Investment Response to Exchange Rate Uncertainty: Evidence from Chinese Exporters *

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Abstract

This paper examines empirically the relationship between exchange rate uncertainty and firm-level investment activity using a natural shock caused by the switch of exchange rate regime in China. Result shows that increased RMB volatility induced by China's policy shift had significantly reduced exporting firms' responsiveness of investment to demand. It is also found that exporters in industries with higher degree of capital irreversibility were more sensitive to the exchange rate uncertainty shock, which is consistent with the capital irreversibility hypothesis in the literature. Moreover, response to exchange rate uncertainty is heterogeneous across firms. Exporters with non-state ownership, less exporting experience, and lower productivity were more affected by the increased RMB volatility.

Keywords: Exchange rate regime, uncertainty, investment
JEL classification codes: E22, F30

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1 Introduction

What happens to the exporting firms when a country increases the flexibility of its exchange rate regime? The exporting firms will experience two shocks at the same time. The first shock is on the level of the exchange rate against a basket of currencies. For instance, if the country's currency is previously under-valued, then it will experience an appreciation against the currency it was previously pegged to. The second and more subtle shock is on the volatility of exchange rate. If, for example, the currency is previously pegged to the US dollar, which is the benchmark currency for many other currencies in the world, then switching to a more flexible currency regime also means an increase in the exchange rate volatility.

This is exactly what happened in China since 2005. In July 2005, the Chinese authority swithced the exchange rate policy from pegging to the US dollar to "managed fluctuation" against the dollar. From 2005 to 2007, the RMB had appreciated vis-a-vis the dollar by about 15% in nominal term. The volatility of RMB against a basket of currencies had also increased, resulting in dramatic increase in exchange rate uncertainty for Chinese exporting firms.

This paper uses the shock on exchange rate uncertainty induced by the switch of currency regime as a natural experiment to test the theoretical causality between uncertainty and firm-level investment. To accomplish the task, we document the following facts. First of all, China's shift of exchange rate regime can be seen as an unexpected and sizeable shock on the exchange rate uncertainty faced by firms. Moreover, the size and the direction of the uncertainty shock differs from industry to industry. This is the cornerstone of our following analysis because the unexpectedness and size validate the natural experiment. The cross-sectional variation is established by considering different firms' export proportion to different currency zones. Since the RMB's volatility experienced different shocks against different currencies, we would expect that firms that export to different currency zones will experience different shocks on their exchange rate

uncertainty. This cross-sectional variation will provide us with the identification strategy.

Secondly, uncertainty does have a significant and negative correlation with firms' investment behavior. A large body of literature showed that, as uncertainty increases, firms will reduce their investment or become more cautious in making investment decisions.[1] In this paper, the dampening effect of uncertainty documented by Bloom et al. (2007) is also found in our empirical examination. The result is highly robust after controling for a set of firm- and industry-level confounding factors, as well as firm- and industry-year fixed effects. We also adopt different measures of exchange rate uncertainty in our analysis, but the main result does not change.

Thirdly, the literature proposed capital irreversibility hypothesis as a potential channel through which uncertainty could affect investment. In our paper, we also test this hypothesis and find evidence supporting the argument. The test is to split firms into two groups by the degree of capital irreversibility. We proxy the degree of irreversibility in two ways. The first way is to use comovement of firm-level sales within industries. It is documented by Guiso and Parigi (1999) that, if firms within the same industry have a high comovement of their sales, then the degree of capital irreversibility in that industry is high. This is because firms in trouble cannot disinvest in difficult times since all the other firms in this industry, who are potential buyers of the disposed capital, are likely to be suffering as well. The second way is to use industry's Research and Development (Research and Development (R&D) as a proxy. Under both measures, we find the result that exchange rate volatility dampens the responsiveness of investment to demand more for firms of higher capital irreversibility.

We also differentiate firms by their ownership structure, export experience, and productivity in order to examine firm's heterogeneous response to exchange rate uncertainty. We propose three hypoetheses. The first one is that State-owned Enterprises (SOEs) are more likely to be less sensitive to the uncertainty comparing to other firms, since they have softer budget constraints and their investment decisions are more independent to

[1]The uncertainty referred by the literature can be supply-side, demand-side, or political uncertainty.

changes of econoimc condition. The second one is that firms with more export experience tend to be more capable in dealing with currency fluctuation, hence, they are expected to perceive less exchange rate uncertainty. The third one is that more productive exporters will be less affected by uncertainty as they are more capable of handling economic shocks. Our findings below confirm these hypotheses.

This paper makes contribution to two strands of literature. The first one is on the correlation between uncertainty and firm-level investment. The theoretical literature such as Bernanke (1983), Hassler (1996) and Bloom (2009) all demonstrate a negative impact on firm-level investment caused by demand uncertainty. These models are all based on the irreversability of investment and the increase of the real option value when firms face higher uncertainty. On the empirical front, Leahy and Whited (1996) used the volatility of a firm's stock market return as a measurement of firm-specific uncertainty. They assumed that the firm-level uncertainty follows an exogenous stochastic process and used the empirical procedure by Holtz Eakin et al. (1988) to show that an increase in uncertainty is negatively correlated with firms' investment rates. Guiso and Parigi (1999) used cross-sectional survey data on manager's subjective distributions of future demand growth to estimate the variance of firm-level demand shocks for a sample of Italian firms. They found that an increase in uncertainty weakens the responsiveness of investment to demand shocks. More recently, Bloom et al. (2007) used a simulated panel data and showed that an ECM model with firm-level investment as dependent variable, and demand shocks (measured by the increments of sales), uncertainty shocks (measured by the stock market volatility), and their interaction term as independent variable can capture the "cautionary effect" caused by uncertainty shocks. They applied this empirical strategy to a data set of manufacturing firms and found that the effect of uncertainty on investment is negative and significant. On top of that, Kannan et al. (2011) employed within-sector dispersion of stock market return as a measurement of uncertainty, and found that an increase in uncertainty greatly raises the magnitude duration of aggregate unemployment.

