Pricing Power in Domestic Market and Exchange Rate Disconnection

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Abstract

By utilizing detailed firm data in China, we structurally estimate the elasticity between export and exchange rate, and disentangle the effect of various hedging behaviors. Before/After the reform of RMB exchange rate regime, financial constraint increases the median of the elasticity for 1.325/1.626, while pricing hedging, financial hedging and operational hedging decrease the median for 0.007/0.015, 0.331/0.159, 0.695/0.929. We verify a significant effect of domestic sales as an operational hedging. Besides, the top 5% largest exporters are much less sensitive to exchange rate movement, and the median of their elasticity is about 0.15/0.24, indicating significant composition effect.

I. Introduction

Export behaviors are significantly influenced by exchange rate movements, which induce not only pricing to different market, but also reallocation of quantity across markets. By building theoretical model and applying it into firm-level data in China, I will: (1) structurally estimate the elasticity between export quantity and exchange rate (the elasticity henceforth) on firm level; (2) separate the effect of exchange rate pass-through (ERPT henceforth), financial constraints, financial hedging and operational hedging (including domestic sales and import); (3) and detect the firm-level heterogeneity and aggregate into a macro-level elasticity.

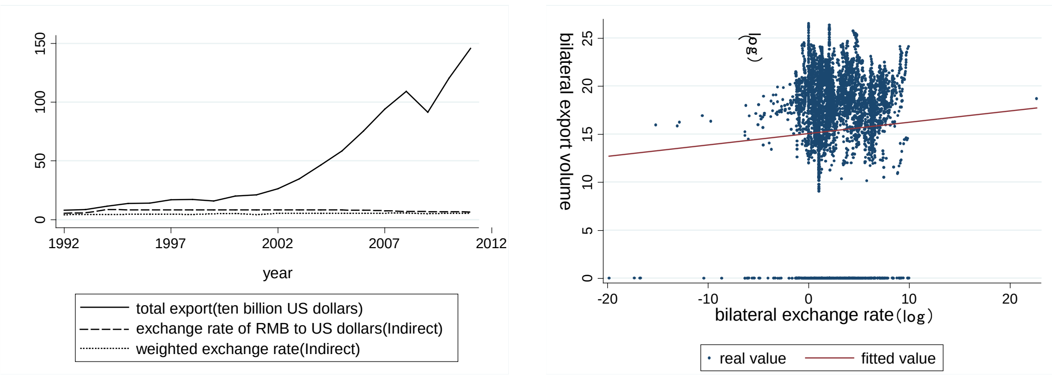

Figure 1 Macro-level export and exchange rate

The problem is of important significance theoretically. As an intriguing but unsolved puzzle, the phenomenon of exchange rate disconnection on country or sector level has attracted many scholars into the micro mechanisms and the corresponding composition effect. It also relates closely to how pricing-to-market exporters pass exchange rate movement to export price, and implement other hedging strategies. As shown in Figure 1, the macro level relation between export

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and exchange rate is highly controversial. The left figure shows a surging export and appreciation of RMB from 1992 to 2012, and the right figure show and modest relation between bilateral export and bilateral export.

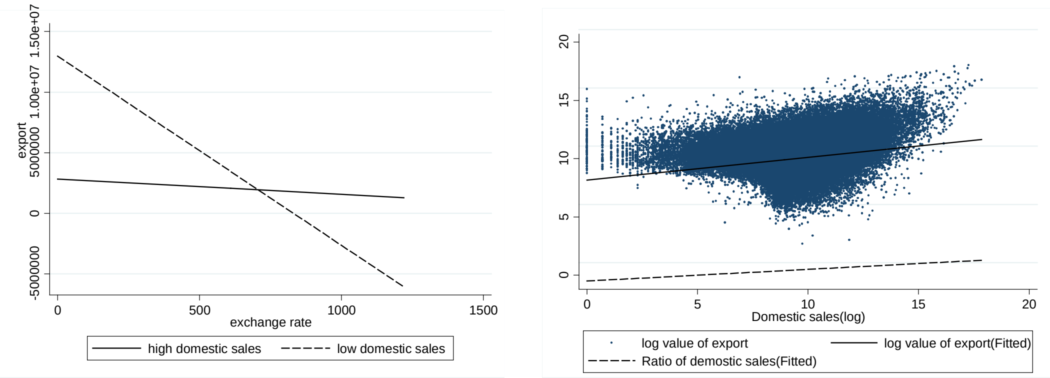

Figure 2 Firm-level export, exchange rate and domestic sales

On the firm-level however, the relation between export and exchange rate is quite significant. In the left figure, we further see the ration in two subsamples. We first calculate the ratio of domestic sales to total sales, and then the quantile of the ratio in each industry and each year. In the group of high domestic sales, the relation is quite modest and in the low group, the relation is quite significant. The right figure suggests the export and the ratio of domestic sales is positively correlates to the domestic sales. In Fact, the correlation is 0.27 and 0.66 respectively. These evidences remind us of two things: (1) large exporters are more likely to be large domestic sellers and (2) large domestic sale seems to induce insensitivity of export to exchange rate. The two things imply the hedging effect of domestic sales.

II. Literature Review

The impact of exchange rate on export is highly controversial. Macroeconomics has long presumed that the appreciation of domestic currency should reduce the export. Equivalently, export should be positively correlated with exchange rate using indirect quotation. However, the presumption has been challenged by recent researches using macro- or industry-level data, which have almost unanimously found that exports quantity and other real-value economic indicators are not subject to exchange rate fluctuations. This discovery is referred to as "Exchange Rate Disconnect Puzzle" (the Puzzle henceforth) (Goldberg and Knetter, 1997; Engle, 2001; Obstfeld and Rogoff, 2001; Devereus and Engel, 2003; Campa and Goldberg (2005; 2010); only to list a few). Meanwhile, some studies (Dekle and Ryoo, 2007; Fitzgerald and Haller, 2014) using firm-level data verify a higher elasticity between export and exchange rate, typically between 0.6 and 2. But the elasticity with such a large magnitude cannot provide direct micro explanations for the Puzzle.

As an export-oriented economy, China has simultaneously experienced surging export volume and RMB appreciation, a fact that at least contradicts with above-mentioned theories, implying that appreciation of local currency will exert either a negative or an insignificant effect on export. Thus analyzing how firms mitigate the exchange rate risk, and estimating the real effect of exchange rate on export, is quite crucial to understand the export phenomenon in China and in other developing countries.

Since export decisions are essentially made on firm level, I should (1) first determine the export decision procedures and estimate the effect of exchange rate on export on firm level; (2) and then detect the firm heterogeneity to demonstrate how the firm-level effect can be aggregated into a macro level effect. The first problem is related with two stands of literature, the exchange rate pass-through (ERPT) in International Finance and the exchange rate risk hedging in Corporate Finance. The second problem is related with the theory of firm heterogeneity in International Trade, though the heterogeneity may take different forms.

