.022)
$\Delta fwd1$		0.073***				0.125***		
		(0.019)				(0.017)		
$\Delta fwd2$			0.097***				0.150***	
			(0.021)				(0.019)	
$\Delta fwd3$				0.114***				0.166***
				(0.022)				(0.019)
Inflation	0.412***	0.342***	0.317***	0.298***	0.332***	0.212***	0.182***	0.164***
	(0.036)	(0.039)	(0.041)	(0.042)	(0.032)	(0.035)	(0.037)	(0.038)
Observations	413,843	413,843	413,843	413,843	467,715	467,715	467,715	467,715
Adjusted R^2	0.005	0.005	0.005	0.005	0.004	0.004	0.004	0.004
Panel B: With firm fixed effects								
Δexr	0.677***	0.703***	0.709***	0.709***	0.623***	0.653***	0.658***	0.658***
	(0.037)	(0.036)	(0.036)	(0.036)	(0.033)	(0.032)	(0.032)	(0.033)
$\Delta fwd1$		0.115***				0.147***		
		(0.032)				(0.028)		
$\Delta fwd2$			0.148***				0.176***	
			(0.035)				(0.031)	
$\Delta fwd3$				0.166***				0.190***
				(0.037)				(0.032)
Inflation	0.501***	0.411***	0.380***	0.362***	0.365***	0.249***	0.219***	0.203***
	(0.054)	(0.058)	(0.061)	(0.062)	(0.047)	(0.051)	(0.053)	(0.054)
Observations	413,843	413,843	413,843	413,843	467,715	467,715	467,715	467,715
Adjusted R^2	0.233	0.233	0.233	0.233	0.235	0.236	0.236	0.236

Notes: $^*p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$. Robust standard errors in parentheses. Robust standard errors clustered by product. Prices and exchange rates are in logarithms. A constant term is included in all regressions. Ordinary trade refers to typical exporting firms that pay import tariffs for imported inputs. Processing trade refers to two types of firms that are not subject to import tariffs: (i) "processing with supplied inputs" (firms receive inputs from their trading partners, assemble them and export directly to their trading partners), and (ii) "processing with imported inputs" (firms pay for imported inputs from foreign suppliers and export all processed goods). The explanatory variable Δfwd (forward premium) is computed as annualized forward premium based on different maturity: $\Delta fwd1$ (the annualized forward premium is computed based on 3-month maturity), $\Delta fwd2$ (the annualized forward premium is computed based on 6-month maturity), and $\Delta fwd3$ (the annualized forward premium is computed based on 12 maturity). The R^2 reported is the overall R^2 value.

processing trade and keep only observations of ordinary trade, and show results in the left panel in Table 7. We then keep all transactions and use the full sample to analyze the firm-level price adjustment in the right panel in Table 7.

The firm-level price elasticity is around 0.07 for expected future exchange rate movements Δfwd based on 3-month forward rates and 0.35 for the realized exchange rate movements Δexr without firm fixed effects (see column (2) in panel A); when including firm fixed effects, both exchange rate pass-through coefficients become larger (see panel B). Although the majority adjustment in price comes from the realized exchange rate fluctuation, the response to the expected future ones still counts almost one-fourth of the total exchange rate pass-through elasticity (including both current and expected pass-through). There is little difference between the sample of ordinary trade in columns (1)–(4) and the full sample in columns (5)–(8).

Exporters' Perspective (II): Firm–Product Price Adjustment

Now we turn to a more disaggregated (firm–product level) analysis of exchange rate pass-through elasticity. The dependent variable Δp_{iht} is the difference in log export price of a Chinese firm *i*'s product *h* between year *t* and $t - 1$.[36] The product category is defined at the HS 6-digit level since HS6 is the most disaggregated product classification that is consistent over time for Chinese products and available to us. The econometric specification is given by

$$\Delta p_{iht} = \beta_1 \Delta exr_t + \beta_2 \Delta fwd_t + \pi_t + F_h + \varepsilon_{iht} \tag{10}$$

where Δfwd_t stands for the log annualized forward premium between RMB and the USD based on various maturity. Both the realized exchange rate changes Δexr_t and inflation rate π_t are included as explanatory variables.[37]

Table 8 reports firm–product level price adjustment results. Columns (1)–(4) report the results based on the full sample of firm–product bundles, including all exported goods from China to the USA; columns (5)–(8) present results using firms only exporting a single product. Both the current exchange rate change Δexr and the forward exchange rate fluctuation Δfwd have positive effects on the firm–product price adjustment.