Although these empirical works provided abundant evidence on the impact of uncertainty on real economic activities, their results are usually under scrunity due to the lack of exogenous shocks on uncertainty. The increase of uncertainty can be the result of many other confounding factors that may also affect firm-level investment. For example, Bachmann and Moscarini (2011) demonstrated that the limited commitment nature of firms will lead to experiments during economic downturn and, hence, a first moment shock can lead to a increase in uncertainty. Arellano et al. (2012) considered the interaction between financial frictions and uncertainty and was able to generate cross-sectional dispersion of firm growth rates in economic downturn. This paper deals with the endogeneity of undertainty by making use of the natural experiment induced by the sudden change of exchange rate regime, and explores the cross-sectional variation of firms' exposures to different currency volatilities to identify the causal relationship between uncertainty shocks and firm-level investment.

The second line of literature is on the correlation between exchange rate regime and economic growth. The theoretical narratives by previous empirical works (Levy Yeyati and Sturzenegger (2003) and Frankel and Rose (2002), for example) indicated that a pegged exchange rate can help economic growth by reducing demand and policy uncertainty, thereby facilitate factor accumulation. However, it can also hamper growth by creating price distortion and reducing the allocative efficiency and competition. On the empirical side, previous literature used cross-country growth accounting method (based on Barro (1991)) in attempt to discover the overall correlation between exchange rate regime and economic growth. The results are mixed. Obstfeld and Rogoff (1995); Frankel and Rose (2002) and Bleaney and Francisco (2007)) agreed that fixed exchange rate can boost investment but will generate slower growth rate. Aghion et al. (2009), however, documented that the impact on growth rate depends crucially on the stage of development. If the country is close to technological frontier, the fixed exchange rate regime will hamper growth by lowering medium-term productivity growth. If the country is far from technological frontier, the fixed exchange rate regime will promote growth by boosting

investment. This paper contributes to this literature by providing detailed micro-level evidence on the causal correlation between the uncertainty brought by a more flexible exchange rate regime and firm-level investment.

The paper is organized as follows: Section 2 discusses the switch of exchange rate policy in China. Section 3 outlines the empirical strategy. Section 4 describes the data. Section 5 presents the results. Section 6 concludes.

2 China's exchange rate regime shift

2.1 Background

Since 1997, the Chinese authority had effectively pegged the RMB to the US dollar at the rate of 8.28 RMB per dollar until 21 July 2005, when the Chinese central bank announced that the RMB would be managed to float with reference to a basket of currencies. On 9 August 2005, the Central Bank Governer Zhou Xiaochuan disclosed a list of 11 currencies as constitues of the reference basket, which includes the US dollar, the euro, and other currencies which are chosen because of the importance of their economies for China's current account.[2] The corresponding weights for each currency, however, were not publicly announced. Nor were the frequency and the criteria with which the weights might be changed. This made the exchange rate of RMB hard to predict and induced larger uncertainty for the Chinese exporters.

Figure 1 plots the trend of nominal exchange rate between the RMB and other four major currencies: the dollar, the euro, the yen, and the pound. Before July 2005, the RMB/dollar rate was fixed at a constant level. After the switch in the regime, the RMB started to appreciate vis-a-vis to the dollar, though the pace was slow and gradual. From July 2005 to the end of 2007, the RMB had appreciated by more than 10% with respect

[2]Frankel and Wei (2007) provide a detailed discussion on the exchange rate policy in China. Based on Zhou's speech on 9 August 2005, they split the 11 currencies into two groups by the relative importance for China: the US dollar, the euro, the yen, and the Korean won are labelled as first-tier currencies; the Singapore dollar, the British pound, the Malaysian ringgit, the Russian ruble, the Australian dollar, the Thai baht, and the Canadian dollar are classified as second-tier currencies.

Figure 1: Trend of the RMB exchange rate index

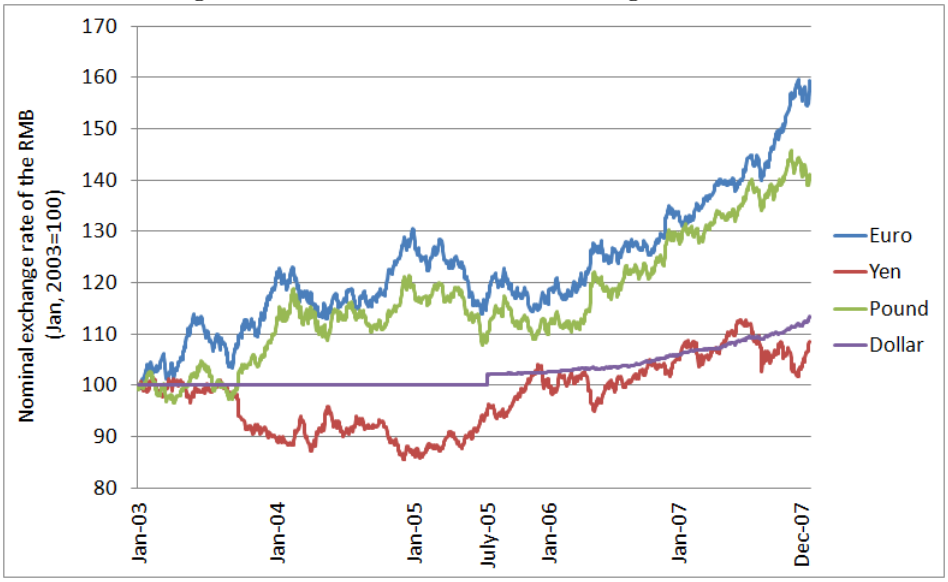
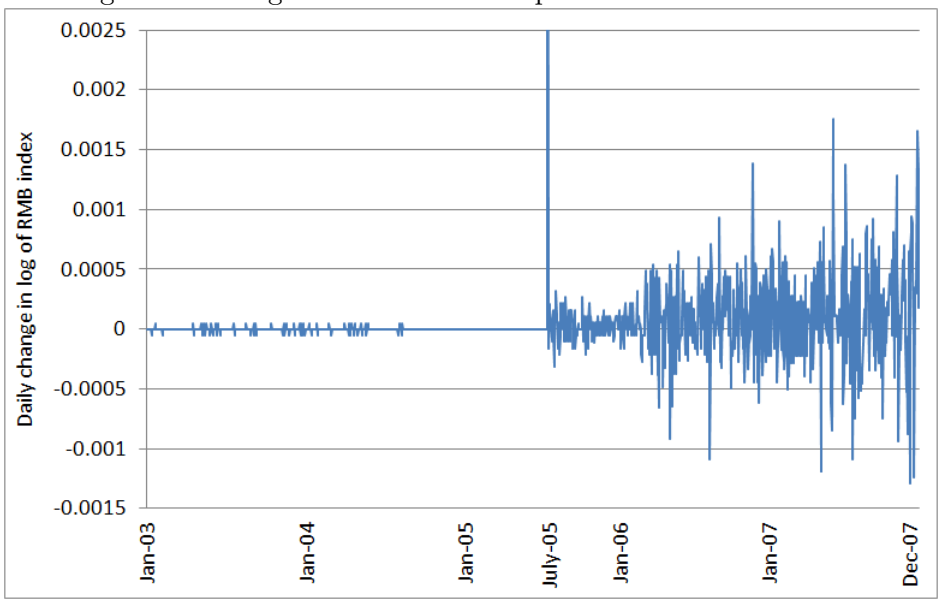