Mechanisms that affect the firm-level elasticity are mainly classified into two categories: the price-channel hedging and quantity-channel hedging, according to Ito et al. (2014). In their framework, incomplete ERPT is interpreted as a price-channel tool to hedge exchange rate risk, while the other operational and financial hedging strategies are categorized as quantity-channel. However, the two channels still have slight differences. Generally, incomplete ERPT and the pricing power are authorized by the firms' market share and the imperfect market structure, and thus cannot be easily changed in the short run. But the quantity-channel hedging strategies can be initially employed by the firm and their effects are almost instantaneous.

Low ERPT, referring to the fact that export price calculated in foreign currency, usually does not move one-for-one with exchange rate variation. As a result, the export price exhibits less volatility than exchange rate, which buffers the impacts of exchange rate fluctuations (Gopinath et al., 2010; Gopinath et al., 2011). Incomplete ERPT could be result of sticky price, yet Gopinath and Rigobon (2008) suggest price rigidities cannot fully explain the phenomenon. The sensitivity, or lack thereof, of prices to exchange rate movements, are essentially relates to variable markup, or demand elasticity to be more precisely. Variable demand elasticity in CES, Nested CES (Atkeson and Burstain, 2008) and Translog demand function (Feenstra and Weinstein, 2014) under imperfect competition, and in Quadratic demand system (Melitz and Ottaviano, 2008) under monopolistic competition, can all lead to similar variable markup.

A common yet powerful property of these variable markup models is that the firm's pricing power is positively related with its quantity and market share, which make them easily connected with productivity heterogeneity. Higher productivity induce more supply and higher market share, and higher-productivity firms thus have stronger pricing power, can pass through less exchange rate into price, and better at mitigate the exchange rate fluctuation. Since these firms are simultaneously large-scale and low-ERPT exporters, macro-level elasticity will be significantly lower than the average firm-level elasticity. Thus the aggregated composition effect can explain both the divergence between macro- and firm-level effect, and the Puzzle (Berman et al., 2012).

Though straight-forward and seemingly sensible, the above analysis are still far from complete. Previous firm-level studies find significant and larger elasticity than macro-level, usually between 0.6 and 2. It remains unclear whether the exporters’ composition is freaky enough to induce almost insignificant macro-level elasticity. Besides, though various composition mechanisms are proposed, the preciseimpacts on the elasticity are not carefully estimated. The deficiency of existing literatures include: (1) a wide range of hedging tools are still overlooked. Firms will utilize various strategies to hedge exchange rate risk, and ignoring some strategies may lead to overestimated firm-level elasticity. The significant macro-level elasticity in Berman et al. (2012) could result from similar reasons; (2) the variable markup brought by productivity heterogeneity is still just one possible source of composition effect. Amiti et al. (2014) emphasize large exporters are simultaneously large importers, who are insensitive to exchange rate due to the “natural hedging” of import on export. Since their exports account for the majority of a country’s export, a macro-level analysis will discover an insignificant elasticity without surprise. In fact, other sources of hedging tools and composition effect are also investigated in this research.

Besides ERPT, exporters will respond to exchange rate risk through quantity-channel hedging strategies, which will directlyalleviate quantity fluctuation. Following this research strand, the strategies are generally categorized into two kinds: the financial hedging and operational hedging (Allayannis et al., 2001; Allayannis and Weston, 2001).Firms will take every effort to hedge exchange rate risk. In fact, any subjective attempts of a firm to mitigate the impact of exchange rate movements can be defined as a hedging strategy.

Financial hedging refers to utilization of financial instruments to transfer exchange rate risk to their counterparties, usually financial institutions. Thus exporters can get compensated even with an adverse exchange rate shock. And operational hedging refers to strategies in daily operation to mitigate the impact of exchange rate risk. Previous researches, which almost entirely focus on developed countries, generally find financial hedging of greater important, and the effect of operational hedging depends on that of financial hedging (Allayannis et al., 2001; Hommel, 2003). In contrast, Kim et al. (2006) believes the effectiveness of two are complementary than mutually determined. However, there lacks systematic researches dissecting the relation in developing countries, whose financial markets are usually incomplete and operational hedging are more available.

Regarding the financial hedging, there are mainly two divergent opinions regarding the optimal hedge ratio. Baron (1976), and Kawai and Zilcha (1986) propose a perfect hedging strategy, meaning that hedge ratio should always equal to oneunity. Thereforethe firmcan completely transfer the exchange rate risk and focus on operations. This idea is known as the Separation Theorem, but it strictly presumes a complete financial market. However, in an incomplete financial market like in developing countries, the premise can hardly hold. Under the circumstances, the optimal hedge ratio should be determined dependently. Wong (2013) proves that the optimal hedge ratio depends on the correlation between exchange rate shock and revenue fluctuation. It should exceed 1 if they are positively correlated, and conversely if the opposite. I also find similar results based on the correlation between exchange rate and cash flow.

Besides, firms will takevarious operational strategies to hedge exchange rate risk. Though implementation forms may vary, the basic idea is consistent: to hedge the revenue in form of foreign currency from export, firms should simultaneously increase their expenditure in foreign currency, to reduce or completely eliminate their net exposure to exchange rate risk. Operational hedging generally include four strategies: (1) export to multi-destinations to mitigate the impact of exchange rate movement of a certain currency (Hutson and Laing, 2014; Héricourt and Nedoncelle, 2014); (2) FDI in foreign countries to increase expenditure in foreign currency (Allayannis and Ofek, 2001); (3) choose domestic currency as the contractual currency to completely eliminate exchange rate risk (Ito et al., 2014); (4) use "natural hedging" of import on export (Campa and Goldberg, 2005; Fauceglia et al., 2012; Amiti et al., 2014).

Although financial hedging and operational hedging have been elaborated, their influences on the elasticity are rarely directly estimated. Usually the hedging effect is incarnated by the change of net exposure to exchange rate risk in previous literatures. One exception is Deckle and Ryoo (2007), who verify financial hedging significantly decrease the export volatility and thus the elasticity, but solely analyze the effect of financial hedging. If the above-mentioned mechanisms all exert some effect on the elasticity, their comprehensive effects should be carefully examined. In this research, Iwill consider both financial hedging and operational hedging, and include many forms of operational hedging to the best of the data.

