

Essays on Firm Investment and Misallocation

by

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Dissertation submitted in partial fulfillment
of the requirements for the degree of Doctor of Philosophy
in the Department of Economics
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ABSTRACT

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Abstract

My dissertation studies how firm investments respond to market frictions such as corporate taxation, housing booms and how productivities and misallocations evolve in the adjustment processes. In the first chapter, I ask what factors contributed to the heterogeneous investment behavior of small and large firms' equipment investment in China's 2009 Value Added Tax (VAT) reform. I first document empirically that small firms responded more than large firms at both the extensive and intensive margins with a difference in differences design. Then I estimate a heterogeneous firm dynamic investment model and show it is investment adjustment costs, rather than financial frictions that contributed to small firms' more aggressive investment responses. To show the irrelevance of the financial constraints, I also estimate a Chinese version of the Whited Wu (2006) financial constraint index.

In the second chapter of my dissertation, I study how the three channels of housing boom: the collateral, the speculation and the crowding out channels affected US manufacturing firms' investment and misallocation over the early 2000s period. I find the traditional collateral channel was very significant during this period as documented by the literature. Both the speculation channel and the crowding out channel were silent. At the aggregate level, using the IV estimation backed by the housing supply elasticity in Saiz (2010), I find the housing boom had a positive effect on productivity growth and the collateral channel dominates the speculation channel and the crowding out channel.

In the last chapter of my dissertation studies how labor market frictions in Portugal contributed to its productivity slowdown and misallocation. The Portuguese government enacted several size-dependent labor market laws in 2012 and 2013 that favor small and medium-sized firms. I identify these laws as the sources of the increasing labor misallocations in Portugal with a difference in differences design. Moreover, I construct measures of labor market frictions using the average labor cost gap be-

tween small and large firms and then evaluate the effects of the size-dependent labor market laws on labor misallocation and reallocation. I find the size-dependent labor market laws reduced unemployment temporally but exacerbated within industry labor misallocation in the long run.

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Part I

Introduction

My dissertation studies how firm investments respond to market frictions such as corporate taxation, housing booms and how productivities and misallocations evolve in the adjustment processes. The first chapter studies what factors contributed to the heterogeneous investment behavior of small and large firms' equipment investment in China's 2009 Value Added Tax (VAT) reform. Equipped with dynamic investment model estimation, I show it is investment adjustment costs, rather than financial frictions that contributed to small firms' more aggressive investment responses.

The second chapter studies how the three channels of housing boom: the collateral, the speculation and the crowding out channels affected US manufacturing firms' investment and misallocation over the early 2000s period. I find the traditional collateral channel was very significant during this period as documented by the literature. Both the speculation channel and the crowding out channel were silent. At the aggregate level, I find the housing boom had a positive effect on productivity growth and the collateral channel dominates the speculation channel and the crowding out channel.

The third chapter studies how labor market frictions in Portugal contributed to its productivity slowdown and misallocation. The Portuguese government enacted several size-dependent labor market laws in 2012 and 2013 that favor small and medium-sized firms. I identify these laws as the sources of the increasing labor misallocations in Portugal and find the size-dependent labor market laws reduced unemployment temporarily but exacerbated within industry labor misallocation in the long run.

Part II

Heterogeneous Investment Behavior in China's 2009 VAT Reform

1 Introduction

How does tax policy affect investment? This question is important to policymakers since they often use tax-based investment incentives to spur growth in economic downturns, e.g., the Great Recession and the recent COVID-19 pandemic. Evidence from empirical studies shows that the investment responses to tax policy changes are heterogeneous at the firm level (Zwick and Mahon, 2017). Understanding which firms respond to the policy changes and why they respond is essential for better policy designs. However, due to the lack of access to micro datasets, the literature has given limited explanations on firms' heterogeneous responses under different tax reform scenarios. This paper complements this part of the literature by studying the heterogeneous investment behavior in China's 2009 value-added tax (VAT) reform with a micro dataset of Chinese firms from 2007–2011.

VAT was introduced to China in 1994, and it composed 32%-45% of China's total tax revenue between 1994 and 2019.¹ Unlike the VAT systems in most developed economies, the Chinese VAT system was inefficient because it did not allow firms to deduct the VAT on fixed investment from their output VAT before 2004. Starting in 2004, some foreign and domestic pilot firms in specific industries were allowed to deduct the VAT on new equipment purchases.² The reform was extended nationwide

¹Based on data from the National Bureau of Statistics of China.

²Domestic pilot firms were in provinces and industries with slower economic growth. More details are in the policy background section below.

on January 1st, 2009, after which all domestic firms were allowed to deduct their equipment VAT. This differential timing of exposure to the VAT reform creates a natural experiment to study the effect of the reform on investment and how it varied across firms.

The first part of the paper employs a difference in differences (DID) design to document the empirical facts that small firms responded more aggressively to the reform than large firms at both the extensive and intensive margins. Since foreign and pilot domestic firms had access to the reform's privileges several years ahead of the rest of the nation, I use these firms as the control groups. The estimates show that large firms were, on average, 5-7% more likely to invest and adjust their investment rates 0-2% more than the control groups after the reform. On top of this, small firms were, on average, 3-5% more likely to invest than the large firms and adjusted their investment rates 2-5% more than the large firms, depending on which control group we use in the DID analysis. The results are robust to different size measures and including different sets of controls.

Many factors may contribute to the heterogeneous investment behavior we observe in the data, such as convex adjustment costs, fixed costs, and financial frictions. In the second part of the paper, I develop structural models to examine how each of the factors contributed to the heterogeneous size responses of investment. Firstly I use a two-period model to show that on the intensive margin, a firm's investment rate's response to the VAT rate is proportional to the firm's productivity to capital ratio. This ratio is a constant if the firm is at its efficient size in the first period.³ If all firms are at their efficient sizes, their marginal revenue products of capital (MRPK) will be the same, and the investment responses would be homogeneous. However, production function estimation shows that before the reform, small firms, on average, had higher MRPK than large firms, and the productivity to capital ratios

³Efficient size is the size a firm attains in the steady-state of a frictionless dynamic setting.

were decreasing in size in the data. This result indicates that small firms were further away from their efficient sizes pre-reform, had higher marginal benefit of investing, and were consequently more willing to invest. Therefore, the two-period model can qualitatively explain the heterogeneous investment responses with the pre-reform firm size distribution, and I call this explanation the size effect.

One concern with this explanation is that the pre-reform size distribution is pre-determined in the two-period model and does not depend on the VAT rate, while in the data, it depends on the VAT rate. To address this concern, I estimate dynamic investment models. In the frictionless dynamic setting, I show the model cannot produce the intensive margin's heterogeneous size responses because the investment rate is only a function of the idiosyncratic productivity shocks, and the shock process is the same across firms.⁴ Then I extend the model to incorporate convex adjustment costs and show the augmented model can reproduce the empirical facts at the intensive margin. To speak to the extensive margin, I add fixed costs into the model. The model with fixed costs can replicate the DID results that small firms are more likely to invest than large firms. In summary, model estimations show that the adjustment costs can rationalize the pre-reform size distribution and very well reproduce the empirical facts, both qualitatively and quantitatively.

The next section looks into how financial frictions contributed to the heterogeneous investment behavior. At the early stages of the reform (2004–2009), foreign and domestic pilot firms could not deduct the equipment VAT from their output VAT directly. Instead, the government collected the equipment VAT during the fiscal year and would refund the collected VAT to the firms at the end of the year if that year's tax revenue target had been reached. If a firm is initially financially constrained and unable to invest, the refund would loosen its financial constraint and induce

⁴The DID estimates measure the average response of the investment rate to the VAT rate change. Since small firms have the same idiosyncratic productivity shock process as the large firms, the frictionless model's implied DID estimates are homogeneous across the size groups.

the firm to invest. Starting in 2009, the government switched to the tax credit accounting method through which firms can deduct their equipment VAT directly. This direct deductibility worked like a decline in the user cost of capital. If a firm is initially financially constrained, it would still be constrained and unable to invest. For this reason, we expect more constrained firms to invest more during the 2004 pilot programs but not during the 2009 VAT reform extension.

To confirm this observation, we need to identify which firms in the sample were financially constrained. The data has no direct information on firms' financial constraints. Therefore, I estimate a Chinese version of the Whited Wu financial constraint index based on Whited and Wu (2006).⁵ DID analysis sorted by estimated firm constraint level shows more constrained firms did not invest more than unconstrained firms during the 2009 VAT reform. There is weak evidence that the more constrained a firm was, the less it would respond to the reform. Given our intuition that the 2009 VAT reform did not generate additional cash flow for constrained firms, the empirical results are consistent with our expectations.

The estimated Whited Wu index shows that small firms were more likely to be financially constrained in the data. Combined with our analysis above, small firms should respond less to the 2009 VAT reform than large firms. Given the small firms responded more, we conclude the size effect, i.e., the higher marginal benefit of investing dominated the financial frictions during the 2009 VAT reform.

1.1 Relation to Literature

This paper follows a long literature that uses cross-sectional variations to study heterogeneous investment behavior: Cummins, Hassett and Hubbard (1994), Goolsbee (1998), House and Shapiro (2008), Yagan (2015), Zwick and Mahon (2017). The studies most closely related to this paper are House and Shapiro (2008) and Zwick

⁵There are several financial constraint indexes in the literature, but they were all estimated using the U.S. data. Thus their validity for use in the Chinese dataset is questionable.

and Mahon (2017). They study how firm investment responded to the acceleration of depreciation schedules in 2001 and 2008 in the U.S.. Financial frictions were important in their settings since the acceleration of the schedules generated cash flows for financially constrained firms and enabled them to invest. I depart by studying a VAT tax reform in China where financial frictions were not playing a central role and propose an explanation to the heterogeneous investment behavior.

The estimation of the dynamic investment model leans this paper close to the structural investment literature: Doms and Dunne (1998); Khan and Thomas (2003, 2008), Cooper and Haltiwanger (2006), Chen et al. (2020). I use the canonical framework in Cooper and Haltiwanger (2006) and the parameters in Chen et al. (2020) and show convex adjustment costs and fixed costs are important on the intensive and extensive margins, respectively, to generate the pre-reform size distribution that was at the core to understand the heterogeneous investment responses by firm size in China's 2009 VAT reform.

In the study of financial frictions in the VAT reform, my estimation of the Chinese version Whited Wu index also links this paper to the financial constraints literature: Fazzari et al. (1988), Whited (1992), Kaplan and Zingales (1997), Whited and Wu (2006), Hadlock and Pierce (2010). Because the Kaplan and Zingales index requires the computation of Tobin's Q, whereas more than 99% of the firms in my sample are private firms, I can not estimate the KZ index. The computation of Tobin's Q also entails a lot of measurement error. The Size–Age index in Hadlock and Pierce (2010) requires SEC's 10K forms in which firms explicitly indicate if they are financially constrained during a year. There is no such information in my sample. Consequently, I estimate the Whited Wu index, which only requires the balance sheet information of a firm. The estimation of the index is important because the literature often uses firm size as a proxy for financial constraints. I show in this paper that size and financial constraints can have very different implications for firm investment.