Figure 2: Change of the U.S. dollar per unit of RMB over time



to the dollar in nominal term. During the same period, the RMB also saw significant appreciation with respect to the euro and the pound.

An worth-noting pattern of Figure 1 is that, although the RMB was announced to be no longer pegged to the US dollar, the volatility between the RMB and the dollar was still much smaller than that between the RMB and other major currencies. This implies that the dollar was assigned a heavy (or even dominant) weight among the currencies in the reference basket. Indeed, as Goldstein and Lardy (2006) pointed out, "there is little evidence of pegging to a basket; rather, the RMB continues to track the US dollar closely." As a result, the fluctuation of the RMB against other currencies mostly reflected the fluctuation between the dollar and these currencies.

To get a better sense of the uncertainty induced by the shift of the regime, we plot the daily change of nominal RMB/dollar exchange rate from 2003 to 2007. As depicted in Figure 2, the day-to-day change of the RMB/dollar rate deviated from zero since 21 July 2005. The initial range of daily exchange rate movement after the regime change was small, mostly within +/- 0.05%. Since the first quarter of 2006, the fluctuation had become more volatile. Several times the day-to-day change went beyond +/- 0.1%.

2.2 The unexpectedness of the regime change

As mentioned above, having an exogenous uncertainty shock is crutial to our study. In China's case, we argue that the shift of exchange rate regime in 2005 was largely an unexpected event. And the evidence of the unexpectedness can be supported by three facts, among others. The first one is that when answering reporter's questions on March 14, 2005, Premier Wen Jiabao said "it is likely to be an unexpected matter" as to when the RMB exchange rate reform would be launched and what strategy would be followed.[3] The second fact is that, as documented by Liu et al. (2013), the major western medias reported the switch in the regime as a "surprise move" (by CNN) or an "unexpected" event (by the Financial Times and BBC). The third fact is that the Chinese private

[3]The article is available at http://english.people.com.cn/200507/29/eng20050729_199099.html

investment of asset denoted by the US dollar surged to historical high in the first half of 2005, right before the switch of exchange rate regime. This is unlikely to happen if the switch of exchange rate regime was widely anticipated.

3 Empirical strategy

3.1 Regression specification

To assess the impact of exchange rate uncertainty on exporting firms' investment, we follow the estimation strategy of Bloom et al. (2007). The regression specification is:

$$\begin{aligned}\Delta logK_{it} =& \beta_1(SD_{jt} * \Delta logY_{it}) + \beta_2 \Delta logY_{it} + \beta_3(\Delta logY_{it})^2 + \beta_4(logY_{i,t-1} - logK_{i,t-1}) \\ &+ \beta_5 X_{ijt} + \theta_{jt} + \alpha_i + \epsilon_{it}\end{aligned} \tag{1}$$

where $\Delta logK_{it} \approx (I_{it}/K_{i,t-1}) - \delta_i$ is an approximation of firms' investment. SD_{jt} measures the uncertainty of RMB exchange rate for industry j at year t. $\Delta logY_{it}$ measures the growth of real sales. The coefficient on the interaction term of SD_{jt} and $\Delta logY_{it}$, β_1, is of our main interests. It indicates how an increase in uncertainty can affect the responsiveness of investment to demand shocks. $(\Delta logY_{it})^2$ is the squared sales growth, which tests potential convexity in the responsiveness of investment to demand. $(logY_{i,t-1} - logK_{i,t-1})$ is the ECM term of the capital stock adjustment process. X_{ijt} is a set of firm- and industry-level covariates, which include firm's ownership status, size, leverage ratio, as well as interaction terms between RMB-USD exchange rate, industry-level export growth, FDI growth, and firm's sales growth. θ_{jt} denotes industry-year fixed effects, which absorbs all the industry-year shocks. α_i captures firm fixed effect. ϵ_{it} is the error term.