Last but not least, financial constraints are stringent for exporters in emerging markets, which significantly impact their daily operations and export behaviors. By using the China Manufacturing Firm Database, Feenstra et al. (2012) find exporters are more financially constrained than pure domestic sellers. Héricourt and Poncet (2013) also verify that the intensive margin and extensive margin of export are both influenced by exchange fluctuation, and the more financial constrained the exporters, the more significant the relation. Thus they conclude financial constraints matter for exporters in China. But in fact they only provide an indirect analysis, and the effect of financial constraints on the relation between exchange rate and export is not quantitatively estimated.

In this research, I also incorporate financial constraints, in a form of increasing marginal cost of an additional unit of external financing capital.In this context, financial constraints have two implications: (1) Financial constraints will significantly magnify the effect of exchange rate fluctuations. I model the impact of aggregate exchange rate shock by assuming the firm cash flow and exchange rate movement are correlated. With the same unity exchange rate shock and cash flow fluctuation, increasing marginal financing cost will dramatically increase the fluctuations of financing and total cost. The higher uncertainty of production will lead to higher volatility of export, and thus a higher elasticity; (2) Increasing financial cost will result in decreasing return to scale (DRS). With an additional unit of product, the firm will finance more capital and increase dramatically its financing cost. Consequently, domestic sale will exert a negative externality on export in the supply side. Since exporters are better off adjust in both domestic and foreign markets, than merely in foreign market, the domestic sale, closely related with export, provides a shield for exporters from exchange rate risk, and should also be interpreted as an operational hedging strategy that decreases the elasticity.

To summarize, this research is relevant with the following three strands of literature: (1) the firm-level price-channel hedging relates to ERPT; (2) the firm-level quantity-channel hedging refers to financial and operational hedging; (3) to estimate macro-level elasticity emphasizes firm heterogeneity and the overall composition effect. However, previous studies are still limited and quite divergent for the following three reasons: (1) usually concentrate on one or two perspectives and lack researches simultaneously considering the mechanisms; (2) the sole effect and correlation of these mechanisms are seldom carefully dissected; (3) the exact composition effects are still not well detected and the Puzzle remains unsolved. Although many possible composition effects are proposed, it remains unclear how they aggregate into a macro impact strong enough to induce the Puzzle. The macro-level elasticity are still either too large or not quantified.

In this research, financially constrained exporters take the following four measures to hedge exchange rate risk: (1) adjust markups, rather than fully incorporate the exchange rate movements into export prices; (2) purchase some financial derivatives, such that the cash flows from the derivatives can compensate for the loss from exchange rate variations, and thus lowering down the cash flow fluctuation and operation uncertainty; (3) modify domestic sales accordingly to absorb part of the effect of exchange rate shock; (4) import intermediate goods to reduce net exposure to exchange rate risk.

This research aims to systematically analyze the effect of financial constraints, ERPT, financial hedging and operational hedging on the relation between export and exchange rate, both on firm level and macro level. I plan to structurally estimate the theoretical model, to separate each effect of above-mentioned factors, and to aggregate the firm-level elasticity on macro level. This paper includes the following three academic innovations:

First, this paper is the first to treat domestic sale as an operational hedging strategy. We observe that export are highly correlated with domestic sales (the correlation coefficient is 0.4341)[1]. Previous studies traditionally treat the relation between export and domestic sales as a result of foreign demand shock or uncertainty (Vannoorenberghe, 2012; Blum et al., 2013). Essentially, the effects of foreign demand shock and exchange rate shock are similar, for they will both affect the marginal return in foreign market, calculated with domestic currency. By introducing increasing financing cost and thus a DRS technology, the domestic sale and export are highly correlated. Exporters will simultaneously determine the optimal sales in foreign and domestic markets, as well as adjust simultaneously in both markets with an exogenous exchange rate shock.

Second, this paper is among the first to consider the sole and comprehensive effect of both price-channel and quantity-channel hedging strategies, and financial constraints on firm level. In this research, structural estimation is utilized to mitigate endogeneity problem. I also directly connect these factors with the elasticity using a specific form of demand function, and estimate the separated effects of each factor.

Third, this paper clearly distinguishes export quantity from export volume, and explicitly investigates the firm heterogeneity and the corresponding composition effect, to provide a relative complete explanation for the Puzzle. Since the puzzle emphasizes the effect of exchange rate on real economic value, I exclude the impact of price and focus on quantity variation. I also include in this research two sources of composition effect brought by productivity heterogeneity. Higher productivity incurs: (1) stronger pricing power and higher markup, as various variable markup demand models suggest; (2) an even larger market share in domestic market and thus a stronger hedging effect of domestic sales, for the firm exceeds the average productivity level more in domestic market than in foreign market.

Specifically, this research mainly consists of three sections: (1) in the first section, I will construct a theoretic model in a general form to show How ERPT is affected by domestic market. The model discusses the most generalized situation, without strictly assuming any specific prerequisites of demand and supply, except requiring a Non-CRS technology; (2) in the second section, I assign a specific form of demand function to incorporate the variable markup, financial constraints and various hedging strategies, and deduce the optimal export and domestic sales endogenously. And the structural estimation of the parameters should be consistent with the specific prerequisites of the demand function; (3) I will further detect the heterogeneous relation between export and exchange rate across different firms, and aggregate into a macro-level effect according to the export weight. Thus, we mainly utilize structural analysis in this research.

[1] Previous researches usually focus on the pricing power in export market and its impact on ERPT, and we emphasize the pricing power in domestic market can also affect the export decision and the correlation between export and exchange rate. Beside, there are reports on Chinese exporters transfer some exported goods to demostic market with huge RMB appreciation. We wonder how export and demostic sale should be correlated with exchange rate movement.

III. Why ERPT is Affected by Domestic Market

There exist two markets, that is, foreign market and domestic market (*f* and *d* for short, respectively). Assume demand elasticity of each market is η^j, which can be either a function of quantity q^j, as in imperfect competition models and quadratic demand function, or a constant in CES demand function under monopolistic competition. Also assume a convex total cost function. Thus in each market, the exporters will choose:

$$e_i^j \cdot P(q_i^j) \cdot \left(1 - \frac{1}{\eta_i^j(q_i^j)}\right) = MC_i^j(q_i^d, q_i^f) \tag{1}$$

Where, subscript *i* represents firms, and *e*, *P* and *MC* refer to exchange rate, price and marginal cost, respectively. Superscript *j* can be *d* or *f*, and $e_i^d = 1$ always holds. Equation (1) implicitly assumes that the demand of domestic and foreign markets is not simultaneously correlated while the supply is. The externality of production in one market exerting on the other market constitute the source of correlation of the quantity between these two markets. Differentiating the equation (1) with the exchange rate:

$$\begin{aligned} &\frac{\partial q_i^d}{\partial e_i^f} f(q_i^d) = \frac{\partial MC_i^d}{\partial q_i^d}\frac{\partial q_i^d}{\partial e_i^f} + \frac{\partial MC_i^d}{\partial q_i^f}\frac{\partial q_i^f}{\partial e_i^f} \\ &\frac{\partial q_i^f}{\partial e_i^f} g(q_i^f) + P(q_i^f)\left(1 - \frac{1}{\eta_i^f(q_i^f)}\right) = \frac{\partial MC_i^d}{\partial q_i^d}\frac{\partial q_i^d}{\partial e_i^f} + \frac{\partial MC_i^d}{\partial q_i^f}\frac{\partial q_i^f}{\partial e_i^f} \end{aligned} \tag{2}$$