This means that the current export price set by a firm is positively affected by both current (and past) and expected exchange rate fluctuations. Also note that the coefficients for Δexr become larger when controlling for the expected future exchange rate changes Δfwd. Compared with the previous firm-level price analysis, the magnitude of forward premium coefficients and the size of current exchange rate pass-through coefficients are larger at the firm–product level, suggesting the possibility that firms may reallocate resources across products within the firm to better absorb exchange rate shocks. Thus, the observed pass-through elasticities for both current and expected future exchange rates are more incomplete at firm level than at firm–product level. Lastly, as a robustness check, we categorize export transactions into ordinary trade and processing trade. For both types of trade modes, the aforementioned results still hold (see Table 9).

8. Conclusion

This paper explores price responses to future exchange rate fluctuations and their effects on exchange rate pass-through into import prices. In the presence of sticky prices, firms incorporate expectations of future exchange rate changes into their current pricing decisions. Consequently, at the aggregate level, the prices of imported products reflect exchange rate changes, including past, current and future exchange rate fluctuations. The empirical tests based on US imports from China and other countries at the HS10 product level confirm that expectations of future exchange rate fluctuations indeed pass through into import prices. Moreover, from the exporting firms' perspective, we use highly disaggregated firm–product level customs data on China's exports to the USA and test the exchange rate pass-through. The results verify that exporting

Table 8. Firm-product Price Adjustment and Forward Premiums

	Dependent variable: Δpiht							
	Full sample				Single product			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Without product fixed effects								
Δ*exr*	0.724***	0.818***	0.847***	0.854***	0.635***	0.703***	0.723***	0.731***
	(0.041)	(0.041)	(0.041)	(0.042)	(0.118)	(0.118)	(0.118)	(0.119)
Δ*fwd*1		0.715***				0.432***		
		(0.037)				(0.108)		
Δ*fwd*2			0.867***				0.546***	
			(0.043)				(0.128)	
Δ*fwd*3				0.962***				0.637***
				(0.049)				(0.144)
Inflation	0.948***	0.358***	0.207***	0.113	0.937***	0.575***	0.465**	0.379*
	(0.065)	(0.071)	(0.075)	(0.078)	(0.184)	(0.200)	(0.210)	(0.219)
Observations	1,029,857	1,029,857	1,029,857	1,029,857	70,706	70,706	70,706	70,706
Adjusted R^2	0.003	0.003	0.003	0.003	0.005	0.005	0.005	0.005
Panel B: With product fixed effects								
Δ*exr*	0.751***	0.858***	0.890***	0.895***	0.680***	0.756***	0.777***	0.784***
	(0.042)	(0.042)	(0.042)	(0.042)	(0.123)	(0.123)	(0.124)	(0.124)
Δ*fwd*1		0.783***				0.462***		
		(0.037)				(0.111)		
Δ*fwd*2			0.944***				0.577***	
			(0.044)				(0.132)	
Δ*fwd*3				1.042***				0.669***
				(0.049)				(0.148)
Inflation	0.961***	0.324***	0.163**	0.066	0.916***	0.536***	0.426**	0.340
	(0.065)	(0.071)	(0.075)	(0.078)	(0.189)	(0.206)	(0.216)	(0.225)
Observations	1,029,857	1,029,857	1,029,857	1,029,857	70,706	70,706	70,706	70,706
Adjusted R^2	0.011	0.012	0.012	0.012	0.055	0.055	0.055	0.055