3.2 Measuring exchange rate uncertainty

We measure the exchange rate uncertainty as the annual volatility of weighted average exchange rate. The construction of the measure follows two steps:

1. For each industry, we construct a series of daily RMB exchange rate indices, which are calculated as the average bilateral exchange rate between the RMB and other currencies, weighted by the export share of the country using that currency. The formula is as follows:

$$ER_{jd} = \Pi_{c \in C}(ER_{cd}/ER_{c0})^{(W_{cjd})} \tag{2}$$

where ER_{cd} is the bilateral exchange rate between the RMB and currency in country c at day d. ER_{c0} is the bilatteral exchange rate at 2 January, 2003, which is considered as the base rate. W_{cjd} denotes the share of exports to market c at day d in the total exports of industry j.[4] In order to address the concern on changing export share, we also use time-invariant export share in 2004 as the weight to construct the volatility. C is the set of export destination countries.

2. For each industry, we compute the standard deviation of the RMB indices obtained from Equation 2 within each year. That is:

$$SD_{jt} = S.D.(ER_{jd}), \quad d \in t \tag{3}$$

The variable SD_{jt} is our measure of exchange rate uncertainty.

Since we use the export share by destination market to calculate the volatility, we refer it as the market-based measure of uncertainty. The implicit assumption is that the Chinese exporters make decisions based on the variability of the currencies of their trade partners. In reality, however, the Chinese exporters may not be aware of the variability of these currencies because a considerable portion of export transactions are invoiced in the US dollar. As a result, the Chinese exporters may only hedge the risk against

[4]We assign the export share of each day equal to the share of the year which the day belongs to.

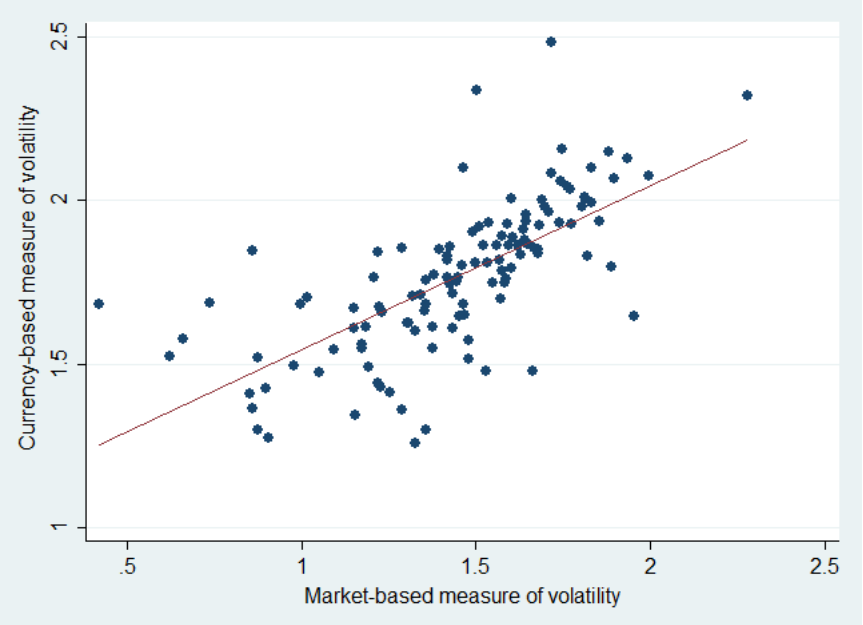
Figure 3: RMB Volatility: Time trend 2002-2007

the dollar rather than other currencies. Indeed, Bernard (2008) conducted a survey and found that many Chinese exporting firms in the textile sector failed to identify their true exchange rate exposure to the currencies other than the dollar, thereby underestimate the exchange rate uncertainty they are actually facing.

To address this issue, we also construct a currency-based measure of uncertainty. To do so, we consider the four major invoicing currencies for the Chinese exporters: the dollar, the euro, the yen, and the pound. We assume that exports to countries in the European Monetary Union, Japan, and Britain are invoiced in the euro, the yen, and the pound, respectively, and exports to the rest of the world are all invoiced in the dollar. Then, we replace the weights in Equation 2 by the export share of the invoicing currencies, and recalculate the exchange rate indices and standard deviation using equation 2 and 3. The obtained volatility is the currency-based uncertainty measure.

Figure 3 plots the trends of both market-based and currency-based RMB volatility. As shown, there was a clear increase in the volatility over time under both measures. The currency-based volatility was smaller than the market-based one before 2005. But

Figure 4: RMB Volatility: Cross-industry variation in 2007



it soon surpassed the latter after the change in exchange rate regime. This is expected because China's exchange rate reform was mainly to increase the fluctuation of the RMB against the dollar, which is assigned greater weight under the currency-based measure. Figure 4 plots the cross-industry variation of the volatility in 2007. As depicted, the volatility varied substantially across industries.

4 Data description

Our main data source is the Chinese industrial census database compiled by the National Bureau of Statistics (NBS) of China. It contains annual balance sheet and income statement data for all Chinese industrial firms with an annual turnover of at least five million yuan. The dataset we use for the current study spans the period 2002 to 2007 and only contains firms in manufacturing industries. In the original dataset, the industry affiliation is based on Chinese Industrial Classification (CIC). To make it compatible with the trade data, which is classified under the International Standard Industrial Classification (ISIC), we use a concordance between CIC and ISIC Rev.3 (at four-digit industry

level) developed by the NBS. We also use two-digit industry-level deflators constructed by Brandt et al. (2012) to deflate firms' sales.

In cleaning the data, we rid the sample of observations containing incomplete and inaccurate information (e.g., negative values for capital or labor). While the database is supposed to cover firms with an annual turnover over five million yuan, there is a sizable number of firms in the database that report turnover well below that threshold. We drop firms that report annual turnover below two million yuan. In addition, to mitigate the impact of outliers, we drop 1 percent of the extreme values at both ends of the distributions of sales, capital stock, and labor, as well as the growth rate of each of the variables. We do this for each four-digit industry separately. A small number of firms in the database have switched their industry affiliation at the two-digit ISIC level. We drop these firms from our analysis as well. Lastly, we keep only exporters, which are the firms with positive export sales. The final data set is an unbalanced panel with about 203,034 observations for five years.