Where, $f(q_i^d) = \dfrac{\partial\left[P(q_i^d)\cdot\left(1 - \dfrac{1}{\eta_i^d}\right)\right]}{\partial q_i^d}$ and $g(q_i^f) = \dfrac{\partial\left[P(q_i^f)\cdot\left(1 - \dfrac{1}{\eta_i^f}\right)\right]}{\partial q_i^f}\cdot e_i^f$.

Define two matrixes *D* and *S*, and two vectors A and *Qe*, as follows:

$$D = \begin{pmatrix} f(q_i^d) & 0 \\ 0 & g(q_i^f) \end{pmatrix}, S = \begin{pmatrix} \dfrac{\partial MC_i^d}{\partial q_i^d} & \dfrac{\partial MC_i^d}{\partial q_i^f} \\ \dfrac{\partial MC_i^f}{\partial q_i^d} & \dfrac{\partial MC_i^f}{\partial q_i^f} \end{pmatrix}, \quad A = \left[0, P(q_i^f)\left(1 - \frac{1}{\eta_i^f(q_i^f)}\right)\right]^T \text{ and}$$

$$Qe = \left(\frac{\partial q_i^d}{\partial e_i^f}, \frac{\partial q_i^f}{\partial e_i^f}\right)^T.$$

Thus, equation (2) is transformed into:

$$D \cdot Qe + A = S \cdot Qe \tag{3}$$

D stands for demand-side property. A diagonal matrix *D* suggests the two markets are disconnected, for consumption in one market will not affect consumption in the other. While *S* stands for supply-side property. A matrix *S* with non-diagonal elements different from zero, suggests the production of the "two" products in two markets are correlated. Technology without constant return to scale (CRS) satisfies this property. A necessary and sufficient condition for equation (3) to have a unique solution is:

$$\left|D - S\right| \neq 0 \tag{4}$$

Equation (4) is equivalent to:

$$\left(f(q_i^d) - \frac{\partial MC_i^d}{\partial q_i^d} \right) \cdot \left(g(q_i^f) - \frac{\partial MC_i^f}{\partial q_i^f} \right) - \frac{\partial MC_i^d}{\partial q_i^f} \cdot \frac{\partial MC_i^f}{\partial q_i^d} \neq 0 \tag{5}$$

Since a firm's demand and supply are determined by different factors, there is no reason to expect the left side of (5) should always equal to zero. Thus the inequality (5) holds in most circumstances. According to Cramer's Rule, the unique solution for system (3) is as follows:

$$Qe = \left[\frac{\begin{vmatrix} 0 & \frac{\partial MC_i^d}{\partial q_i^f} \\ P(q_i^f)\left(1 - \frac{1}{\eta_i^f(q_i^f)}\right) & \frac{\partial MC_i^f}{\partial q_i^f} - g(q_i^f) \end{vmatrix}}{|S-D|}, \frac{\begin{vmatrix} \frac{\partial MC_i^d}{\partial q_i^d} - f(q_i^d) & 0 \\ \frac{\partial MC_i^f}{\partial q_i^d} & P(q_i^f)\left(1 - \frac{1}{\eta_i^f(q_i^f)}\right) \end{vmatrix}}{|S-D|} \right]^T$$

$$= \left[\frac{-P(q_i^f)\left(1 - \frac{1}{\eta_i^f(q_i^f)}\right) \cdot \frac{\partial MC_i^d}{\partial q_i^f}}{|S-D|}, \frac{\left[\frac{\partial MC_i^d}{\partial q_i^d} - f(q_i^d)\right] \cdot P(q_i^f)\left(1 - \frac{1}{\eta_i^f(q_i^f)}\right)}{|S-D|} \right]^T \tag{6}$$

We further assume that exported and domestic goods are homogeneous, the marginal cost is the same in the two market and only decided by the overall quantity and the technology.

Proposition 1

Thus, with an exchange rate shock, the sufficient and necessary condition for positive correlated variation of quantity in domestic and foreign market can be derived as follows:

$$\begin{aligned} &\frac{\partial q_i^f}{\partial e_i^f} \cdot \frac{\partial q_i^d}{\partial e_i^f} > 0 \\ &\Leftrightarrow \left[P(q_i^f)\left(1 - \frac{1}{\eta_i^f(q_i^f)}\right) \right]^2 \cdot \frac{\partial MC_i^d}{\partial q_i^f} \left[f(q_i^d) - \frac{\partial MC_i^d}{\partial q_i^d} \right] > 0 (\because |D-S| \neq 0) \\ &\Leftrightarrow \frac{\partial MC_i^d}{\partial q_i^f} \left[f(q_i^d) - \frac{\partial MC_i^d}{\partial q_i^d} \right] > 0 \end{aligned} \tag{7}$$

Equation (7) implies that with exchange movement, the correlation of quantity adjustment in domestic and foreign market depends only on the pricing power in domestic, measured with $f(q_d)$.

Proposition 2

Equation (6) show that :

$$\frac{dq_f}{de_f}=\frac{p(q_f)(1-\frac{1}{\eta_f})}{g(q_f)+\frac{\frac{dMC}{dq}}{\frac{dMC}{dq}/f(q_d)-1}}.$$

The impact of exchange rate on export quantity is affected by pricing power in domestic and foreign market, and the shape of cost function.

IV. The Specific-form Model

In empirical analysis, I introduce a specific demand function for convenience. Currently a simple Cournot quantity competition model has been employed to stress the problem. And I will mainly report the results of the model here. Still, one policy should be highlighted specifically. That is, China altered its exchange rate regime from fixed to limited float in 2005, which brings exporters exposed to exchange rate risk after 2005, meanwhile the commercial banks began to offer exchange rate forwards extensively since then. The Cournot model is constructed as follows:

With two firms employ quantity competition, the residual demand for firm *i* in sector *s* and market *j* can be interpreted as:

$$p_{is}^{j}=\frac{\alpha_s^j-\gamma_s^j q_{is}^j+c_{is}^j}{2} \tag{6}$$

Where, *p*, *q* and *c* are price, quantity and average cost of its competitor, respectively. α and γ are parameters with the constraint larger than 0.