The rest of the paper is organized as follows: Section 2 details the policy background. Section 3 introduces the datasets. Section 4 establishes the heterogeneous size responses of investment with difference in differences. Section 5 uses the models to explain the empirical facts. Section 6 investigates the role of financial frictions in the 2009 VAT reform, and section 7 concludes. Model derivations are contained in the model appendices.

2 Policy Background

2.1 The VAT System

A value-added tax is a tax placed on a product whenever the value is added at each stage of the supply chain, from the production of the intermediate inputs to the sale of the final goods. Because the VAT only taxes the value-added part of a firm's production, it acts like a consumption tax on the final goods and avoids repetitive taxation. As a result, the choice of production inputs is not distorted, and the production efficiency is preserved.

To be more concrete, consider a firm producing a table with a value of \$400. To produce the table, the firm purchases raw materials with a value of \$100 and a wood cutting machine with a value of \$100. The value-added of the table is $\$400 - \$100 - \$100 = \200 . Suppose the VAT rate is 17%, then the purchase price of both the raw materials and the machine is $\$100 \times 1.17 = \117 . The sale price of the table is $\$400 \times 1.17 = \468 . The tax agency collects \$17 VAT from both the raw material seller and the machine seller (for simplification, assume they do not have intermediate inputs) and collects $\$200 \times 17\% = \34 VAT from the table producing firm. That is when the firm pays its VAT, it can deduct the VAT paid in the purchase of the raw materials and the machine. As a result, the tax agency collects \$68 VAT in total, like a final goods consumption tax. All the table producing firm, the material seller and

the machine seller earn their respective value added.

2.2 The 2009 Chinese VAT Reform

The VAT system mentioned in the last subsection is efficient because it does not distort firms' choice of production inputs. However, this was not the case in China before 2004. Chinese firms were allowed to deduct the input expenses on materials and labor when calculating their VAT but were not allowed to deduct the input expenses on fixed investment, such as equipment and buildings. Citing our example in the last subsection, the scenario is the table producing firm can deduct the \$100 purchase of raw materials from its VAT base but can not deduct the \$100 purchase of the machine. The firm needs to pay $(\$400 - \$100) \times 17\% = \$51$ VAT rather than \$34 if it operated in China. This lack of deductibility discouraged fixed investment in China and made the production chain less efficient.

The Chinese government started a VAT reform and allowed firms to deduct equipment investment expenses from their VAT base since 2004. The reform was firstly piloted on firms in eight industries in Northeastern China, namely Heilongjiang, Jilin, and Liaoning.⁶ The reform was extended in 2007 to 26 cities in another six provinces (Anhui, Henan, Hubei, Jiangxi, and Shanxi) and in 2008 to five cities in eastern Mongolia and cities affected in the Wenchuan earthquake in the same eight industries. On December 19, 2008, the government announced starting January 1st, 2009, the reform would be extended nationwide and to all industries. All firms then would be able to deduct the expenses on equipment purchases from their VAT base.⁷ However, building and housing purchases were still not allowed for deduction after the reform. The VAT rate in China is 17% for general goods. After the extension, the effective

⁶The eight industries include equipment manufacturing, petrochemical, metallurgical, automotive manufacturing, shipbuilding, agricultural product processing, military manufacturing and new and high tech industries.

⁷Equipment includes machinery, mechanical apparatus, means of transportation and other production tools or fixtures that are used for over 1 year.

VAT rate for equipment investment decreased to 0%. The extension was unexpected and considered permanent upon announcement. It was unexpected because it broke the original reform expansion plan and considered permanent since it fixed an undesirable tax system feature. Therefore, our empirically identified firm investment responses during the reform are unlikely to be attributed to substitution effects, i.e., firms did not invest before January 1st, 2009, and waited to invest until the reform was implemented.

We name the domestic firms included in the VAT reform up to 2007 as the pilot firms and the reform itself to domestic firms up to 2007 as the pilot program. Parallel to the pilot program, all foreign firms in industries classified as encouraged by the government were also allowed to deduct their equipment purchase VAT starting from 1999 or the date they enter the Chinese market, whichever is later.⁸ The extension of the reform on Jan 1st, 2009, created a natural experiment since pilot firms and foreign firms with preferential treatment already enjoyed the benefit of the reform before 2009 and should had finished their equipment investment responses to the reform when the 2009 extension started. Therefore, pilot firms and foreign firms with preferential treatment are used as two control groups in my difference in differences analysis of firms' responses to the 2009 VAT reform in later sections.

In the early stage of the VAT reform from 2004-2009, the government firstly collected input VAT on equipment during the fiscal year and would refund it to firms at the end of the year if that year's tax revenue target had been reached. From 2009 on, the government switched to the tax credit accounting method through with firms can deduct input VAT on equipment from total output VAT directly.

⁸The government classified foreign investment projects as encouraged, allowed, restricted, or prohibited.

3 Data

The main dataset I use is a balanced panel of manufacturing firms from the administrative tax records in the Chinese State Administration of Tax (SAT) from 2007–2011. The dataset contains detailed information on each firm’s asset, liability, sales, cash flow, tax payments, and more importantly separate accounts of investment on equipment and buildings. This distinction is important because the 2009 VAT reform was only on equipment investment, not on building investment. In the difference in differences analysis in the next section, I am therefore able to document firms’ differential investment patterns of equipment and buildings. I exclude firm–year observations with negative capital stock values and arrive at a sample with 332,300 firm–year observations. Table 1 lists the summary statistics of all firms in my sample. Units are in millions of RMB.

From table 1, we see the dataset consists mainly of small and medium-sized firms. It includes firms as small as with assets less than 1 million RMB and as large as with assets more than 1 billion RMB. More than 99.3% of the firms in the dataset are non-listed private firms. The sampling of this dataset ensures that large firms are included every year and smaller firms are included on a rotating basis. Table 1 also reports summary statistics on firms’ financial variables such as liability, sales, and cash flow. These variables are used to estimate the Whited Wu index later when I need to identify which firms in the sample were financially constrained. In addition, we see that investment is lumpy in the data. There is a wide inaction region where 31% of firm–year observations have zero investment.

Table 2 lists the summary statistics of firms grouped by non-pilot domestic firms, pilot domestic firms, and foreign firms. These groups of firms are used as treatment (first) and control groups (latter two) in my difference in differences analysis. There are 58,500 non-pilot domestic firms, 7400 pilot domestic firms, 23,000 foreign firms, and 6,000 foreign firms with preferential treatment in the sample. From table 2, we

Table 1: Summary Statistics (All sample)

	Mean	Std Dev	10%	25%	50%	75%	90%
Asset	118.19	252.94	2.76	8.27	30.02	106.02	305.93
Liability	70.23	159.56	1.23	4.26	16.24	59.78	179.03
Sales	118.13	265.47	2.53	7.90	29.30	101.68	291.99
Cash Inflow	114.29	284.48	0.00	1.04	18.56	90.31	290.30
Fixed Asset	28.86	68.32	0.31	1.26	6.10	23.86	72.97
Investment	3.45	11.29	0.00	0.00	0.19	1.69	7.66
Investment Rate	0.13	0.19	0.00	0.00	0.04	0.17	0.39

Notes: This table presents the summary statistics of the administrative tax records dataset by percentile. Fixed asset and investment are deflated by the national price index of equipment investment. The financial variables are deflated by the GDP deflator. Units are in millions of RMB.

see the statistics of the pilot and non-pilot domestic firms are similar while foreign firms are on average larger, but when it comes to investment rate, all three groups have similar averages.

In addition to the administrative tax records from SAT, I use data on foreign direct investment records from China's Ministry of Commerce (MOC). The MOC classifies the industries of foreign firms in China as encouraged, allowed, restricted, and prohibited. I merge this dataset with the main dataset and create the control group of foreign firms with preferential treatment.

Table 2: Summary Statistics by Treatment and Control Groups

	Domestic, Non Pilot		Domestic, Pilot		Foreign Firms	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Asset	99.94	237.09	88.41	240.02	172.37	284.43
Liability	63.03	152.71	54.98	151.51	92.79	175.43
Sales	92.07	218.27	78.94	216.28	194.38	354.65
Cash Inflow	84.26	232.69	74.38	225.73	200.43	381.76
Fixed Asset	23.10	60.36	20.26	57.02	45.70	85.06
Investment	2.77	9.99	2.43	9.00	5.43	14.30
Investment Rate	0.12	0.20	0.14	0.21	0.13	0.18

Notes: This table presents the summary statistics of the administrative tax records dataset by the treatment and the control groups. Units are in millions of RMB.

4 Difference in Differences sorted by Size

Now we turn to the empirical studies of the 2009 VAT reform. To identify the reform's effect on firm investment and how the effect varies with firm size, I implement difference in differences (DID) analyses on firm investment measures at both the extensive and intensive margins. Because building and real estate investments were not included in the 2009 VAT reform extension, I can compare the firms' investment in equipment and buildings during the reform. The investment responses on buildings are used as placebo tests to the investment responses on equipment. As mentioned in section 2, the non-pilot domestic firms are in the treatment group. The pilot domestic firms and foreign firms with preferential treatment are used as two separate control groups because they had access to the VAT reform several years before the non-pilot domestic firms did, and the 2009 VAT reform extension should have no effect on these firms.

To identify how the reform differentially affected firms by size, I define a firm's size as its log asset level and define the size groups of firms as in Zwick and Mahon (2017).⁹ In addition, I fix each firm's affiliation with a size group based on its size in 2008, one year before the reform. This addresses the concern that the heterogeneous size responses we observe in the empirical analysis are potentially due to firms changing sizes during the reform. To be more concrete, if a firm's log asset level in 2008 lies within the 0%–30% percentiles of the sample's 2008 size distribution, I classify the firm into the small group. If its 2008 size lies within the 30%–70% percentiles of the 2008 size distribution, I classify the firm into the medium-sized group, and if its 2008 size lies within the 70%–100% percentiles of the 2008 size distribution, I classify the

⁹I also test the empirical results using the number of employees as an alternative measure of firm size. All results are robust to using this alternative size measure.

firm into the large group. To implement the DID analysis, I use the specification

$$\begin{aligned}
Y_{ijkt} = & \beta_0 + \beta_1 Treat_i \times Post_t + \beta_2 Treat_i \times Post_t \times Medium \\
& + \beta_3 Treat_i \times Post_t \times Small + \beta_4 Post_t \times Medium \\
& + \beta_5 Post_t \times Small + \mu_i + \delta_{jt} + \eta_{kt} + \epsilon_{ijt}
\end{aligned} \tag{1}$$

where i, j, k, t index firm, CIC 2-digit industry, province and year respectively. The dependent variable Y_{ijkt} has four components, two on equipment investment and two on building investment. On the extensive margin, it is an indicator of if a firm has a positive investment in a year. On the intensive margin, it is a firm's investment rate, i.e., the investment to capital ratio in year t . Here I measure capital by a firm's fixed assets used for production and measure investment by its increase of fixed assets used for production. $Treat_i$ is an indicator of if the firm is a non-pilot domestic firm. $Post_t$ is an indicator of if $t \geq 2009$. $Small$ and $Medium$ are indicators if a firm belongs to the small or medium size groups as defined above. μ_i is the firm fixed effect, δ_{jt} is the industry year fixed effect, and η_{kt} is the province year fixed effect. I do not list the standard DID control variables $Treat_i$ and $Post_t$ in the specification because $Treat_i$ is absorbed in the firm fixed effect, and $Post_t$ is absorbed in the year fixed effect.