The trade data comes from World Integrated Trade Solution (WITS), which is jointly managed by the World bank and WTO. The database documents the total value of exports and imports between China and each of other economies at ISIC four-digit industry level. We collect the data from 2002 to 2007 and use it to calculate the export share of China's trade partners.

The exchange rate data is from the IMF exchange rate database, which documents exchange rates as currency units per US dollar for more than 60 countries. Between 2002 and 2007, the data is available for more than 50 countries.[5] The IMF records the exchange rates data on daily basis. For most of the countries, there are more than 200 exchange rate data per year.[6] In our analysis, we drop those countries which have less than 100 exchange rate data for any given year since they could dampen the measure of volatility. In the end, we have 38 countries in the data. The summary statistics of the

[5]The exchange rates for the currencies of Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, and Spain are reported as exchange rate of euro, which are published by the European Central Bank.

[6]The IMF does not record exchange rates on weekends and some holidays.

Table 1: Summary statistics

Variables	**Mean**	**Std. Dev.**	**N**
Firm-level variables			
Log(capital)	8.56	1.6	203034
Log(labor)	5.26	1.03	203034
Log(sales)	10.52	1.2	203034
Change in Log(capital)	0.09	0.48	203034
Change in Log(sales)	0.16	0.4	203034
Leverage	0.54	0.24	203034
Share of SOEs in total number of exporters	0.023		
Share of FIEs in total number of exporters	0.47		
Share of small firms in total number of exporters	0.79		
Industry-level variables			
Log(total export value in US dollar)	14.611	1.705	112
Log(capital to labor ratio)	4.378	0.662	112
Log(R&D to sales ratio)	0.02	0.015	112
RMB volatility (marketd-based measure)	1.108	0.161	112
RMB volatility (currency-based measure)	1.133	0.16	112

variables are presented in Table 1

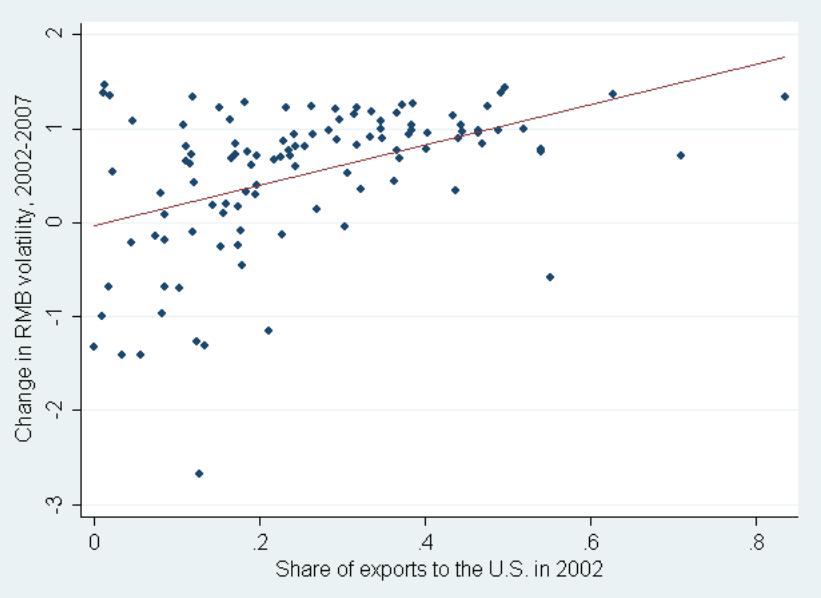
5 The Result

5.1 Baseline result

Table 2 reports the baseline result under market-based measure of exchange rate uncertainty. For all the regressions, we control for both firm - and industry-year fixed effects. In column (1), the coefficient on the interaction term of exchange rate uncertainty and firms' sales growth is negative and significant, which suggests that increase in the uncertainty would dampen exporting firms' responsiveness of investment to demand shocks. The coefficients on sales growth, its squared term, and the ECM term are all both positive and significant. These are consistent with the findings of Bloom et al. (2007). In column (2), we include lagged dependent variable to deal with potential serial correlation problem. The coefficient on the interaction term does not change, and the coefficient on the lagged captial growth is negative and significant, indicating a mean-reverting process of investment. In column (3) we throw in more control variables. We firstly add dummy variables for SOE and SME, as well as controling for firms' leverage, defined as the ratio of total liabilities to total assets. In addtion, we interact the annually-averaged RMB-US dollar exchange rate with firms' sales growth to capture the potential trend effect of RMB appreciation. On top of that, we control for industry's export and FDI growth so that we can shut down other channels through which the exchange rate policy shift would affect firms' investment behavior. As shown, the inclusion of these additional controls does not alter the main result.

Although we claim that the switch of China's exchange rate policy is an unexpected and exogenous event, our measure of uncertainty could still be endogenous due to the endogeneity of export share of China's trade partners. To deal with this concern, we also construct the exchange rate volatility using the export share in 2004 as fixed weight. The result using the time-invariant weight remains stable. In order to further alleviate the

Figure 5: Exports to the U.S. and increase in market-based volatility



concern on endogeneity, we adopt two stage least square (2SLS) estimation. Specifically, we instrument exchange rate uncertainty using interaction of a post dummy, which equals to one for years after 2005, and the initial export share of the US in China's total export (at industry-level). The rationale is that industries exporting more to the US tend to see greater exchange rate volatility after 2005 since the thesis of China's exchange rate reform is to increase the band of fluctuation of RMB against the dollar. Figure 5 and 6 plot the correlation between export share of the US and change in RMB volatility. As shown, the two variables are highly correlated with industries exporting more to the US associated with greater increase in RMB volatility. The result from 2SLS estimation is reported in column (4). It is broadly consistent with the baseline findings, except that the magnitude of coefficient on the uncertainty-sales interaction term becomes larger. Finally, Table 3 presents the result under currency-based measure of exchange rate uncertainty. As shown, the coefficients on the interaction term are all negative and significant, suggesting that our main findings are robust to different measure of uncertainty.[7]

In interpreting the result, we argue that an increase in exchange rate uncertainty

[7]The first stage regression results are shown in the Appendix.