As for the supply side, I henceforth omit superscript *s* and subscript *i* for simplicity, and add subscript *t* to demonstrate the decision sequence. The three decision procedures are shown in the following figure 1:(1) on time *t-1*,the firm must decide on export quantity q_{is}^{f} and price p_{is}^{f}, domestic quantity q_{is}^{d} and price p_{is}^{d}, hedge ratio h_i^s and imported intermediary I_i^s at exogenous price pi^s; (2) during the period from *t-1* to *t*, the exchange rate may change, and consequently induces cash flow fluctuation. The firm may have to finance some external capital to produce all the goods to be sold. And I neglect stock adjustment strategy in this model; (3) on time *t*, the firm will sell out all the goods and acquire the revenue with current exchange rate.

On time t-1, the firm decides:	In period t, the firm:	On time t, the firm:
· export and domestic sale	· produce all the goods	· sell good in domestic market
· import		· sell good in foreign market and acquire revenue
· hedge ratio		

Figure 1 Firm Decision Sequence

For firm-level export exchange rate, I assume it satisfy a first-order random walk process and only consider an aggregate exogenous shock, which implies:

$$e_t = e_{t-1} + \mu_t \tag{7}$$

Where, μ_t refers to aggregate exchange rate shock, and e_t the exchange rate of export. However, the exchange rate shock also leads to fluctuation of cash flow. To mitigate this effect, firm will choose to hedge a proportion h_t of total exchange rate risk, which is defined as the hedge ratio, and the net exposed proportion decease to $1-h_t$. Thus, at the production point during the period *t*, the cash flow that the firm will have in hand w_t^e can be expressed as:

$$w_t^e = w_{t-1}\left[1+(1-h_t)\cdot\lambda_t\cdot\mu_t\right] \tag{8}$$

Where, λ_t stands for the original correlation between cash flow fluctuation and exchange rate shock, which can be either negative or positive depending on the type of shock. If the required production cost exceeds w_t^e, the firm needs to finance external capital. If not, the firm can purely rely on internal cash flow. Thus, the amount of external financing capital v_t is calculated as:

$$v_t = max(c_t\,(q_t^f + q_t^d) - w_t^e, 0) \tag{9}$$

Where, c_t represents the average cost. In this model, the "pure" technology is CRS, and thus marginal production cost equals to average production cost. But financial constraints induce an increasing cost of an additional unit of external capital. To grasp the property, I set the financing cost and total cost in the form of the equations (10) and (11), respectively:

$$f(v_t) = v_t^{\beta}, with\ \beta > 1 \tag{10}$$

$$C = c_t\,(q_t^f + q_t^d) + [max(c_t\,(q_t^f + q_t^d) - w_{t-1}\left[1+(1-h_t)\cdot\lambda_t\cdot\mu_t\right], 0)]^{\beta} \tag{11}$$

Still, average cost c_t is determined by technology level, the price and proportion of domestic input and imported intermediary goods. I assume a simple Cobb-Douglas production function:

$$q_t = q_t^d + q_t^f = T_t\, D_t^{\alpha_t} I_t^{1-\alpha_t} \tag{12}$$

Where, D_t and I_t stand for input of domestic factors and imported intermediary, α_t refers to the proportion of domestic input and T_t represents the technology level. Rational firms will choose optimal quantity of inputs to minimize its cost, which implies:

$$c_t = A_t\, e_{It}^{1-\alpha_t}\, pd_t^{\alpha_t}\, pi_t^{1-\alpha_t} \tag{13}$$

Where, $A_t = \alpha_t^{-\alpha_t}(1-\alpha_t)_t^{\alpha_t-1}/T_t$, pd_t and pi_t stand for factor prices of domestic inputs and imported intermediary goods, respectively. e_{It} refers to the exchange rate of import. Till now, the optimization of exporters can be accurately characterized as follows:

$$\underset{q_t^f, q_t^d, h_t}{Max}\ E_t(\pi_t) = E_t[e_t\cdot p_t^f\cdot q_t^f + p_t^d\cdot q_t^d - c_t\cdot(q_t^f + q_t^d) - f(v_t)] \tag{14}$$

V. The Empirical Analysis

With above analysis, I can explain how these factors affect the relation between exchange rate and optimal export quantity: (1) the degree of ERPT varies with the quantity. As the demand function in equation (6) suggests, higher quantity leads to lower demand elasticity and higher markup. Therefore the impact of the same exchange shock will be further lessened in large exporters, as they drasticallyadjust export price; (2) with $\beta > 1$, financial constraints (FC) magnify the exchange rate shock and increase the production uncertainty; (3) financial hedging (FH) proportionally reduces the effect of the exchange rate shock; (4) both domestic sales (DS) and export are adjusted in response to exchange rate movement; (5) if export and import exchange rate are positively correlated, the average cost in equation (13) with imported intermediary (IM), increases as domestic currency depreciates, and therefore the export will be depressed. Therefore, FC should increase the elasticity, while ERPT, FH, DS and IM should decrease preliminarily.

Then I turn to the empirical analysis. For simplicity, firms in the same sector are believed to have similar market structure and thus share the same demand parameters. With the Cournot model, I can derive a specific form of the optimal quantity of export and domestic sale. Together with the demand functions in foreign and domestic markets, a structural estimation is applied to the four equations as follows:

$$p_{it}^f = (a - b \cdot q_{it}^f + c_t^f)/2 + \varepsilon_{it} \tag{15}$$

$$p_{it}^d = (c - d \cdot q_{it}^d + c_t^d)/2 + \mu_{it} \tag{16}$$

$$q_{it}^d = [c + c_t^d - e_{t-1}(a + c_t^f - 3bq_{it}^f)]/3d + \nu_{it} \tag{17}$$

$$q_{it}^f = \frac{a}{3b} + \frac{c_t^f}{3b} - \frac{2c_{it}}{3be_{t-1}} - \frac{4c_{it}}{3be_{t-1}}[c_{it}(q_{it}^d + q_{it}^f) - w_t^e] + \theta_{it} \tag{18}$$