Notes: $*p < 0.10$; $**p < 0.05$; $***p < 0.01$. Robust standard errors in parentheses. Robust standard errors clustered by product. Prices and exchange rates are in logarithms. A constant term is included in all regressions. Columns (1)–(4) use full sample; columns (5)–(8) use the subsample of firms with single product. If a firm exports only one HS6 product, we label as "single product". The explanatory variable Δ*fwd* (forward premium) is computed as annualized forward premium based on different maturity: Δ*fwd*1 (the annualized forward premium is computed based on 3-month maturity), Δ*fwd*2 (the annualized forward premium is computed based on 6-month maturity), and Δ*fwd*3 (the annualized forward premium is computed based on 12-month maturity). The R^2 reported is the overall R^2 value.

firms indeed significantly adjust their export prices in response to anticipated changes in exchange rates.

Our paper reveals a previously overlooked "pass-through" response to future exchange rates, which results from firms' pre-reactions to expected exchange rate movements. It provides a new perspective to examine how price rigidity plays a role in the low "pass-through" coefficients observed in the literature and suggests a potentially important factor in helping explain incomplete pass-through of exchange rates to prices. Our findings suggest that firms' responses to future expectations should be considered when studying exchange rate pass-through. We find that the trade price

Table 9. Firm-product Price Adjustment: Ordinary Trade vs Processing Trade

	Dependent variable: $\Delta piht$							
	Full sample				Single product			
	Ordinary	Processing	Ordinary	Processing	Ordinary	Processing	Ordinary	Processing
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Δexf	0.711***	0.927***	0.814***	1.025***	0.845***	1.068***	0.853***	1.071***
	(0.048)	(0.085)	(0.048)	(0.085)	(0.048)	(0.085)	(0.048)	(0.085)
$\Delta fwd1$			0.688***	1.224***				
			(0.042)	(0.077)				
$\Delta fwd2$					0.855***	1.365***		
					(0.050)	(0.088)		
$\Delta fwd3$							0.970***	1.399***
							(0.057)	(0.095)
Inflation	1.163***	0.211*	0.603***	−0.772***	0.442***	−0.943***	0.332***	−0.998***
	(0.076)	(0.124)	(0.083)	(0.137)	(0.087)	(0.144)	(0.091)	(0.150)
Product fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
Observations	826,358	203,499	826,358	203,499	826,358	203,499	826,358	203,499
Adjusted R^2	0.012	0.026	0.012	0.028	0.012	0.028	0.012	0.027

Notes: $*p<0.10$; $**p<0.05$; $***p<0.01$. Robust standard errors in parentheses. Robust standard errors clustered by product. Prices and exchange rates are in logarithms. A constant term is included in all regressions. Columns (1)–(4) use full sample; columns (5)–(8) use the subsample of firms with single product. If a firm exports only one HS6 product, we label as "single product". Ordinary trade refers to typical exporting firms that pay import tariffs for imported inputs. Processing trade refers to two types of firms that are not subject to import tariffs: (i) "processing with supplied inputs" (firms receive inputs from their trading partners, assemble them, and export directly to their trading partners), and (ii) "processing with imported inputs" (firms pay for imported inputs from foreign suppliers and export all processed goods). The explanatory variable Δfwd (forward premium) is computed as annualized forward premium based on different maturity: $\Delta fwd1$ (the annualized forward premium is computed based on 3-month maturity), $\Delta fwd2$ (the annualized forward premium is computed based on 6-month maturity), and $\Delta fwd3$ (the annualized forward premium is computed based on 12-month maturity). The R^2 reported is the overall R^2 value.

response to expected future exchange rate changes accounts for approximately over one-third of the total "pass-through" coefficient, which is of significant importance.

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Notes

1. For example, Campa and Goldberg (2005), Goldberg and Campa (2010) and Parsons and Sato (2006) find a partial pass-through of exchange rates into import prices when considering cross-country and cross-product perspectives.