Table 2: Baseline results I: Market-based measure of exchange rate uncertainty

	(1)	(2)	(3)	(4)
ER uncertainty*sales growth	-0.0966***	-0.115***	-0.0961***	-0.232***
	[0.0224]	[0.0250]	[0.0373]	[0.0594]
Sales growth	0.413***	0.425***	0.0969	0.811**
	[0.0244]	[0.0300]	[0.285]	[0.330]
Sales growth squared	0.107***	0.0599***	0.0603***	0.0672***
	[0.00625]	[0.0110]	[0.0108]	[0.0110]
Error correction term	0.554***	0.529***	0.528***	0.532***
	[0.0116]	[0.0134]	[0.0133]	[0.0129]
Lagged capital growth		-0.121***	-0.122***	-0.123***
		[0.00765]	[0.00766]	[0.00765]
SOE dummy			0.00775	0.00693
			[0.0390]	[0.0393]
SME dummy			-0.0215**	-0.0256**
			[0.0101]	[0.0105]
Leverage			-0.0601**	-0.0597**
			[0.0244]	[0.0246]
RMB-USD exchange rate*sales growth			0.0397	-0.0300
			[0.0314]	[0.0334]
Export growth*sales growth			-0.00931	-0.00491
			[0.0295]	[0.0383]
FDI growth*sales growth			-0.00152	-0.0709
			[0.0472]	[0.0548]
Estimation strategy	OLS	OLS	OLS	2SLS
Observations	203,034	118,786	118,748	118,748
R-squared	0.635	0.645	0.681	0.681
Firm fixed effects	Yes	Yes	Yes	Yes
Industry-year fixed effects	Yes	Yes	Yes	Yes

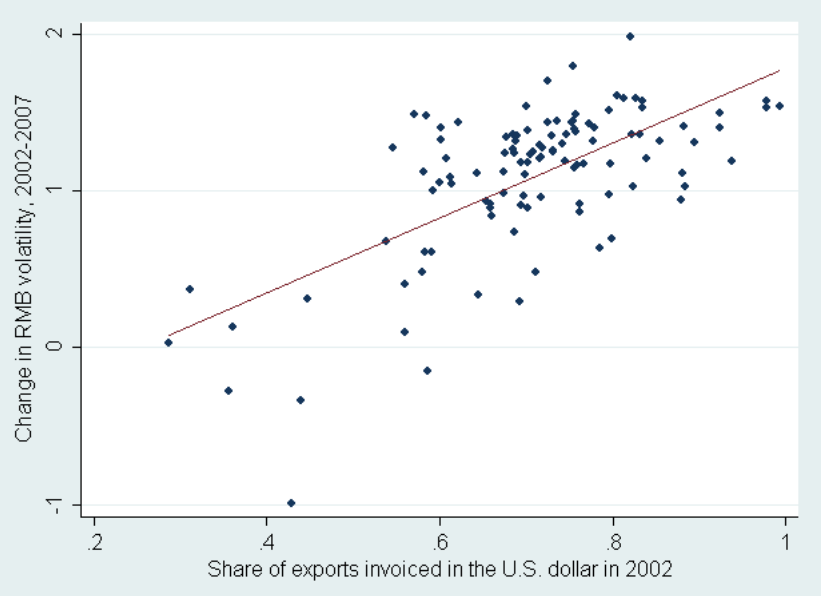
The dependent variables are capital growth for all columns.
Standard errors are clustered at industry level. *** p<0.01, ** p<0.05, * p<0.1

Table 3: Baseline results II: Currency-based measure of exchange rate uncertainty

	(1)	(2)	(3)	(4)
ER uncertainty*sales growth	-0.131***	-0.137***	-0.143***	-0.163***
	[0.0172]	[0.0187]	[0.0374]	[0.0377]
Sales growth	0.456***	0.462***	0.476	0.603**
	[0.0200]	[0.0254]	[0.319]	[0.263]
Sales growth squared	0.106***	0.0609***	0.0617***	0.0624***
	[0.00635]	[0.0109]	[0.0108]	[0.0107]
Error correction term	0.556***	0.533***	0.532***	0.532***
	[0.0115]	[0.0133]	[0.0137]	[0.0132]
Lagged capital growth		-0.120***	-0.120***	-0.122***
		[0.00772]	[0.00776]	[0.00766]
SOE dummy			0.00636	0.00600
			[0.0394]	[0.0392]
SME dummy			-0.0240**	-0.0249**
			[0.0100]	[0.0101]
Leverage			-0.0601**	-0.0601**
			[0.0243]	[0.0247]
RMB-USD exchange rate*sales growth			0.000833	-0.0119
			[0.0351]	[0.0278]
Export growth*sales growth			-0.00559	-0.00457
			[0.0276]	[0.0382]
FDI growth*sales growth			-0.0397	-0.0521
			[0.0501]	[0.0464]
Estimation strategy	OLS	OLS	OLS	2SLS
Observations	203,034	118,786	118,748	118,748
R-squared	0.636	0.646	0.682	0.681
Firm fixed effects	Yes	Yes	Yes	Yes
Industry-year fixed effects	Yes	Yes	Yes	Yes

The dependent variables are capital growth for all columns.
Standard errors are clustered at industry level. *** p<0.01, ** p<0.05, * p<0.1

Figure 6: Exports to the U.S. and increase in currency-based volatility



would cause exporting firms to be less responsive in making investment with respect to demand. That is, exporters tend to adopt "wait-and-see" strategy of investment when feeling more uncertain about future movement of exchange rate. While our findings are consistent with the literature which found negative correlation between uncertainty and investment, the novelty of our analysis makes us believe that a causal relationship between the two can be established.