Table 1 Parameter Estimation

Sector	Obs	Foreign market		Domestic market	
		a	*b*	*c*	*d*
Food Processing	7106	3,164***	63.63***	30,151***	43.46***
		(229.5)	(0.462)	(2,161)	(0.167)
Textile	20066	126.2*	11.70***	51,333***	85.77***
		(75.21)	(0.0557)	(3,168)	(0.0329)
Apparel	13249	1,745***	47.81***	4,788***	43.92***
		(126.5)	(0.250)	(635.9)	(0.105)
Leather	5870	525.6**	22.22***	20,628***	82.94***
		(217.6)	(0.189)	(1,518)	(0.179)
Sporting	4635	1,543***	37.59***	9,672***	62.59***
		(88.78)	(0.351)	(530.0)	(0.370)
Chemical	11682	950.5***	55.14***	62,320***	49.86***
		(115.5)	(0.321)	(2,277)	(0.108)
Plastic	9430	932.3***	38.03***	14,896***	46.19***
		(65.89)	(0.250)	(706.5)	(0.151)
Nonmetallic	7131	903.7***	35.27***	27,198***	50.90***
		(87.53)	(0.261)	(1,102)	(0.174)
Metalwork	10068	883.1***	49.88***	23,924***	60.94***
		(73.90)	(0.324)	(790.9)	(0.179)
General Equipment	12800	773.6***	70.57***	27,775***	33.99***
		(56.22)	(0.401)	(1,291)	(0.0883)
Special Equipment	7690	455.5***	60.05***	30,574***	35.68***
		(63.61)	(0.439)	(1,842)	(0.0990)
Transportation Equipment	7577	1,374***	43.25***	90,752***	29.32***
		(235.3)	(0.318)	(8,261)	(0.0761)
Electrical Equipment	13610	746.2***	69.83***	24,224***	42.20***
		(109.0)	(0.327)	(2,106)	(0.0662)
Communication Equipment	14748	938.1***	52.33***	83,248***	45.53***
		(241.1)	(0.277)	(4,573)	(0.0556)
Crafting	5291	411.3***	29.41***	11,964***	72.05***
		(82.32)	(0.263)	(654.0)	(0.228)

*Notes: ***, **, * represent significance at 1%, 5% and 10% confidence level. In parentheses reports the standard error of each parameter.*

The results of the empirical model are listed in Table 1. Obviously, the estimated coefficients are almost unanimously significant and satisfy the constraint larger than zero.

After that, since the specific form of optimal export quantity is well established, I can (1) first acquire a specific form of its first-order derivative with exchange rate;(2) then plug the estimated parameters back into the derivative equation;(3) finally multiply the derivative equation with exchange rate and divide it with export quantity, to calculate a firm-level elasticity between export quantity and exchange rate. Specifically, the optimal export quantity is expressed as:

$$q_t^f = \frac{a}{3b} + \frac{c_t^f}{3b} - \frac{2c_t}{3be_{t-1}} - \frac{4c_t}{3be_{t-1}}[c_t\,(q_t^d + q_t^f) - w_t^e] \tag{19}$$

Next job is to separate the effect of each mechanism mentioned above. I estimate each effect as follows: (1) first estimate a benchmark elasticity, without considering any of these mechanisms; (2) then add one mechanism for one time to observe the variation of the elasticity, by assuming the derivative of this mechanism with exchange rate is different from zero; (3) calculate the difference between the neighboring elasticity, and report the median values of each firm-level elasticity and the differences.

The benchmark is the elasticity without considering any above-mentioned mechanisms. In this situation, the firm will pass-through completely the exchange rate movement into export price, or stated equivalently, the markup should hold constant. Thus, a 1% movement of exchange rate will simply induce the same 1% movement of foreign price in the opposite way, and the elasticity is just the opposite value of the demand elasticity, as follows:

$$ela1 = \frac{\partial \ln q_t^f}{\partial \ln e_t} = -\frac{\partial \ln q_t^f}{\partial \ln p_t^f} = \frac{2p_t^f}{bq_t^f} \tag{20}$$

With incomplete ERPT, the demand elasticity varies with export quantity. By differentiating the third part of the right side in the equation (19) with exchange rate, I get the elasticity as:

$$ela2 = \frac{2c_t\, e_t}{3b \cdot e_{t-1}^2 \cdot q_t^f} \tag{21}$$

Then, I further consider the financial constraints (FC) and financial hedging (FH). If FC and FH take effect, I simply assume $\frac{\partial v_t}{\partial e_t} = \frac{\partial\left[c_t\,(q_t^d + q_t^f) - w_t^e\right]}{\partial e_t} \neq 0$ and $\frac{\partial w_t^e}{\partial e_t} \neq 0$ in equation (19). Finally, the effects of domestic sale (DS) and import (IM) are investigated similarly. And these four kinds of elasticity are expressed in detail as follows (Assume $\beta = 2$):

$$ela3 = \frac{\dfrac{2c_t}{3b \cdot e_{t-1}^2 \cdot q_t^f} + \dfrac{4c_t}{3b \cdot e_{t-1}^2} v_t + \dfrac{4c_t}{3b \cdot e_{t-1}} w_{t-1}(1-h_t)\lambda_t}{1 + \dfrac{4c_t^2}{3b \cdot e_{t-1}}} \cdot \frac{e_t}{q_t^f} \tag{22}$$

$$ela4 = \frac{\dfrac{2c_t}{3b \cdot e_{t-1}^2 \cdot q_t^f} + \dfrac{4c_t}{3b \cdot e_{t-1}^2} v_t}{1 + \dfrac{4c_t^2}{3b \cdot e_{t-1}}} \cdot \frac{e_t}{q_t^f} \tag{23}$$

$$ela5 = \frac{\dfrac{2c_t}{3b \cdot e_{t-1}^2 \cdot q_t^f} + \dfrac{4c_t}{3b \cdot e_{t-1}^2} v_t + \dfrac{4c_t^2 (a + C_t^f - 3bq_{2t})}{9b \ \ de_{t-1}}}{1 + \dfrac{4c_t^2}{3b \cdot e_{t-1}} + \dfrac{4c_t^2}{3d}} \cdot \frac{e_t}{q_t^f} \tag{24}$$

$$ela6 = \frac{\dfrac{2(c_t - e_{t-1}\dfrac{dc_t}{de_{t-1}})}{3b \cdot e_{t-1} \cdot q_t^f} + \dfrac{4(c_t - e_{t-1}\dfrac{dc_t}{de_{t-1}})}{3b \cdot e_{t-1}} v_t + \dfrac{4c_t}{3b}[\dfrac{dc_t}{d\ e_{t-1}}(q_t^d + q_t^f) + \dfrac{c_t (a + c_t^f - 3bq_t^f)}{3d}]}{1 + \dfrac{4c_t^2}{3b \cdot e_{t-1}} + \dfrac{4c_t^2}{3d}} \cdot \frac{e_t}{q_t^f} \tag{25}$$

The effect of each mechanism is simply the difference between two adjacent elasticity indexes. I report the median values of the firm-level elasticity and the effect of each mechanism across sectors in table 2. Here I choose the medians rather than the means, in order to abate the influence of extreme values.