2. For example, see Devereux et al. (2004) for the importance of the stability of monetary policy, Campa and Goldberg (2005) for exchange rate volatility and Choudhri and Hakura (2015) for the choice of invoicing currency.
3. Another example is Auer and Chaney (2009) who develop a quality pricing model to predict the incomplete exchange rate pass-through into product prices, but find only weak empirical evidence in favor of the theory based on disaggregated price and quantity of US import data.
4. Price adjustment in this paper refers to the adjustment of (unit value) trade prices based on the availability of micro-level trade data from US and Chinese customs. We will interpret the elasticity of trade price adjustment to exchange rate movements as the exchange rate "pass-through".
5. Our sample period covers an important reform in which China's exchange rate regime switched from a fixed regime (pegged to the USD) to a managed floating one. Within the sample period, nominal spot exchange rates were initially fixed but market expectations of exchange rates began fluctuating even before the change in regime.
6. Berman et al. (2012) links exchange rate fluctuations to firm characteristics such as productivity and shows that firms may vary mark-ups in response to exchange rate shocks. Moreover, firms with higher import intensity and larger market shares exhibit greater incomplete pass-through (see Amiti et al., 2014). Chatterjee et al. (2015) uses Brazilian customs data to study how firms adjust their prices, quantities, product scope across products in the event of exchange rate fluctuations. More examples include Li et al. (2015), Tang and Zhang (2012), Grier and Smallwood (2013), Viaene and De Vries (1992), Cushman (1988) and Wong et al. (2012).
7. For example, see Amiti et al. (2014), Choudhri and Hakura (2015), Auer and Chaney (2009), Gust et al. (2010), Daniels and VanHoose (2013), Wang (2007), Strasser (2013), Gopinath et al. (2010), Devereux et al. (2004) and Gopinath and Itskhoki (2010).
8. The assumption of local-currency pricing is reasonable because, in reality, the majority of Chinese exporters use USD to price products when exporting to the US market.
9. In our framework, we model the representative firm's price behavior under price rigidity in the most parsimonious way. Hence, we do not address either market or competitors' responses to the expected exchange rate changes, which may also affect an exporter's price decision. This simple framework is silent on issues of what the firm's competitors are doing, which constitutes a limit of our paper. It would be fruitful to incorporate firms' response to their competitors under expected exchange rate shocks with a more comprehensive framework in future research. As for firms' pricing responses to competitors under current exchange rate shocks, please see Auer and Schoenle (2016).
10. Since our focus here is the impact of exchange rate fluctuations, we suppress $\tilde{P}_t$ for simplicity but will incorporate the change in domestic inflation rates into regressions in later empirical analysis to capture the effect of $\tilde{P}_t$ owing to inflation.
11. Ma and McCauley (2008) provided evidence that China had effective capital control over the sample period, and Mehl and Cappiello (2009) proved that uncovered interest rate parity condition does not hold between US dollar and other currencies in emerging market economies.
12. The correlations between 3-month forward rates and 6-month forward, between 3-month and 12-month and between 6-month and 12-month are 0.98, 0.96 and 0.99, respectively.
13. Here subscript t indexes period, and it can be month, quarter, half-year, or year, depending on various maturities.
14. For example, we compare a 3-month forward rate in January with the realized spot rate in April, then a 3-month forward rate in February with the realized spot rate in May, and so on. This correlation aims to verify that forward rates are a valid proxy for the realized future spot exchange rates.
15. The slope coefficient of the regression as in Froot and Frankel (1989) where we regress Δfwd_t on Δexr_{t+1} is significantly positive and as high as 0.84 for 6-month forward rates and 0.62 for 3-month forward rates. This suggests that it is safe to avoid the concern of forward premium puzzle based on our data.