5.2 Robustness tests

We perform several robustness tests for the baseline result, as shown in Table 4. We conduct the tests under both market-based and currency-based uncertainty. In column (1) and (5), we focus on the sample of firms who reported positive investment. It is to exclude those firms who are deinvesting. In column (2) and (6), we use a balanced sample, which contains only firms that survive throughout the data period. In column (3) and (7), we drop SOEs because they are not always profit maximizers, and inclusion of these firms may violate the profit-maximization assumption of the ECM model. In column (4) and (8), we calculate the volatility using monthly-averaged exchange rate

Table 4: Robustness checks

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Market-based measure of ER uncertainty				Currency-based measure of ER uncertainty			
	Positive investment	Balanced panel	Excl. SOEs	Monthly volatility	Positive investment	Balanced panel	Excl. SOEs	Monthly volatility
ER uncertainty*sales growth	-0.125***	-0.127***	-0.115***	-0.105***	-0.164***	-0.149***	-0.144***	-0.134***
	[0.0326]	[0.0241]	[0.0290]	[0.0218]	[0.0260]	[0.0196]	[0.0227]	[0.0183]
Observations	53,357	35,610	116,164	118,748	53,357	35,610	116,164	118,748
R-squared	0.804	0.432	0.647	0.645	0.805	0.433	0.647	0.646
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

The dependent variables are capital growth for all columns. Standard errors are clustered at industry level.
*** p<0.01, ** p<0.05, * p<0.1

data. For all these regressions, the baseline result remains unchanged.

5.3 Capital irreversibility

How does uncertainty affect firms' investment behavior? One conjecture provided by the literature is the captial irreversibility hypothesis. It is argued that firms which cannot easily liquidate installed capital tend to be more cautious in making investment when facing uncertainty. To test this hypothesis, we characterize firms as either high- or low irreversiblity firm based on the degree of capital irreversibility of the industry they affiliate. To gauge industry's degree of capital irreversibility, we use two measures. The first one is related to "industry comovement", which is put forward by Shleifer and Vishny (1992). The idea is as follows: when a firm liquidates its capital, it is most likely to sell it to another firm in the same industry. If such firm (the buyer) can be easily found, then the liquidation cost will be low. Oppositely, if the resale market is limited, then the cost will be high. Hence, in an industry where firms' output is highly sensitive to aggregate shock (i.e. firms have high degree of comovement in output), liquidating capital will be difficult since all the potential buyers are affected by the same shock. As a proxy of irreversibility, we measure "industry comovement" by the standard deviation of firms' sales growth in the industry. The larger the spread, the less comovement have the firms. We define the industries with standard deviation of sales growth above (below) the median value as low (high) irreversibility industries.

The second measure is based on industry's R&D intensity. As the literature points out, R&D activities usually incur large sunk cost and are highly irreversible. Thus, it is plausible to use R&D intensity as a proxy for capital irreversibility. The higher R&D intensity has an industry, the higher degree of irreversibility it faces. In our analysis, we define an industry as high(low) irreversibility industry if its R&D intensity is above(below) the median level.[8]

[8]The R&D data we use is for the year of 2005.

Table 5: Irreversibility, uncertainty and investment

	(1)	(2)	(3)	(4)
	Market-based measure of ER uncertainty		Currency-based measure of ER uncertainty	
Degree of irreversibility based on industry comovement				
	Low	High	Low	High
ER uncertainty*sales growth	-0.0916***	-0.167***	-0.121***	-0.169***
	[0.0334]	[0.0272]	[0.0260]	[0.0216]
Observations	65,701	53,085	65,701	53,085
R-squared	0.643	0.650	0.643	0.651
Degree of irreversibility based on industry's R&D intensity				
	Low	High	Low	High
ER uncertainty*sales growth	-0.0962***	-0.155***	-0.123***	-0.167***
	[0.0330]	[0.0306]	[0.0258]	[0.0207]
Observations	73,236	45,550	73,236	45,550
R-squared	0.636	0.664	0.637	0.665
Firm fixed effects	Yes	Yes	Yes	Yes
Industry-year fixed effects	Yes	Yes	Yes	Yes

The dependent variables are capital growth for all columns.
Standard errors are clustered at industry level. *** p<0.01, ** p<0.05, * p<0.1

5.4 Firm Heterogeneity

Table 5 presents the result of the test. The upper panel uses "industry comovement" as the measure of irreversibility and the lower panel uses industry' R&D intensity. As shown, under both measures of uncertainty, the negative effect from exchange rate uncertainty on investment is greater for high capital irreversibility firms. This confirms the captial irreversibility hypothesis.

Are firms' responses to uncertainty heterogenous? To answer the question, we firstly examine firms with different ownership structure. In Table 6, we split firms into SOEs, private firms, foreign-owned firms, and other firms. As shown, the result suggests that increase in uncertainty has no significant impact on SOEs, but has negative and significant effect on private and foreign-owned firms. A possible explanation is that SOEs often have softer budget constraint so that their investment decisions are not sensitive to change in economic conditions such as exchange rate shock. In addition, the point estimates on private firms have larger magnitude than those on foreign-owned firms, indicating that private firms are more adversely affected by exchange rate uncertainty. This can be explained by the fact that multinational firms tend to be more experienced in handling exchange rate volatility than domestic firms.

Secondly, we split firms based on their exporting experience. We define experienced exporters as firms starting to export before 2001 (which is the year of China's entry into WTO). The rest of exporters are regarded as less-experienced exporters. Table 7 shows the regression result. The coefficients on the interaction term for both groups of firms are negative and significant, with the magnitude of less-experienced being larger. This implies that less-experienced exporters are more affeced by increased exchange rate uncertainty. A possible explanation is that experienced exporters are relatively more familiar with fluctuations in the exchange rate market so that they can handle exchange rate shock better.