Table 2 Median of the Elasticity for All Sample and Sectors

Sector	*e1*	*e2*	*e3*	*e4*	*e5*	*e6*	*ERPT*	*FC*	*FH*	*DS*	*IM*
All Sectors	0.011	0.004	1.329	0.998	0.290	0.303	-0.007	1.307	0.000	-0.544	-0.001
	0.020	0.005	1.631	1.472	0.530	0.543	-0.014	1.592	0.001	-0.859	0.000
Food Processing	0.002	0.001	1.038	0.897	0.086	0.087	-0.001	1.033	0.000	-0.673	-0.001
	0.002	0.001	1.113	1.054	0.115	0.114	-0.001	1.101	0.000	-0.848	-0.001
Textile	0.015	0.006	1.265	1.007	0.389	0.399	-0.008	1.243	0.000	-0.348	-0.003
	0.029	0.010	1.466	1.328	0.856	0.886	-0.019	1.409	0.000	-0.399	0.014
Apparel	0.005	0.002	0.995	0.813	0.122	0.136	-0.003	0.988	-0.002	-0.438	0.006
	0.021	0.007	1.022	0.994	0.456	0.483	-0.013	1.001	0.000	-0.463	0.012
Leather	0.029	0.011	1.170	0.935	0.616	0.632	-0.016	1.127	0.000	-0.110	0.010
	0.024	0.009	1.122	1.072	0.746	0.759	-0.014	1.093	0.001	-0.341	-0.001
Sporting	0.020	0.007	0.977	0.909	0.379	0.422	-0.013	0.950	0.000	-0.253	0.001
	0.029	0.009	1.212	1.100	0.408	0.429	-0.019	1.163	0.000	-0.582	-0.001
Chemical	0.006	0.002	2.122	1.619	0.282	0.290	-0.003	2.101	0.014	-1.103	-0.001
	0.006	0.002	2.722	2.615	0.423	0.432	-0.004	2.696	0.010	-1.775	-0.002
Plastic	0.015	0.006	1.363	1.010	0.373	0.395	-0.009	1.343	0.000	-0.538	-0.004
	0.029	0.009	1.710	1.487	0.583	0.602	-0.020	1.662	0.001	-0.905	0.001
Nonmetallic	0.008	0.003	1.343	0.990	0.225	0.223	-0.005	1.322	0.000	-0.523	-0.003
	0.012	0.004	1.815	1.385	0.500	0.518	-0.008	1.757	0.003	-0.774	-0.001
Metalwork	0.021	0.007	1.161	0.990	0.373	0.400	-0.013	1.138	0.008	-0.425	0.003
	0.027	0.007	1.421	1.350	0.524	0.533	-0.019	1.378	0.000	-0.827	0.000
General Equipment	0.026	0.007	2.998	1.454	0.350	0.367	-0.018	2.944	-0.006	-0.882	-0.001
	0.038	0.006	3.756	3.061	0.435	0.433	-0.030	3.699	-0.001	-2.208	-0.008
Special Equipment	0.030	0.007	5.162	1.671	0.270	0.266	-0.021	5.154	-0.009	-1.091	-0.004
	0.057	0.008	4.938	3.920	0.482	0.490	-0.047	4.853	0.002	-2.913	0.000
Transportation Equipment	0.012	0.004	2.508	1.346	0.391	0.412	-0.007	2.443	-0.002	-0.848	0.000
	0.016	0.004	3.014	2.438	0.639	0.660	-0.012	2.997	0.002	-1.548	0.000
Electrical Equipment	0.007	0.002	1.401	1.043	0.191	0.191	-0.005	1.392	0.007	-0.765	-0.002
	0.016	0.004	1.563	1.573	0.381	0.382	-0.011	1.537	0.029	-1.067	-0.001
Communication Equipment	0.012	0.004	1.324	1.010	0.353	0.353	-0.007	1.318	0.004	-0.556	-0.006
	0.018	0.004	1.630	1.601	0.534	0.534	-0.013	1.619	0.014	-1.020	-0.002
Crafting	0.012	0.004	1.001	0.863	0.207	0.210	-0.007	0.989	0.000	-0.347	-0.001
	0.060	0.020	1.148	1.077	0.764	0.752	-0.038	1.084	0.000	-0.276	-0.008

The current findings on firm level suggest: (1) financial constraints significantly increase the firm-level elasticity between export quantity and exchange rate. The within-firm effect implies an increase of 1.46 of the median value, while the total effect is around 1.49 (*e3*-*e2*); (2) domestic sale dramatically hedges the exchange rate risk and reduce the export volatility, with within-firm effect -0.75 and total effect -0.89 (*e5*-*e4*); (3) incomplete ERPT, FH and IM have similar moderate effect on the elasticity, with within-firm effect -0.02, 0.00, 0.00 and total effect -0.02, -0,28 and -0.21(*e2*-*e1*, *e4*-*e3*, *e6*-*e5*), respectively. These results are consistent across different sectors.

The empirical evidence indicates extreme financial constraints on exporters in China. The stringent constraints also induce a substantial connection between export and domestic sales, and therefore a strong hedging effect of domestic sales. Besides, as an emerging market, the effect of financial hedging is not as strong as expected. Finally, the nature hedging effect if import is also mildest , since structure of export and import destinations are significantly divergent and the correlation coefficient is merely 0.233. The next section is to detect firm heterogeneity and to aggregate into macro-level elasticity.

VI. Heterogeneity and Aggregation

To explain the differences between firm-level and sector-level elasticity, we report the result of the median of the elasticity of the top 5% largest exporters, as shown in Table 3. Firstly, the elasticity is significantly lower compared with Table 2, indicating that there might exist significant composition effect. Secondly, the effect of ERPT and DS is much larger. Possible explanation is the stronger pricing power in foreign and domestic market. Meanwhile the negative effect of FH is much lower; this could be the result of more cash hold by large firms.