The identifying assumption is after controlling for all the fixed effects, the treatment group and the control groups differ only in the timing of access to the VAT reform. Table 3 reports our baseline regression results using pilot domestic firms as the control group. The base size group in the regressions is the large firm group. The first column of Table 3 shows the results of the equipment investment responses on the extensive margin. It indicates that large non-pilot domestic firms are 7.2% more likely to invest after the reform than large pilot domestic firms. This is the baseline effect of the VAT reform. On top of this, medium-sized non-pilot domestic

firms are 5.4% more likely to invest than the large non-pilot domestic firms, or 12.6% more likely to invest than the medium-sized pilot domestic firms. In addition, small firms non-pilot domestic firms are 4.9% more likely to invest than the large non-pilot domestic firms, or 12.1% more likely to invest than the small pilot domestic firms. We see the small and medium-sized firms are more likely to have positive equipment investment within the treatment group than the large firms after the reform.

The second column of Table 3 shows the results of the equipment investment responses on the intensive margin: the investment rate. We see large non-pilot domestic firms do not significantly invest more than large pilot domestic firms in terms of the investment rate. However, medium-sized non-pilot domestic firms on average adjust their investment rates 3% more than the large non-pilot domestic firms and the medium sized pilot domestic firms. As firm size decreases, small non-pilot domestic firms on average adjust their investment rates 4.6% more than the large non-pilot domestic firms or 1.6% more than the medium sized non-pilot domestic firms. Within the treatment group, we see the investment rate responses after the reform decrease by size. Therefore, the first two columns of table 3 tell us investment responses on equipment decline by firm size at both the extensive and intensive margins.

As a placebo test, the third and fourth columns of table 3 list the results of the building investment responses on the extensive and intensive margins. Because the reform was on equipment purchases only, the user cost of capital for buildings stayed the same. We expect to find no significant positive results on building purchases, which is indeed the case here. Medium-sized non-pilot domestic firms are 4.4% less likely to invest than their large peers. This is not a concern for us since the estimate is negative, and on the intensive margin, we do not see significant different investment rate adjustment between the medium and large non-pilot domestic firms.

Table 3: Difference in Differences sorted by Firm Size

Control Group: Pilot Domestic Firms				
	Equipment		Building	
	$1(I > 0)$	I/K	$1(I > 0)$	I/K
$Treat \times Post$	0.072*** (0.013)	0.007 (0.013)	0.016 (0.013)	0.013 (0.012)
$Treat \times Post \times Medium$	0.054*** (0.016)	0.030** (0.015)	-0.044*** (0.016)	0.001 (0.016)
$Treat \times Post \times Small$	0.049*** (0.018)	0.046*** (0.018)	0.015 (0.015)	0.033 (0.024)
$Post \times Medium$	-0.007 (0.015)	0.0005 (0.015)	0.067*** (0.015)	-0.030* (0.015)
$Post \times Small$	0.013 (0.017)	-0.004 (0.017)	0.109*** (0.014)	-0.035 (0.023)
Constant	0.453*** (0.008)	0.186*** (0.008)	0.176*** (0.008)	0.132*** (0.007)
Adjusted R^2	0.330	0.111	0.343	0.127
# Obs	228,879	222,487	230,265	223,851

Standard errors in parentheses (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

Notes: This table estimates the investment responses to the VAT reform sorted by the firm sizes, using the pilot domestic firms as the control group. The DID specification is

$$Y_{ijkt} = \beta_0 + \beta_1 Treat_i \times Post_t + \beta_2 Treat_i \times Post_t \times Medium + \beta_3 Treat_i \times Post_t \times Small + \beta_4 Post_t \times Medium + \beta_5 Post_t \times Small + \mu_i + \delta_{jt} + \eta_{kt} + \epsilon_{ijt}$$

where i, j, k, t index firm, CIC 2-digit industry, province and year respectively. Y_{ijkt} represents the investment response measures at the top of each column. $Treat_i$ is an indicator of if the firm is a non-pilot domestic firm. $Post_t$ is an indicator of if $t \geq 2009$. $Small$ and $Medium$ are indicators if a firm belongs to the small or medium size groups. μ_i is the firm fixed effect, δ_{jt} is the industry year fixed effect, and η_{kt} is the province year fixed effect. All regressions include all the fixed effects. Standard errors cluster at the firm level.

To show the heterogeneous investment responses documented above are robust to the selection of the control group, I perform a second set of regressions with the same specification in equation (1) but use foreign firms with preferential treatment as the control group. Table 4 reports the regression results. In column 1, we see on the extensive margin, large non-pilot domestic firms are 5.6% more likely to invest in equipment than large foreign firms with preferential treatment. Medium-sized non-pilot domestic firms are 4.8% more likely to invest than the large non-pilot domestic firms, and small non-pilot domestic firms are 3.4% more likely to invest than the large non-pilot domestic firms. Within the treatment group, again, the small and medium-sized firms are more likely to invest than their large peers.

On the intensive margin, column 2 of Table 4 tells us large non-pilot domestic firms, on average, adjust their investment rate 2.1% more than large foreign firms with preferential treatment. Though medium-sized non-pilot domestic firms do not show significantly different investment rates than those of the large non-pilot domestic firms, small non-pilot domestic firms, on average, adjust their investment rates 1.3% more than the large non-pilot domestic firms. Within the treatment group, again, the investment rate responses after the reform decrease by size.

Column 3 and 4 of Table 4 report the placebo tests on building investment responses. Here we see small non-pilot domestic firms are 4.9% more likely to invest than large non-pilot domestic firms. This is probably because buildings are complementary to equipment in the production process. Since small firms invested aggressively in equipment, it is not surprising they also invested in buildings. This is not a concern to our identification since, again, we do not see significant different size responses on the intensive margin.

As a result, I establish the empirical observation that investment responses on equipment decline by firm size at both the extensive and intensive margins, and the observation is robust to the selection of the control group. Then a natural question

is what factors contribute to the heterogeneous investment responses by firm size. Structural modeling helps us answer this question. This is the part we now turn into.

Table 4: Difference in Differences sorted by Firm Size II

Control Group: Foreign Firms with Preferential Treatment				
	Equipment		Building	
	$1(I > 0)$	I/K	$1(I > 0)$	I/K
<i>Treat</i> × <i>Post</i>	0.056*** (0.009)	0.021*** (0.004)	0.014 (0.010)	-0.003 (0.003)
<i>Treat</i> × <i>Post</i> × <i>Medium</i>	0.048*** (0.012)	0.005 (0.005)	-0.008 (0.012)	-0.0005 (0.004)
<i>Treat</i> × <i>Post</i> × <i>Small</i>	0.034** (0.014)	0.013** (0.006)	0.049*** (0.013)	0.006 (0.004)
<i>Post</i> × <i>Medium</i>	0.001 (0.010)	0.008* (0.004)	0.028** (0.011)	-0.007** (0.003)
<i>Post</i> × <i>Small</i>	0.032*** (0.012)	0.013** (0.005)	0.070*** (0.012)	-0.001 (0.004)
Constant	0.482*** (0.006)	0.073*** (0.002)	0.196*** (0.006)	0.039*** (0.002)
Adjusted R^2	0.336	0.153	0.354	0.092
# Obs	248,581	242,009	250,064	243,465

Standard errors in parentheses (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

Notes: This table estimates the investment responses to the VAT reform sorted by the firm sizes, using the foreign firms with preferential treatments as the control group. The DID specification is the same as in Table 3. All regressions include all the fixed effects. Standard errors cluster at the firm level.

5 Structural Model

In this section, I first use a two-period model to show the heterogeneous investment responses we observe in the last section can be explained by the fact that small firms on average had higher marginal revenue product of capital (MRPK) than large firms before the 2009 VAT reform. Because the marginal benefit of investing was higher for small firms, they were more likely to invest and invested at a larger scale. However, this explanation relies on a pre-reform size distribution where small firms, on average, were further away from their efficient sizes than large firms. The two-period model takes the pre-reform size distribution as given and cannot speak to the formation of the distribution. This limitation calls for dynamic models. In the second part, I first solve a frictionless dynamic investment model and show the model cannot generate the heterogeneous investment responses because firms' investment rates depend only on their productivities, not on their capital (size). In the next two subsections, I extend the model by adding convex adjustment costs to look at investment responses at the intensive margin (investment rate) and adding fixed costs to look at investment responses at the extensive margin (probability of investment). Model estimations show the dynamic models with the adjustment costs can generate the pre-reform size distribution required in the two-period model. The model implied DID estimates of the investment responses decrease in size as we observe in the data and quantitatively are very close to the estimates we find in the empirical studies of the last section.

5.1 Two-Period Model

Consider a firm i maximizing its dividends subject to budget constraints at $t = 0, 1$ and a collateral constraint

$$\max_{D_{i0}, D_{i1}, B_{i0}, K_{i1}} u(D_{i0}) + \beta \mathbb{E}(u(D_{i1}) | A_{i0})$$

such that

$$\begin{aligned}
K_{i1} &= (1 - \delta)K_{i0} + I_{i0} \\
D_{i0} + \underbrace{p_k(1 + \nu)(1 - \tau p_\nu)}_{p_b} I_i &= (1 - \tau)A_{i0}^{1-\alpha} K_{i0}^\alpha + B_{i0} \\
D_{i1} + (1 + r)B_{i0} &= (1 - \tau)A_{i1}^{1-\alpha} K_{i1}^\alpha + \underbrace{p_k(1 - \tau(1 + \nu)p_\nu)}_{p_s} (1 - \delta)K_{i1} \\
(1 + r)B_{i0} &\leq \theta(1 - \delta)p_s K_{i1}
\end{aligned}$$

where A_i , D_i , B_i , K_i and I_i are firm i 's productivity, dividend, debt, capital, and investment of equipment respectively. $A_i^{1-\alpha} K_i^\alpha$ is the profit function. ν is the value-added tax rate, and τ is the corporate income tax (CIT) rate. p_k is the price of capital, $p_\nu = \sum_{j=0}^{T-1} \frac{(1+\nu)}{T(1+r)^j} \leq 1$ is the present value of depreciation deductions.¹⁰ p_b is the purchase price of capital, and p_s is the sell price of capital. Here I incorporate partial irreversibility: firm i can not charge VAT when it sells its capital. r is the interest rate. δ is the capital depreciation rate, and θ is the fraction of the resale value of capital that is pledgeable as collateral. In addition, I assume productivity has two components: $a_{it} \equiv \log(A_{it}) = \omega_i + b_{it}$, where ω_i captures firm-specific heterogeneity, and b_{it} is an idiosyncratic transitory shock that evolves according to an AR(1) process $b_{i1} = \rho b_{i0} + \epsilon_{i1}$.