Lastly, we differentiate firms by their productivity. The productivity is measured by firms' total sales per worker (i.e. labor productivity) and we split firms into four groups

Table 6: Ownership, uncertainty and investment

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Market-based measure of ER uncertainty				Currency-based measure of ER uncertainty			
	SOE	Other	Private	Foreign	SOE	Other	Private	Foreign
ER uncertainty*sales growth	-0.0590	-0.0647	-0.135**	-0.115***	-0.0699	-0.0949**	-0.171***	-0.141***
	[0.0728]	[0.0463]	[0.0535]	[0.0271]	[0.0579]	[0.0435]	[0.0462]	[0.0204]
Observations	2,118	15,468	30,638	57,812	2,118	15,468	30,638	57,812
R-squared	0.729	0.669	0.713	0.624	0.730	0.670	0.714	0.625
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

The dependent variables are capital growth for all columns. Standard errors are clustered at industry level.
*** p<0.01, ** p<0.05, * p<0.1

Table 7: Exporting experience, uncertainty and investment

	(1)	(2)	(3)	(4)
	Market-based measure of ER uncertainty		Currency-based measure of ER uncertainty	
	Less Experienced	More Experienced	Less Experienced	More Experienced
ER uncertainty*sales growth	-0.143***	-0.106***	-0.175***	-0.124***
	[0.0346]	[0.0254]	[0.0268]	[0.0205]
Observations	77,452	41,334	77,452	41,334
R-squared	0.699	0.508	0.700	0.509
Firm fixed effects	Yes	Yes	Yes	Yes
Industry-year fixed effects	Yes	Yes	Yes	Yes

The dependent variables are capital growth for all columns.
Standard errors are clustered at industry level. *** p<0.01, ** p<0.05, * p<0.1

based on quartiles. Firms in the first quartile are the least productive exporters, while firms in the fourth quartile are the most productive ones. The result in Table 8 shows that firms in all productivity quartiles are not immune to increased uncertainty, but more productive exporters are less affected.

6 Conclusion

Conventional wisdom suggests that a flexible exchange rate regime can reduce price distortion and enhance allocative efficiency, but it may also lead to greater uncertainty in the exchange rate market. Such uncertainty can have significant impact on exporting firms' behavior. In this paper, we demonstrate that an increase in exchange rate uncertainty can dampen exporting firms' responsiveness of investment to demand. The finding is consistent with the literature, in which investment is found to be negatively correlated with uncertainty. Moreover, we show that the effect from increased uncertainty is stronger for firms with high degree of capital irreversibility, which confirms the capital irreversibility hypothesis in the literature. Lastly, we show that firm heterogeneity matters. Firms with state ownership, more exporting experience, and higher

Table 8: Productivity, uncertainty and investment

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Market-based measure of ER uncertainty				Currency-based measure of ER uncertainty			
	Firtst quartile	Second quartile	Third quartile	Fourth quartile	Firtst quartile	Second quartile	Third quartile	Fourth quartile
ER uncertainty*sales growth	-0.137***	-0.159***	-0.143***	-0.0890**	-0.164***	-0.165***	-0.155***	-0.112***
	[0.0340]	[0.0404]	[0.0400]	[0.0439]	[0.0300]	[0.0348]	[0.0352]	[0.0402]
Observations	28,508	30,204	30,367	29,669	28,508	30,204	30,367	29,669
R-squared	0.736	0.799	0.806	0.730	0.737	0.799	0.807	0.731
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

The dependent variables are capital growth for all columns. Standard errors are clustered at industry level.
*** p<0.01, ** p<0.05, * p<0.1

productivity are less affected by increased exchange rate uncertainty.

While our paper documents evidence of negative investment-uncertainty relationship, there is still room to improve the analysis. For example, the exchange rate volatility in our study is constructed based on industry's exposure to exchange rate fluctuation, which may not precisely capture the uncertainty faced by the firms. Hence, one direction of improvement is to explore more detailed firm-level data and construct firm-specific measure of uncertainty. Moreover, one may extend the analysis to a variety of firms' performance, such as employee hiring and R&D spending. In such way, the real impact of exchange rate uncertainty on firms' behavior will be better understood.

7 Appendix: First-stage result for 2SLS estimation

Table 9 reports the result of first stage regression of the IV estimation. The dependent variables in the two columns are market-based and currency-based exchange rate volatility, respectively. The instrument is the interaction of post dummy, which equals to one for years after 2005, and initial share of exports to the U.S., which is time-invariant. As shown, the instrument is positively and significantly related to the exchange rate volatility. That means the volatility increases more for industries exporting more to the U.S. after the shift of exchange rate policy.

Table 9: First stage result for IV estimation

	Market-based measure	Currency-based measure
Post*Share of exports to the U.S.	0.811***	0.843***
	[0.139]	[0.0778]
Sales growth	4.143***	3.323***
	[0.743]	[0.512]
Sales growth squared	0.0385**	0.0125
	[0.0190]	[0.0184]
Error correction term	0.0276***	0.0322***
	[0.00371]	[0.00288]
SOE dummy	-0.00636	-0.0130
	[0.0112]	[0.0106]
SME dummy	-0.0244***	-0.0241***
	[0.00474]	[0.00461]
Leverage	0.00315	0.00187
	[0.00796]	[0.00789]
RMB-USD exchange rate*sales growth	-0.396***	-0.313***
	[0.0966]	[0.0654]
Export growth*sales growth	0.0172	-0.106
	[0.199]	[0.203]
FDI growth*sales growth	-0.340**	-0.183
	[0.155]	[0.122]
Observations	118,748	118,748
R-squared	0.946	0.959

The dependent variables are exchange rate volatility.
Standard errors are clustered at industry level. *** p<0.01, ** p<0.05, * p<0.1

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