Table 3 Median of the Elasticity for 5% Largest Exporters

Sector	*e1*	*e2*	*e3*	*e4*	*e5*	*e6*	*ERPT*	*FC*	*FH*	*DS*	*IM*	*Ratio*
All Sectors	0.09	0.00	0.99	0.97	0.15	0.15	-0.09	0.99	0.00	-0.60	0.00	50.46%
	0.10	0.00	1.05	1.04	0.24	0.24	-0.10	1.04	0.00	-0.84	0.00	60.46%
Food Processing	0.14	0.00	1.03	0.98	0.10	0.09	-0.14	1.03	0.00	-0.85	0.00	38.08%
	0.11	0.00	0.97	0.98	0.13	0.13	-0.11	0.97	0.00	-0.84	0.00	39.11%
Textile	0.12	0.00	0.99	0.97	0.28	0.28	-0.12	0.99	0.00	-0.56	0.00	40.26%
	0.17	0.00	0.88	0.86	0.38	0.40	-0.17	0.88	0.00	-0.16	0.01	71.73%
Apparel	0.05	0.00	0.95	0.88	0.13	0.13	-0.05	0.95	0.00	-0.58	0.00	41.09%
	0.02	0.00	0.92	0.94	0.28	0.30	-0.02	0.92	0.00	-0.47	0.01	42.68%
Leather	0.08	0.00	1.01	0.95	0.72	0.72	-0.08	1.00	0.00	-0.19	0.01	49.66%
	0.09	0.00	0.97	0.97	0.57	0.56	-0.09	0.97	0.00	-0.36	0.00	59.73%
Sporting	0.06	0.00	0.94	0.93	0.28	0.28	-0.06	0.94	0.00	-0.60	0.00	36.66%
	0.06	0.00	0.95	0.95	0.24	0.24	-0.06	0.95	0.00	-0.65	0.00	42.25%
Chemical	0.13	0.00	1.28	1.23	0.09	0.09	-0.13	1.28	0.01	-0.94	0.00	41.37%
	0.16	0.00	1.32	1.40	0.10	0.10	-0.16	1.32	0.01	-1.13	0.00	47.60%
Plastic	0.03	0.00	1.01	1.00	0.53	0.52	-0.03	1.01	0.00	-0.43	-0.01	42.40%
	0.11	0.00	1.05	1.04	0.28	0.28	-0.11	1.04	0.00	-0.75	0.00	40.44%
Nonmetallic	0.04	0.00	0.94	0.88	0.13	0.13	-0.04	0.94	0.00	-0.51	0.00	44.35%
	0.10	0.00	1.02	0.92	0.13	0.13	-0.10	1.02	0.01	-0.55	0.00	44.31%
Metalwork	0.05	0.00	0.98	0.96	0.35	0.35	-0.05	0.97	0.00	-0.49	0.00	45.11%
	0.10	0.00	1.01	1.04	0.29	0.29	-0.10	1.01	0.00	-0.70	0.00	48.63%
General Equipment	0.08	0.00	1.16	1.00	0.15	0.15	-0.08	1.16	0.00	-0.74	0.00	48.54%
	0.10	0.00	1.22	1.23	0.12	0.11	-0.10	1.22	0.00	-1.02	0.00	52.79%
Special Equipment	0.09	0.00	1.22	1.01	0.11	0.11	-0.09	1.22	0.00	-0.74	0.00	53.28%
	0.10	0.00	1.86	1.67	0.25	0.24	-0.10	1.85	0.00	-1.20	0.00	57.50%
Transportation Equipment	0.10	0.00	0.92	0.90	0.11	0.11	-0.10	0.92	0.00	-0.71	0.00	50.89%
	0.14	0.00	1.08	1.10	0.11	0.11	-0.14	1.08	0.00	-0.89	0.00	59.28%
Electrical Equipment	0.12	0.00	0.99	0.98	0.06	0.06	-0.12	0.99	0.00	-0.80	0.00	51.25%
	0.10	0.00	1.08	1.10	0.14	0.13	-0.10	1.08	0.01	-0.90	0.00	53.00%
Communication Equipment	0.18	0.00	1.12	1.08	0.22	0.22	-0.18	1.12	0.00	-0.81	0.00	63.76%
	0.13	0.00	1.13	1.20	0.24	0.24	-0.13	1.13	0.00	-0.87	0.00	71.12%
Crafting	0.00	0.00	0.95	0.91	0.30	0.30	0.00	0.95	0.00	-0.42	0.00	43.87%
	0.08	0.00	1.02	1.01	0.67	0.64	-0.08	1.02	0.00	-0.27	-0.01	42.51%

Notes: Ratio refers to the ratio of the total export quantity of top 5% largest exporters to that of the whole sector.

Finally, we directly aggregate the firm-level elasticity into sector-level elasticity. In table 4, we see in sample of all sectors, the mean of the elasticity is 1.07, while for the top 5% largest exporters is 0.47, merely half of the total sample. In the last row, we calculate the sector-level weighted elasticity using the ratio of the firm's export to total export as the weight. The sector-level is 0.54, which is much lower than 1.07, the mean of the elasticity, indicating a significant composition effect. Still, domestic sales display a strong hedging effect, which mitigate the effect of exchange rate on export for about 1.19 (ela5-ela4). All industries demonstrate similar effect.

Table 4 Aggregation and Composition Effect

Sector	Mean; All sample	Mean; High 5%	composition effect					
	ela6	ela6	ela1	ela2	ela3	ela4	ela5	ela6
All Sectors	1.07	0.47	0.13	0.01	1.16	1.73	0.54	0.54
Agriculture	0.57	0.28	0.11	0.00	1.71	1.71	0.34	0.34
Textile	1.34	0.63	0.17	0.01	0.93	0.93	0.52	0.54
Apparel	0.82	0.52	0.02	0.01	0.68	1.21	0.58	0.60
Leather	1.16	0.63	0.09	0.01	1.11	1.14	0.68	0.67
Sporting	0.84	0.39	0.06	0.01	1.28	1.27	0.48	0.48
Chemical	1.11	0.36	0.16	0.00	1.98	2.47	0.51	0.51
Plastic	1.12	0.42	0.11	0.01	1.71	1.74	0.58	0.58
Nonmetallic	1.08	0.39	0.10	0.01	2.95	1.58	0.56	0.56
Metalwork	1.07	0.48	0.10	0.01	0.76	1.65	0.57	0.57
General Equipment	1.11	0.43	0.10	0.01	3.05	3.51	0.54	0.53
Special Equipment	1.18	0.56	0.10	0.01	4.16	4.20	0.67	0.66
Transportation Equipment	1.25	0.40	0.14	0.00	2.70	2.81	0.48	0.48
Electrical Equipment	0.95	0.39	0.10	0.00	1.70	2.42	0.61	0.60
Communication Equipment	1.06	0.44	0.13	0.00	0.15	1.84	0.51	0.51
Crafting	1.02	0.70	0.08	0.02	1.24	1.25	0.74	0.73

Notes: the row "Mean; All sample" reports the mean the elasticity between export and exchange rate of all samples. The row "Mean; High 5%" reports the mean the elasticity of the top 5% largest exporters. The row "composition effect" reports the weighted elasticity of all samples.

VII. Conclusions

By utilizing detailed firm-level data in China, we study the Exchange Rate Disconnection Puzzle. We first estimate the firm-level elasticity between export and exchange rate with a structure model and then detect heterogeneous effect of exchange rate on export on firm level. However, we cannot explicitly disentangle between the externality of domestic market to foreign market in supply side and that of demand side. Besides, since the pricing powers in the two markets cannot be separated, we are considering revising the model, with pricing power in domestic market(like translog) and no pricing power in domestic market (like CES).

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