During the 2009 VAT reform, the VAT rate ν decreased from 17% to 0%. To connect to the empirical observation in the last section, we are interested in how the response of the investment rate I_{i0}/K_{i0} to the VAT rate ν varies with size in this model. The investment rate is

$$\frac{I_{i0}}{K_{i0}} = \frac{K_{i1} - (1 - \delta)K_{i0}}{K_{i0}} = \frac{K_{i1}}{K_{i0}} - 1 + \delta$$

Given K_{i0} is predetermined when firm i enters the first period, the response of

¹⁰We assume a straight-line depreciation schedule and usually $T = 10$ years, i.e., capital depreciates fully in 10 years.

the investment rate to the VAT rate ν is

$$\frac{\partial(I_{i0}/K_{i0})}{\partial\nu} = \frac{\partial K_{i1}}{\partial\nu} \cdot \frac{1}{K_{i0}}$$

It is shown in appendix 8.1 that we can solve analytically for K_{i1} when the collateral constraint does not bind. In this case

$$K_{i1} = \left(\frac{p_b(1+r) - p_s(1-\delta)}{\alpha(1-\tau)} \right)^{1/(\alpha-1)} e^{\omega_i + \rho b_{i0} - \frac{1}{2}(1-\alpha)\sigma_\epsilon^2}$$

Due to the fact this is a partial equilibrium model and all prices are fixed, it is shown in appendix 8.1

$$\begin{aligned} \frac{\partial K_{i1}}{\partial\nu} &\propto -e^{\omega_i + \rho b_{i0}} \\ \frac{\partial(I_{i0}/K_{i0})}{\partial\nu} &\propto -\frac{e^{\omega_i + \rho b_{i0}}}{K_{i0}} \approx -\frac{A_{i0}}{K_{i0}} \end{aligned} \quad (2)$$

Hence the response of the investment rate to the VAT rate ν is proportional to firm i 's first period's ratio of productivity to capital. Since we can estimate firms' productivities A_{i0} in the data and the sample has the data on capital K_{i0} , we can compute the productivity to capital ratio and measure the response of the investment rate to the VAT rate directly in the data. In order for this model to explain the heterogeneous size responses of investment, we need the productivity to capital ratio to decrease in size, and we will see this ratio indeed decreases in size in the data.

Production Function Estimation

To compute the productivity to capital ratio, we need to estimate firm-level productivities. I use the two-step generalized method of moments (GMM) implementation of Levinsohn and Petrin (2003) developed in Wooldridge (2009) to estimate productivity and the elasticities of value-added with respect to inputs. I allow the elasticities of value-added with respect to inputs to vary at the CIC 2-digit industry

level. Specially for each CIC 2-digit industry, I estimate

$$\log(y_{ist}) = \beta_0 + \beta_l(s)\log(l_{ist}) + \beta_k(s)\log(k_{ist}) + \beta_t(s) + \epsilon_{ist} \quad (3)$$

where i, s, t index firm, the CIC 2-digit industries and year respectively. y_{ist} , l_{ist} and k_{ist} are firm i 's value added, wage bill and capital stock in year t respectively. $\beta_l(s)$ and $\beta_k(s)$ are industry specific factor shares and $\beta_t(s)$ is a industry specific time fixed effect. Given the estimates of the coefficients in equation (3), I compute the implied (log) of revenue total factor productivity (TFPR) and (log) of marginal revenue product of capital (MRPK) as

$$\text{TFPR}_{ist} = \log(y_{ist}) - [\beta_0 + \beta_t(s) + \beta_l(s)\log(l_{ist}) + \beta_k(s)\log(k_{ist})]$$

$$\text{MRPK}_{ist} = \log(\beta_k(s)) + \log(Y_{ist}) - \log(k_{ist})$$

where Y_{ist} is firm i 's revenue. Figure 1 plots the estimated MRPK over the size (log of asset) for six representative CIC 2-digit industries (textile, chemical, non-metal, metal, general equipment, and vehicle manufacturing) in 2008, one year before the reform. I pick these industries because they have the most observations in the sample. The data pattern for other industries is similar. Figure 1 shows that firms' MRPK decreases with the size or small firms on average have higher MRPK than large firms. In a frictionless environment, in equilibrium, all firms are at their efficient sizes, which are determined by their productivities, and their MRPKs are all the same. The fact that we observe small firms have higher MRPK than large firms means small firms are further away from their efficient sizes. Given the higher marginal benefit of investment, small firms are more willing to invest than large firms. As a result, we can observe the heterogeneous investment responses in the last section.

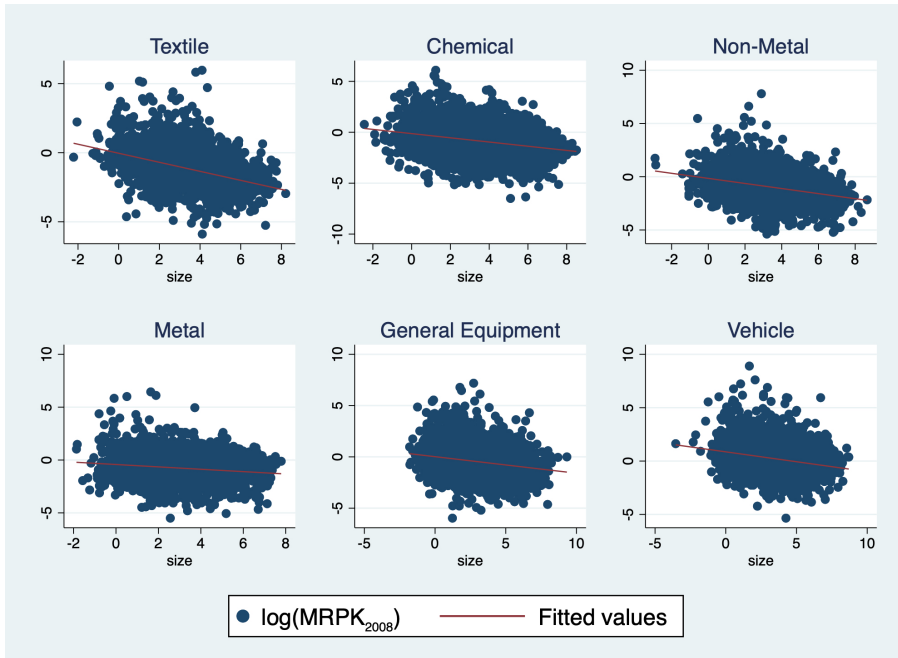


Figure 1: log MRPK vs log Size in 2008 for six representative industries

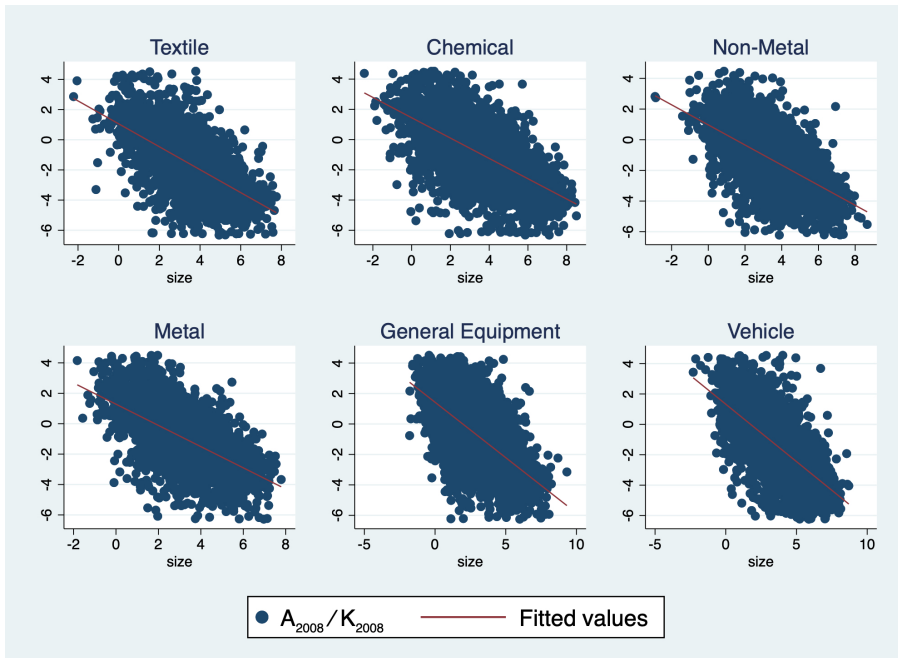


Figure 2: A/K vs log Size in 2008 for six representative manufacturing industries

Notes: Productivity A is estimated as in Wooldridge (2009), capital K is measured by the net value of fixed assets and size is the firm's log asset level at the end of 2008.

To speak more directly to the response of the investment rate to the VAT rate ν in this two-period model, I compute the productivity to capital ratio in the data and plot the ratios over firm size in 2008. The results are displayed in figure 2. Because the VAT reform extension was in 2009, here the years 2008 and 2009 correspond to the first and the second periods in our two-period model. Figure 2 shows for all the six representative CIC 2-digit industries, there are strong negative relations between the productivity to capital ratio and the firm sizes, or equivalently from equation (2), a strong negative relation between the response of the investment rate to the VAT rate and the firm sizes. This result is consistent with the empirical results in the last section and the observation that small firms have higher MRPK in this section. Hence we say small firms invest more aggressively because they have relatively higher MRPK.

One concern with the two-period model is the pre-reform distribution of capital K_{i0} is pre-determined and does not depend on the VAT rate ν . Our explanation above depends on this feature, but the distribution of capital K_{i0} depends on ν in the data. What happens if the distribution of K_{i0} is generated endogenously within the model? I answer this question with dynamic investment models in the next subsection and show the model with investment adjustment costs can rationalize the pre-reform distribution of capital and reproduce the empirical observations in section 4.

5.2 Dynamic Investment Model

In this sub-section, I first show that the frictionless dynamic model can not reproduce the heterogeneous investment responses by firm size to the VAT reform and then estimate augmented models with convex adjustment costs and fixed costs. The results show the convex adjustment costs and the fixed costs are essential for the model to generate the pre-reform size distribution where firms were not at their efficient sizes and to reproduce the heterogeneous investment responses at the intensive

and extensive margins, respectively. Because these models do not connect directly with the cross-section data, I use capital K as the size measure in the models.

Frictionless Dynamic Model

Consider a firm i maximizing its discounted sum of dividends

$$\max_{K_{it+1}} E_0 \left[\sum_{t=0}^{\infty} \beta^t D_{it} \right]$$

such that

$$K_{it+1} = (1 - \delta)K_{it} + I_{it}$$

$$D_{it} + p_t I_{it} = (1 - \tau)A_{it}^{1-\alpha} K_{it}^\alpha$$

where similar to the setting in the two-period model, A_i , D_i , K_i , and I_i are firm i 's productivity, dividend, capital, and investment of equipment, respectively. ν is the VAT rate and τ is the CIT rate. $p \equiv (1 + \nu)(1 - \tau p_\nu)$ is the purchase price of capital and p_ν is the present value of depreciation deductions. p_t is indexed by t because it may change value during the reform when ν changes. I assume the same productivity process as in the two-period model, i.e., $a_{it} = \log(A_{it}) = \omega_i + b_{it}$, where ω_i is firm-specific heterogeneity and b_{it} is an AR(1) type idiosyncratic transitory shock: $b_{it+1} = \rho b_{it} + \epsilon_{t+1}$.