16. As the FXFC Index is only available after June 2006 while our test is for 2000–2008 at a yearly basis, we cannot use it as alternative measure of expected future exchange rates in our robustness check.
17. The data are downloaded from the Trade Data and Concordances at Schott's International Economics Resource Page, available at http://faculty.som.yale.edu/peterschott/sub_international.htm. Please see Schott (2008) for detailed data descriptions.
18. The original data for US imports can extend beyond 2008. Here we choose our sample period as 2000–2008 to be consistent with the later analysis using the micro-level exporting firm–product data from China owing to the availability of Chinese customs data.
19. This dataset has been used in many previous studies, especially those that focus on firm-level analysis of exports/imports, e.g. Khandelwal et al. (2013).
20. The literature indicates that exchange rates almost completely pass through into prices within one or two years (e.g. Campa and Goldberg, 2005).
21. For example, the classic paper by Campa and Goldberg (2005), among many others, estimated the exchange rate pass-through into the import price of developed countries but did not address the endogeneity of exchange rates.
22. The previous literature has addressed the relationship between invoicing currency choice and pass-through estimation (e.g. Gopinath et al., 2010; Devereux et al., 2004).
23. Since the 1980s China has encouraged exports to other countries using USD as the invoicing currency in order to earn and accumulate foreign reserves. This situation lasted until very recently (after 2010).
24. Although we control for the fixed effects at the product level, we do not include changes in marginal cost in the main estimating equation. We acknowledge the caveat in our specification without measure of marginal cost in the equation because exporters may also adjust prices owing to changes in production cost.
25. For example, when we use 3-month maturity forward rate (FWD^{3month}) to compute the annualized forward premium, the calculation formula is $\Delta fwd = (\log FWD^{3month} - \log S) * (12/3)$, where S is the year-end quarterly spot exchange rate.
26. The difference between homogeneous goods exporters and differentiated goods exporters regarding the flexibility of their price adjustment has been discussed both theoretically and empirically in the recent quality-and-trade literature (e.g. Fan, Li and Yeaple, 2015; Fan, Lai and Li, 2015). This literature shows that differentiated goods present a larger scope for quality differentiation such that the producers of differentiate goods have more flexibility in adjusting product prices.
27. Nevertheless, future or forward contracts are rarely used by Chinese producers to hedge future exchange rate risk, even for homogeneous goods producers. For example, the statistics released by the China's central bank show that forward contracts take only 2–4% of total foreign exchange trade in China in 2005. Hence, the hypothesis of "hedged exchange rate risk" is still difficult to be fully proved by just providing different results based on homogeneous goods vs heterogeneous goods. It is one potential limit of our current test and it would be interesting to further explore this in future study when a richer dataset is available.
28. We acknowledge the conventional concern of the "forward premium puzzle" and the random walk of exchange rates fluctuations for some countries under floating exchange rate regimes and without capital control. Hence, when we experimented with the samples of each individual trading partner country (other than China) of the USA separately, the effect of forward exchange rate movement is not always stable. Nevertheless, once we include China into the sample (recall the discussion in section 4), the results are robust as in our main test.
29. As this test focuses on the pricing behavior of continuous exporters, we drop those firms that exited from the export market or were dis-continuous exporters.
30. Based on various maturity, Δfwd_t could be computed as three different measures, namely, $\Delta fwd1$ (3-month maturity), $\Delta fwd2$ (with 6-month maturity), and $\Delta fwd3$ (with 12-month maturity).
31. We pick up the HS6 product that has the largest export value within each firm as major product.
32. In Chinese customs data we are able to identify the product category for each firm's major product or single product.

33. Another possibility is that exchange rate risks (and risks to profits more generally) for multi-product firms are more diversified, so multi-product exporters could adjust prices in a more sluggish way in response to future exchange rate shocks. We thank Referee 1 for pointing this out.
34. The only difference is that they use the average share between period t and $t - 1$ as weight, while we use the initial share as weight. Our results remain qualitatively similar when using the average share.
35. Processing trade includes "processing and assembling" and "processing with imported inputs". A significant proportion (approximately 30%) of Chinese exports belongs to the processing trade, suggesting that Chinese producers import intermediate components to assemble or process them into final products in China and then export them abroad. The price decisions of a processing-trade firm may differ from those of a firm engaging in ordinary trade. Thus, we exclude processing-trade transactions from the firm-level regression in the left panel in Table 7. For the recent development of the literature on the processing trade, see, e.g. Yu (forthcoming) and Manova and Yu (2014).
36. As we take price difference, we focus on the price adjustment pattern of continuing firm–product bundles.
37. Including product fixed effects (and firm fixed effects) does not qualitatively alter the main results on the importance of forward exchange rate movements.