It is shown in appendix 8.2 that we can solve analytically for K_{it+1}

$$K_{it+1} = \left(\frac{\alpha\beta(1-\tau)}{p_t - \beta(1-\delta)p_{t+1}} \right)^{1/(1-\alpha)} e^{\omega_i + \rho b_{it} + \frac{1}{2}(1-\alpha)\sigma_\epsilon^2}$$

The investment rate is

$$\frac{I_{it}}{K_{it}} = \frac{K_{it+1}}{K_{it}} - (1 - \delta) = \left(\frac{p_{t-1} - \beta(1-\delta)p_t}{p_t - \beta(1-\delta)p_{t+1}} \right)^{1/(1-\alpha)} e^{\rho(b_{it} - b_{it-1})} - 1 + \delta$$

During the 2009 VAT reform, the VAT rate ν declined from 17% to 0%. To generate the heterogeneous size responses of investment, the investment rate's response to ν needs to decrease by size where size is proxied by K_{it} . Suppose the economy is in pre-reform equilibrium up until period $t - 1$ and the reform occurs at period t , appendix 8.2 shows the DID estimate of the investment rate's response to ν is

$$\begin{aligned} \text{DID estimate} &= \left(\frac{p^{17\%} - \beta(1 - \delta)p^{0\%}}{p^{0\%}(1 - \beta(1 - \delta))} \right)^{\frac{1}{1-\alpha}} \mathbb{E} (e^{\rho(b_{it} - b_{it-1})}) \\ &\quad - \left(\frac{p^{17\%}(1 - \beta(1 - \delta))}{p^{17\%} - \beta(1 - \delta)p^{0\%}} \right)^{\frac{1}{1-\alpha}} \mathbb{E} (e^{\rho(b_{it-1} - b_{it-2})}) \end{aligned}$$

where $p^{17\%} = (1 + 17\%)(1 - \tau p_{17\%})$ and $p^{0\%} = (1 + 0\%)(1 - \tau p_{0\%})$. Because productivity is assumed to be exogenous and $p^{17\%}$ and $p^{0\%}$ are constants, in this frictionless dynamic model, the investment rate and the DID estimate are only functions of productivity and do not vary with size. In other words, the frictionless model can not reproduce the heterogeneous size responses of investment.

This is consistent with our intuition: without any friction, firm i can adjust to its expected efficient size immediately and its next period's size (K_{it+1}) only depends on this period's productivity, no matter how big or small the firm is this period. The independence of sizes between adjacent periods makes the investment rate's response homogeneous across the size distribution.

Dynamic Model with Convex Adjustment Costs

In this sub-section, I add in convex adjustment cost to the frictionless dynamic model. The adjustment cost makes the firm sizes in adjacent periods dependent and, the DID estimate of investment rate's response to the reform dependent on size. Numerically I show this addition enables the model to reproduce the heterogeneous

size responses of investment we observe in the data. The modified firm i 's problem is

$$V(K, A) = \max_{K'} D + \beta \mathbb{E}(V(K', A')|A)$$

such that

$$K' = (1 - \delta)K + I$$

$$D + pI + \frac{\gamma}{2} \left(\frac{I}{K} \right)^2 K = (1 - \tau)A^{1-\alpha}K^\alpha$$

where $p = (1 + \nu)(1 - \tau p_\nu)$, $a' \equiv \log(A') = \rho_A a + \epsilon'$ and γ is the convex adjustment cost parameter. To solve the model, I take the parameter values from Chen et al. (2020) because the dataset I use is the same as theirs. The productivity and profit parameters are estimated by the dynamic panel data model of Blundell and Bond (2000). The adjustment cost and capital depreciation parameters are estimated by the simulated method of moments (SMM). Table 5 lists the parameter values I use in the model solution. The model is solved using the collocation method.

Figure 3 plots the policy function implied investment rate responses to the change of the VAT rate ν over productivity under three levels of size and over size under three levels of productivity. Specifically it plots $(I_{0\%} - I_{17\%})/K$, where $I_{0\%}$ and $I_{17\%}$ are investment policy functions under $\nu = 0\%$ and $\nu = 17\%$ respectively. From panel A of the figure, we see a high productivity firm will invest more aggressively than a low productivity firm. This is consistent with intuition since, at the same level of size, firms with higher productivities also have higher MRPK, and the marginal benefit to invest is more than that of low productivity firms. The more important observation here is the blue line, which represents small firms, is above the orange line, which represents medium-sized firms, and is above the yellow line, which represents the large firms. In other words, as size increases, the investment rate response to ν declines. This result is consistent with the heterogeneous size responses of investment we observe in the data.

Table 5: Summary of Parameters in the Dynamic Model

Fixed Parameters		Value
Discount factor	β	0.950
VAT rate (Pre-reform)	ν_0	17%
VAT rate (Post-reform)	ν_1	0%
CIT rate	τ	15.4%
PV of depreciation deductions	p_ν	0.803
Parameters estimated by System GMM		
Profit curvature	α	0.734
Persistence of firm transitory shocks	ρ_A	0.860
SD firm transitory shocks	σ_ϵ	0.529
Parameters estimated by SMM		
Convex Adjustment Cost	γ	1.432
Fixed Cost	ξ	0.119
Capital depreciation rate	δ	0.071

Notes: This table lists the parameters we use in the estimation of the dynamic investment models in section 5. The parameter values are taken from Chen et al. (2020) because the dataset I use is the same as theirs. The productivity and profit parameters are estimated by the dynamic panel data model of Blundell and Bond (2000). The adjustment cost and capital depreciation parameters are estimated by the simulated method of moments (SMM).

From the panel B of the figure, we see that the blue line is below the orange line, which is below the yellow line. This is the same as in panel A that the more productive a firm is, the more aggressively it will invest. On the other hand, for all three productivity levels, the implied investment rate responses to the change of ν are decreasing in size. Again the result is consistent with the pattern we find in the data. One concern of these results' compatibility with the empirical observations is that policy functions do not tell us how many small and large firms there are in the economy. It might be the case there are few small firms and a lot of large firms in the equilibrium then, on average, the small firm group's investment rate response is lower than that of the large firm group, although an individual small firm's investment rate response is larger.

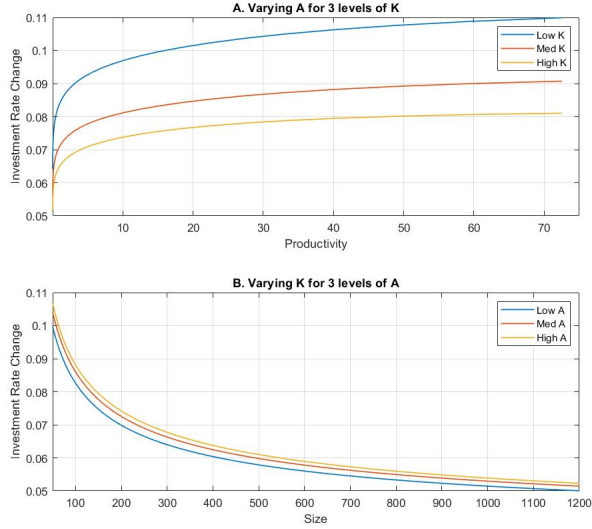


Figure 3: Policy function implied investment rate responses to VAT reform

Notes: This figure plots $(I_{0\%} - I_{17\%})/K$, where $I_{0\%}$ and $I_{17\%}$ are investment policy functions under $\nu = 0\%$ and $\nu = 17\%$ respectively. Low $K = 0.5 \times \text{Med } K$ and High $K = 1.5 \times \text{Med } K$. Same for the productivities. Size is measured by K in the dynamic models.

To address this concern and to connect more directly to the DID estimate in the empirical analyses, we need to compute the model implied DID estimate of the investment rate's response to ν ¹¹

$$\text{DID estimate} = \mathbb{E} \left(\frac{I}{K} \mid \nu = 0\%, t = 1 \right) - \mathbb{E} \left(\frac{I}{K} \mid \nu = 17\%, t = 0 \right) \quad (4)$$

In order to compute the expectations, we need to compute the stationary distributions of the economy pre and post-reform. Figure 4 plots the stationary distributions of (A, K) . The top left panel is the marginal stationary distribution of K pre-reform, and the bottom left panel is the joint stationary distribution of (K, A) pre-reform. The top right panel is the marginal stationary distribution of K post-reform, and the bottom right panel is the joint stationary distribution of (K, A) post-reform. From

¹¹The control group's average response is 0 since the economic environment is the same for them pre and post-reform.

the figure, we see that the size distribution shifts to the right after the reform, and there are more large firms in equilibrium. This is consistent with our intuition since the reform makes it cheaper for firms to purchase capital.

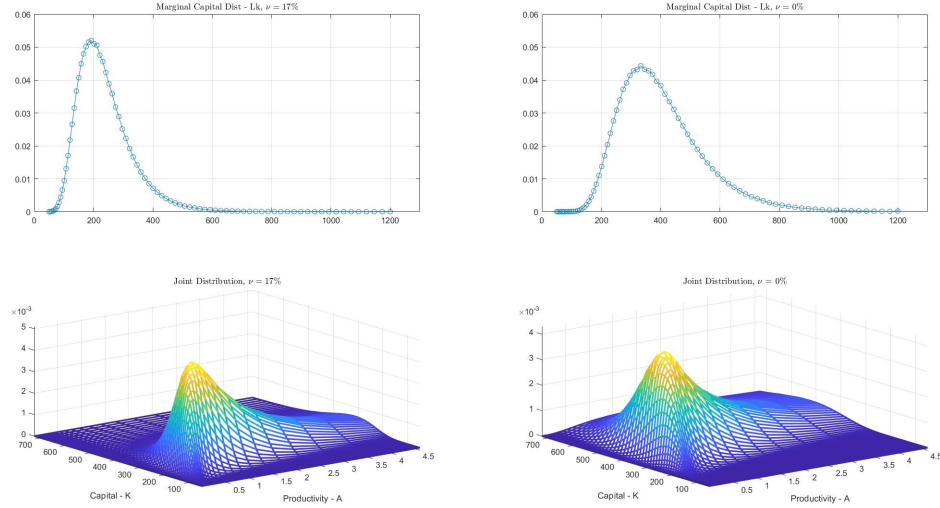


Figure 4: Stationary distributions of (K, A) (Convex Adjustment Costs only)

Notes: This figure plots the stationary dists of (K, A) in the dynamic model with convex adjustment costs only. The top panel plots the marginal dist of K and the bottom panel plots the joint dists of (K, A) . The left panel plots the pre-reform and the right panel plots the post-reform.

Given the stationary distributions, we would like to know how the economy and its associated size distribution and investment distribution transit from the pre-reform equilibrium to the post-reform equilibrium. Given the model is a partial equilibrium model, during the transitory process, the policy functions of all firms do not vary with time and are the same as the policy functions in the post-reform equilibrium. This feature simplifies the model simulation and the computation of the transitory dynamics. I use the same size group definition as in the empirical studies, i.e., small firms are those within the bottom 30% of the size distribution, medium-sized firms are those within the middle 40% of the size distribution, and large firms are those within the top 30% of the size distribution. Then we are able to compute the transitory

dynamics of the model variables by the size groups. Figure 5 plots the transitional dynamics of the quantities K' , I , the investment rate the DID estimate in equation (4) by the size groups. From figure 5, we see large firms invest more in terms of quantities than small firms but when it comes to the investment rate and the DID estimate of the response of the investment rate to ν , small firms respond more aggressively. Therefore, the dynamic model with investment adjustment cost can reproduce the heterogeneous size responses of investment we observe in the data.

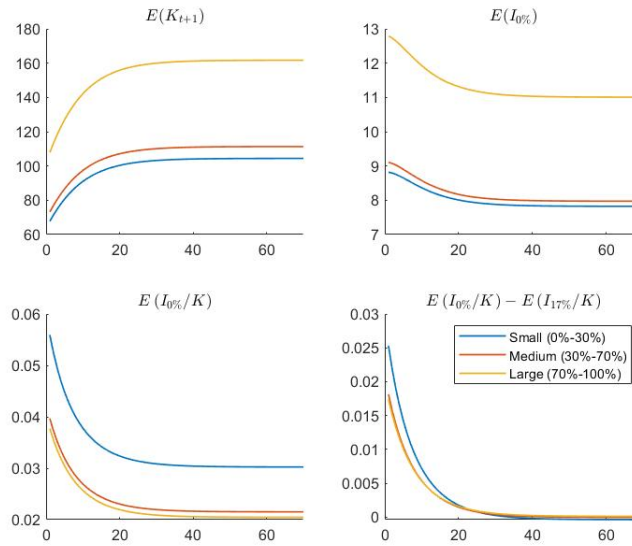


Figure 5: Transitional Dynamics of K' , I , I/K and DID estimates

Notes: This figure plots the transitional dynamics of capital, investment, investment rate and the DID estimate of the investment rate's response to ν . Though large firms respond more in quantities, they respond less in terms of investment rates and DID estimates.

In terms of intuition, we see the investment rate's response to the reform is homogeneous across sizes in the frictionless model. In the model with adjustment cost, large firms need to pay higher adjustment costs if they adjust their investment rates on the same scale as small firms do. Because the profit function is concave in K and the adjustment cost is linear in K once the investment rate is fixed, the marginal benefit of investing is larger for small firms while the marginal cost is the same for

small and large firms. As a result, small firms respond more aggressively in this model with convex adjustment costs.

Dynamic Model with Convex Adjustment Costs and Fixed Costs

Up to now, we have been focusing on the investment responses on the intensive margin. This subsection introduces fixed costs into the model and extends the model to the extensive margin. With fixed costs, firms need to make decisions on whether to invest in a given period. Firm i 's problem is

$$V(K, A) = \max (V^I(K, A), V^N(K, A))$$

where V^I is the value function if the firm decides to invest and V^N is the value function of not investing. If firm i decides to invest, it solves

$$V^I(K, A) = \max_{K'} D + \beta \mathbb{E} (V(K', A')|A)$$

such that

$$K' = (1 - \delta)K + I$$

$$D + pI + \frac{\gamma}{2} \left(\frac{I}{K} \right)^2 K + \xi K' = (1 - \tau)A^{1-\alpha} K^\alpha$$

where $p = (1 + \nu)(1 - \tau p_\nu)$, $a' \equiv \log(A') = \rho_A a + \epsilon'$, γ is the convex adjustment cost parameter and ξ is the fixed cost parameter. The fixed costs are proportional to firm i 's next period's capital level K' since K' reflects its profitability.

If firm i decides not to invest, it solves

$$V^N(K, A) = \max_{K'} D + \beta \mathbb{E} (V(K', A')|A)$$

such that

$$K' = (1 - \delta)K + I$$

$$D = (1 - \tau)A^{1-\alpha}K^\alpha$$

The model is again solved using the collocation method. Figure 6 plots the stationary distributions of (A, K) in the model with convex adjustment costs and the fixed costs. As in the model with the convex adjustment costs only (figure 4), we see after the reform, the size distribution shifts to the right, and there are more large firms in equilibrium. Moreover, the equilibrium sizes in figure 6 are much smaller than those in figure 4. This is expected since the fixed costs take up resources the firms should have used for investment if there are no such costs.

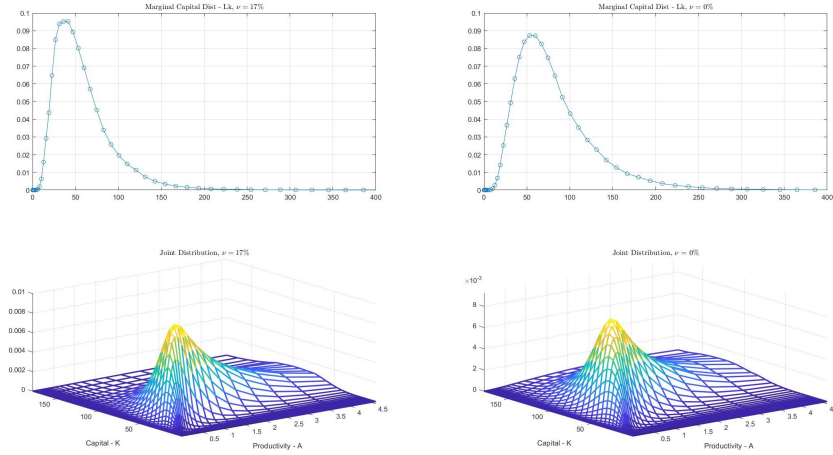


Figure 6: Stationary distributions of (K, A) (Convex Costs and Fixed Costs)

Notes: This figure plots the stationary dists of (K, A) in the dynamic model with convex adjustment costs and fixed costs. The top panel plots the marginal dist of K and the bottom panel plots the joint dists of (K, A) . The left panel plots the pre-reform and the right panel plots the post-reform distributions.

Equipped with the probability distributions, we can compute the model implied DID estimate of the investment responses to ν at the extensive margin:

$$\begin{aligned} \text{DID estimate} &= \mathbb{E}(1_{I>0} \mid \nu = 0\%, t = 1) - \mathbb{E}(1_{I>0} \mid \nu = 17\%, t = 0) \\ &= P(I_{0\%} > 0) - P(I_{17\%} > 0) \end{aligned} \tag{5}$$

where again $I_{0\%}$ and $I_{17\%}$ are investment policy functions under the VAT rate $\nu = 0\%$ and $\nu = 17\%$ respectively. To look at how the economy transits from the pre-reform equilibrium to the post-reform equilibrium, figure 7 plots the transitional dynamics of the quantities K' , I , the investment rate, the DID estimate of the investment rate's response to the VAT rate ν 's change in equation (4), the probability of positive investment post-reform, and the DID estimate of the investment responses at the extensive margin in equation (5) by the same size groups as in previous sections. From figure 7, we see all the properties in the model with the convex adjustment costs only carry to the model with both convex adjustment costs and fixed costs. Moreover, firms' probabilities to invest are decreasing in their sizes and the DID estimates of the investment responses at the extensive margin are also decreasing in sizes. The dynamic model with convex adjustment costs and fixed costs can generate the pre-reform size distribution where firms were not at their efficient sizes and reproduce the heterogeneous size responses at both the intensive and extensive margins.

In addition to the adjustment costs, there are other factors that may affect the heterogeneous investment responses by firm size. In the next section, we look into how financial frictions affected the heterogeneous investment responses to the VAT reform.

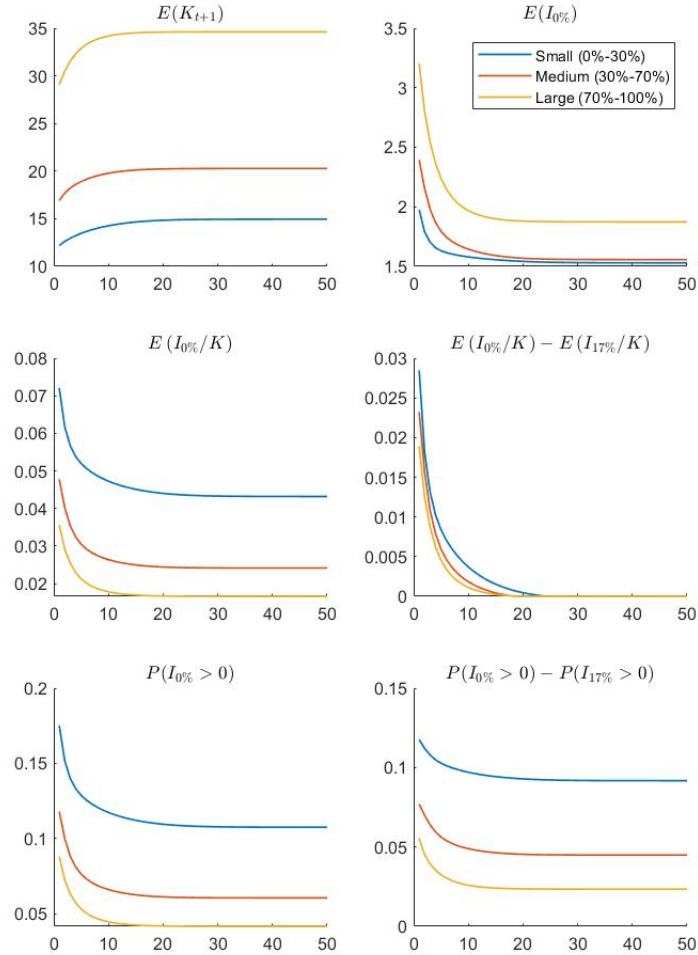


Figure 7: Transitional Dynamics of K' , I , I/K , $P(I > 0)$ and DID estimates

Notes: This figure plots the transitional dynamics of capital, investment, investment rate and the DID estimate of the investment rate's response to the ν , the probability of positive investment and the DID estimate of the likelihood of investment's response to ν , in the dynamic model with convex adjustment costs and fixed costs. As in figure 5, though large firms respond more in quantities, they respond less in terms of investment rates, likelihood of investment and DID estimates.

6 Financial Frictions in the VAT Reform

From the policy background, we know at the early stage of the reform (2004–2009), the government firstly collected input VAT on the equipment during the fiscal year then refunded the collected VAT if that year’s tax revenue had reached its target. If a firm is initially financially constrained and unable to invest, the refund would loosen its financial constraint and induce the firm to invest. Since the reform extension in 2009, all firms can deduct input VAT on equipment from total output VAT directly. In this case, the reform acted like a decline in the user cost of capital or the price of the equipment. If a firm is initially financially constrained, it would still be constrained even though the user cost of capital declined. For this reason, we expect more constrained firms to invest more during the 2004 pilot programs but not during the 2009 VAT reform.

To confirm this observation, we need to identify which firms in the sample were financially constrained and, therefore, a measure of the severity of the financial constraints. There are several approaches to provide such a measure in the literature, e.g., the investment–cash flow sensitivities (Fazzari et al. 1988), the Kaplan and Zingales index of constraints (Lamont et al. 2001), the Whited Wu index of constraints (Whited and Wu 2006) and the Size–Age index of constraints (Hadlock and Pierce 2010).

Since all these indexes were estimated using the U.S. data, their validity for use in the Chinese dataset is questionable. As mentioned in the introduction, because the Kaplan and Zingales index requires the computation of Tobin’ Q whereas 99.3% of the firms in my sample are private firms, I can not estimate the KZ index. The Size–Age index requires SEC’s 10K forms in which firms explicitly indicate if they are financially constrained during a year. There is no such information in our sample. Consequently, I estimate a Chinese version of the Whited Wu financial constraint index with the data and re-do the difference in differences analysis as in section

4, but sorted by firms' financial constraint levels rather than their sizes. We will see indeed there were no heterogeneous investment responses to the VAT reform by financial tightness or financial frictions were not a dominating factor for investment in the 2009 VAT reform.

6.1 Whited Wu index Estimation

In this sub-section, I use the Whited Wu (2006) framework to estimate a Chinese version Whited Wu index. The index is the Lagrangian multiplier (shadow value) of one of the financial constraints firms face. Consider the partial equilibrium investment model in Whited Wu (2006). Firm i 's problem is

$$\max_{K_{it+1}, B_{it+1}} V_{i0} = \mathbb{E}_{i0} \left(\sum_{t=0}^{\infty} \prod_{s=0}^t \beta_s D_{it} \right)$$

such that

$$D_{it} = \pi(A_{it}, K_{it}) - \psi(I_{it}, K_{it}) - I_{it} + B_{it+1} - (1 + r_t)B_{it}$$

$$K_{it+1} = (1 - \delta_i)K_{it} + I_{it}$$

$$D_{it} \geq D_{it}^* \quad (\lambda_{it})$$

$$B_{it+1} \leq B_{it+1}^* \quad (\gamma_{it})$$

where A_i , D_i , B_i , K_i and I_i are firm i 's productivity, dividend, debt, capital and investment respectively. $\pi(A, K)$ is profit function with $\pi_K > 0$. $\psi(I, K)$ is investment adjustment cost with $\psi_I > 0$, $\psi_K < 0$ and $\psi_{II} > 0$. β is discount factor, δ_i is the capital depreciation rate and r_t is interest rate. D_{it}^* is the firm time varying lower limit on dividends and B_{it}^* is the upper limit on the stock of debt. A negative value of D_{it}^* can be considered as new share issues. λ and γ are the Lagrangian multipliers

of the dividend constraint and the debt constraint respectively.

The Whited Wu index is the estimated λ in the data where a higher value of λ indicates firm i 's external equity financing is more costly than its internal financing and hence the firm is more constrained. The F.O.C.s with respect to K_{it+1} and B_{it+1} are

$$\mathbb{E}_{it} \left(\beta \left(\frac{1 + \lambda_{it+1}}{1 + \lambda_{it}} \right) \left\{ \frac{\partial \pi_{it+1}}{\partial K_{it+1}} - \frac{\partial \psi_{it+1}}{\partial K_{it+1}} + (1 - \delta_i) \left(\frac{\partial \psi_{it+1}}{\partial I_{it+1}} + 1 \right) \right\} \right) = \frac{\partial \psi_{it}}{\partial I_{it}} + 1 \quad (6)$$

$$(1 + \lambda_{it}) = \mathbb{E}_{it} (\beta(1 + \lambda_{it+1})(1 + r_t)) + \gamma_{it} \quad (7)$$

The reason we use λ rather than γ as the Whited Wu index is once we have estimated λ , we can compute γ directly from equation (7). We estimate the index using equation (6) through nonlinear generalized method of moments (NL-GMM). To estimate the index λ , we replace the expectational operator in equation (6) with an expectational error e_{it} where $\mathbb{E}_t(e_{it+1}) = 0$ and $\mathbb{E}_t(e_{it}^2) = \sigma_{it}^2$. GMM allows us for heteroscedasticity. In addition, we add in a firm fixed effect f_i and a year fixed effect y_t . Then the estimation equation becomes

$$\beta \left(\frac{1 + \lambda_{it+1}}{1 + \lambda_{it}} \right) \left\{ \frac{\partial \pi_{it+1}}{\partial K_{it+1}} - \frac{\partial \psi_{it+1}}{\partial K_{it+1}} + (1 - \delta_i) \left(\frac{\partial \psi_{it+1}}{\partial I_{it+1}} + 1 \right) \right\} = \frac{\partial \psi_{it}}{\partial I_{it}} + 1 + f_i + y_{t+1} + e_{it+1} \quad (8)$$

From equation (8) we see the estimation requires us to parameterize π_K , ψ and λ . We assume

$$\frac{\partial \pi_{it}}{\partial K_{it}} = \frac{Y_{it} - \mu C_{it}}{K_{it}}$$

where Y_{it} is business income, C_{it} is variable costs (labor cost+material cost in my estimation) and μ is a constant markup over marginal cost. This specification is justified by an environment where firms have constant returns to scale production functions and face downward sloping demand curves. For the adjustment cost function

ψ , we assume

$$\psi(I_{it}, K_{it}) = \left(\sum_{m=2}^M \frac{1}{m} \alpha_m \left(\frac{I_{it}}{K_{it}} \right)^m \right) K_{it}$$

This specification uses a flexible functional form that is linearly homogeneous and allows for nonlinearities in the marginal adjustment cost function. If $M = 2$, ψ degenerates to the traditional quadratic adjustment cost function. To determine M , I first start with $M = 3$ and find the model specification is not rejected by the Hansen's J test in GMM estimation. Then I estimate nested specifications with $M = 2$. The J test always rejects $M = 2$ so my final specification is $M = 3$.

We parameterize λ as

$$\lambda_{it} = b_0 + b_1 LNTA_{it} + b_2 TLLD_{it} + b_3 IDAR_{jt} + b_4 SG_{it} + b_5 ISG_{jt} + b_6 CF_{it} + b_7 CASH_{it}$$

where i indexes firm and j indexes industry. $LNTA$ is log total asset, $TLLD$ is debt to asset ratio, $IDAR$ is industry debt to asset ratio (at CIC 3-digit level), SG is sales growth, ISG is industry sales growth (at CIC 3-digit level), CF is cash flow and $CASH$ is current asset cash. Because small firms are more likely to be financially constrained, we expect $b_1 < 0$. Because a firm with a high leverage ratio is more likely to be constrained, we expect $b_2 > 0$. If a firm has a higher leverage ratio than its industry peers, then it is more likely to be constrained so we expect $b_3 < 0$. Because a firm with high sales growth is less likely to be constrained, we expect $b_4 < 0$ and similarly, if a firm has lower sales growth than its industry peers, then it is more likely to be constrained so we expect $b_5 > 0$. In addition, more cash flow and cash holding suggest the firm is less likely to be constrained so we expect $b_6 < 0$ and $b_7 < 0$. In our estimation results below, we will see the estimates are consistent with the expectations here.

Equipped with all the structures, we are able to estimate the Whited Wu index λ . The rational expectations assumption provides model identification since it implies

any variable z_{it-1} known to the firm at period $t - 1$ can be used as an instrument to estimate equation (8). Because we have included fixed effects, we estimate the model in first differences, i.e. $\mathbb{E}_{t-1}(z_{i,t-1} \otimes (e_{it+1} - e_{it})) = 0$.¹² My instruments include all variables in λ , Y/K , C/K , I/K , current liabilities and a dummy of positive profit last period, all at $t - 1$. β is calculated as the inverse of ones plus the lending rate in China from 2007-2011 where the lending rate data comes from WorldBank.org.

I implement the two step GMM procedure subject to the constraint that the shadow value must be nonnegative in expectation

$$\min \mathcal{J} = ng'_n \hat{W} g_n \quad \text{s.t.} \quad \mathbb{E}(\lambda_{it}) \geq 0$$

where $g_n = \frac{1}{n} \sum_i^n g_i = \frac{1}{n} \sum_i^n z_{it-1} \otimes (e_{it+1} - e_{it})$. Table 6 shows the estimation results (standard errors in the parentheses).

Table 6: GMM Estimation of the Whited Wu Index

	1	2	3
α_2	-14.82***(0.80)	-13.31***(0.51)	-14.61***(0.72)
α_3	14.23***(1.48)	11.91***(0.96)	15.34***(1.29)
b_0	2.91***(0.55)	2.35***(0.43)	0.39(0.30)
<i>LNTA</i>	-0.61***(0.19)	-0.45***(0.06)	-0.30***(0.03)
<i>TLTD</i>	4.91***(1.26)	3.64***(0.37)	0.95***(0.16)
<i>IDAR</i>	-5.57***(1.10)	-4.32***(0.78)	0.76(0.55)
<i>SG</i>	-4.55***(1.11)	-3.67***(0.33)	-2.02***(0.09)
<i>ISG</i>	0.60***(0.21)	0.42***(0.09)	
<i>CF</i>	2.39*(1.33)		
<i>J</i> -Test Statistic	0.22	0.54	3.00

Notes: This table presents the estimation results of the Chinese version Whited Wu index. From column 1–3, I continue dropping financial variables from the index to find the most parsimonious model specification. Column 3 only lists the result of dropping *ISG* from the index in column 2, which is rejected by Hansen’s *J* test. The specifications of dropping other financial variables are also rejected. As a result, column 2 is the most parsimonious specification that is not rejected by Hansen’s *J* test.

¹²Estimation specification in levels are all rejected by Hansen’s *J* test.

Column 1 lists the most general specification that is not rejected by Hansen's J test. All the coefficients are consistent with our intuition above, except CF 's coefficient is expected to be negative but is 2.39. However, the estimate has only one star and is not significant. Then I estimate a nested model specification without CF in column 2. Again the specification is not rejected by the J test and all the coefficients are consistent with intuition. I continue estimating nested specifications by dropping more variables from λ . J tests show that column 2 is the most parsimonious model specification that is not rejected. Column 3 lists the estimation result when I exclude ISG from λ and is rejected by the J test. Consequently, I name column 2 my estimated Chinese version of the Whited Wu index:

$$\lambda_{it} = 2.35 - 0.45LNTA_{it} + 3.64TLTD_{it} - 4.32IDAR_{jt} - 3.67SG_{it} + 0.42ISG_{jt}$$

Figure 8 plots the estimated Whited Wu index over its five components and current liability to asset ratio in its 2008 level, one year before the VAT reform. We see the Whited Wu index is decreasing in size, increasing in debt to asset ratio, decreasing in industry debt to asset ratio, decreasing in sales growth, and increasing in industry sales growth. The results are consistent with our expectations. In the last plot, because the current liability to asset ratio is not included in λ , the positive correlation between the Whited Wu index and the ratio confirms the validity of our estimates. In addition, I compute the average Whited Wu index by if a firm is publicly listed and if a firm had a positive profit last period. The result is listed firms and firms with positive profit last period on average have lower levels of the index and lower standard deviation within the listed or positive profit groups. Again the validity of our estimates is confirmed.



Figure 8: Chinese Whited Wu index in 2008

Notes: This figure plots the the estimated Whited Wu index over its five components and current liability to asset ratio in its 2008 level.

6.2 Difference in Differences sorted by Whited Wu index

Equipped with the Chinese Whited Wu index, we are able to identify which firms in the sample were constrained and perform the DID analysis sorted by the index. If financial constraints were important to explain the heterogeneous investment responses to the 2009 VAT reform, we would see more constrained firms responded more aggressively. I use a similar empirical specification as in section 4

$$\begin{aligned} Y_{ijkt} = & \beta_0 + \beta_1 Treat_i \times Post_t + \beta_2 Treat_i \times Post_t \times Intermediate \\ & + \beta_3 Treat_i \times Post_t \times Constrained + \beta_4 Post_t \times Intermediate \\ & + \beta_5 Post_t \times Constrained + \mu_i + \delta_{jt} + \eta_{kt} + \epsilon_{ijt} \end{aligned} \quad (9)$$

The only difference of equation (9) from equation (1) is here firms are sorted by their Whited Wu index levels in 2008, one year before the reform. *Constrained* is an indicator = 1 if the firm's 2008 Whited Wu index level is in the top 30% (70%-100%) of the 2008 index distribution. *Intermediate* is an indicator = 1 if the firm's 2008 Whited Wu index level is in the middle 40% (30%-70%) of the 2008 index distribution. The base type here is the relatively unconstrained firms.

Table 7 reports the regression results of the specification in equation (9) using pilot domestic firms as the control group. We see after the reform, the relatively unconstrained group are 9% more likely to invest and adjust their investment rates 5.6% more than unconstrained pilot domestic firms. However, we do not observe significant heterogeneous investment responses by the severity of the financial constraint. There is weak evidence that the more constrained group responded less on the intensive margin.

Table 7: Difference in Differences sorted by Whited Wu index

Control Group: Pilot Domestic Firms				
	Equipment		Building	
	$1(I > 0)$	I/K	$1(I > 0)$	I/K
<i>Treat</i> × <i>Post</i>	0.090*** (0.010)	0.056*** (0.010)	0.028*** (0.009)	0.006 (0.011)
<i>Treat</i> × <i>Post</i> × <i>Intermediate</i>	-0.002 (0.013)	-0.016 (0.012)	0.007 (0.012)	0.001 (0.014)
<i>Treat</i> × <i>Post</i> × <i>Constrained</i>	-0.011 (0.014)	-0.022* (0.013)	-0.014 (0.013)	-0.003 (0.015)
<i>Post</i> × <i>Intermediate</i>	-0.003 (0.012)	0.020* (0.011)	-0.031*** (0.011)	0.009 (0.012)
<i>Post</i> × <i>Constrained</i>	-0.009 (0.012)	-0.035*** (0.012)	-0.022* (0.012)	-0.014 (0.013)
Constant	0.491*** (0.007)	0.182*** (0.006)	0.231*** (0.006)	0.128*** (0.006)
Adjusted R^2	0.336	0.113	0.351	0.129
# Obs	243,406	157,183	244,871	119,801

Standard errors in parentheses (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

Notes: This table estimates the investment responses to the VAT reform sorted by the Whited Wu index, using the pilot domestic firms as the control group. The DID specification is

$$Y_{ijkt} = \beta_0 + \beta_1 \textit{Treat}_i \times \textit{Post}_t + \beta_2 \textit{Treat}_i \times \textit{Post}_t \times \textit{Intermediate} + \beta_3 \textit{Treat}_i \times \textit{Post}_t \times \textit{Constrained} \\ + \beta_4 \textit{Post}_t \times \textit{Intermediate} + \beta_5 \textit{Post}_t \times \textit{Constrained} + \mu_i + \delta_{jt} + \eta_{kt} + \epsilon_{ijt}$$

where i, j, k, t index firm, CIC 2-digit industry, province and year respectively. Y_{ijkt} represents the investment response measures at the top of each column. \textit{Treat}_i is an indicator of if the firm is a non-pilot domestic firm. \textit{Post}_t is an indicator of if $t \geq 2009$. $\textit{Constrained}$ and $\textit{Intermediate}$ are indicators if a firm belongs to the financially constrained or intermediately constrained groups, defined by the Whited Wu index. μ_i is the firm fixed effect, δ_{jt} is the industry year fixed effect, and η_{kt} is the province year fixed effect. All regressions include all the fixed effects. Standard errors cluster at the firm level.

Table 8 reports the regression results using foreign firms with preferential treatment as the control group. The general message is similar. We see after the reform, the relatively unconstrained group are 4.5% more likely to invest and adjust their investment rates 6.4% more than unconstrained foreign firms with preferential treatment. Again we do not observe significant heterogeneous investment responses by the

severity of the financial constraint. There is weak evidence the more constrained the firm was, the less the response.

These results are consistent with our expectation that the financial frictions were not a dominating factor for investment in the 2009 VAT reform. Since the government changed the implementation of the reform to the tax credit accounting method, the reform acted like a decline in the user cost of capital. As a result, a financially constrained firm would still be constrained and unable to aggressively invest after the reform.

Table 8: Difference in Differences sorted by Whited Wu index II

Control Group: Foreign Firms with Preferential Treatment				
	Equipment		Building	
	$1(I > 0)$	I/K	$1(I > 0)$	I/K
<i>Treat</i> × <i>Post</i>	0.045*** (0.015)	0.064*** (0.013)	0.048*** (0.015)	0.004 (0.014)
<i>Treat</i> × <i>Post</i> × <i>Intermediate</i>	0.011 (0.018)	-0.010 (0.016)	0.002 (0.019)	-0.007 (0.017)
<i>Treat</i> × <i>Post</i> × <i>Constrained</i>	0.017 (0.019)	-0.030* (0.017)	-0.034* (0.019)	-0.003 (0.019)
<i>Post</i> × <i>Intermediate</i>	-0.013 (0.017)	0.015 (0.015)	-0.027 (0.019)	0.018 (0.016)
<i>Post</i> × <i>Constrained</i>	-0.034* (0.018)	-0.027* (0.016)	-0.002 (0.019)	-0.014 (0.018)
Constant	0.513*** (0.010)	0.171*** (0.009)	0.220*** (0.010)	0.129*** (0.009)
Adjusted R^2	0.342	0.115	0.353	0.131
# Obs	215,341	139,401	216,676	107,100

Standard errors in parentheses (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

Notes: This table estimates the investment responses to the VAT reform sorted by the Whited Wu index, using the foreign firms with preferential treatments as the control group. The DID specification is the same as in Table 7. All regressions include all the fixed effects. Standard errors cluster at the firm level.

7 Conclusion

This paper studies the heterogeneous investment behavior in China's 2009 VAT reform. I show small firms responded more aggressively to the reform than large firms at both the extensive and intensive margins through the difference in differences analysis. In a simple two-period model, I show the heterogeneous investment responses by firm size are due to small firms' relatively higher marginal benefit of investing, which I call the size effect. This explanation relies on a size distribution where small firms were further away from their efficient sizes pre-reform, and this size distribution can be rationalized in a dynamic investment model with convex adjustment costs and fixed costs. Estimating the dynamic model with the adjustment costs shows the model can reproduce the empirical facts very well both qualitatively and quantitatively.

In the studies of the financial frictions in the reform, I estimate a Chinese version of the Whited Wu (2006) financial constraint index and show that financial frictions were not a dominating factor in generating the heterogeneous investment responses. The fact that small firms were more likely to be financially constrained but invested more indicates the size effect dominated the financial frictions during China's 2009 VAT reform.

8 Model Appendix

8.1 Two-Period Model

Firm i 's problem is

$$\max_{D_{i0}, D_{i1}, B_{i0}, K_{i1}} u(D_{i0}) + \beta \mathbb{E}(u(D_{i1}) | A_{i0})$$

such that

$$K_{i1} = (1 - \delta)K_{i0} + I_{i0}$$

$$D_{i0} + p_b I_i = (1 - \tau)A_{i0}^{1-\alpha} K_{i0}^\alpha + B_{i0}$$

$$D_{i1} + (1 + r)B_{i0} = (1 - \tau)A_{i1}^{1-\alpha} K_{i1}^\alpha + p_s(1 - \delta)K_{i1}$$

$$(1 + r)B_{i0} \leq \theta(1 - \delta)p_s K_{i1}$$

where $p_b = p_k(1 + \nu)(1 - \tau p_\nu)$, $p_s = p_k(1 - \tau(1 + \nu)p_\nu)$ and $p_\nu = \sum_{j=0}^{T-1} \frac{(1+\nu)}{T(1+r)^j}$. $a_{it} \equiv \log(A_{it}) = \omega_i + b_{it}$, where ω_i captures firm-specific heterogeneity, and b_{it} is an idiosyncratic transitory shock that evolves according to an AR(1) process $b_{i1} = \rho b_{i0} + \epsilon_{i1}$. In order to derive analytical results and without loss of generality, we assume ϵ_{i1} follows a normal distribution $\epsilon \sim N(0, \sigma_\epsilon^2)$. The two budget constraints at $t = 0, 1$ can be combined into one intertemporal budget constraint

$$D_{i0} + p_b(K_{i1} - (1 - \delta)K_{i0}) = (1 - \tau)A_{i0}^{1-\alpha} K_{i0}^\alpha + \frac{(1 - \tau)A_{i1}^{1-\alpha} K_{i1}^\alpha + p_s(1 - \delta)K_{i1} - D_{i1}}{1 + r}$$

The F.O.C.s with respect to D_{i0} , D_{i1} and K_{i1} are

$$u'(D_{i0}) = \lambda_i \tag{10}$$

$$\beta \mathbb{E}(u'(D_{i1}) | A_{i0}) = \frac{\lambda_i}{1 + r} - \mu_i \tag{11}$$

$$\mathbb{E} \left[\lambda_i \left(\frac{(1 - \tau)\alpha A_{i1}^{1-\alpha} K_{i1}^{\alpha-1} + p_s(1 - \delta)}{1 + r} - p_b \right) | A_{i0} \right] =$$

$$\mathbb{E} \left[\mu_i \left((1 - \theta)(1 - \delta)p_s + (1 - \tau)\alpha A_{i1}^{1-\alpha} K_{i1}^{\alpha-1} \right) | A_{i0} \right] \tag{12}$$

where λ_i and μ_i are Lagrangian multipliers of the intertemporal budget constraint and the collateral constraint respectively. If the collateral constraint does not bind,

i.e. $\mu_i = 0$ then combine equation (10) and equation (12), we have

$$\mathbb{E} \left[u'(D_{i0}) \left(\frac{(1-\tau)\alpha A_{i1}^{1-\alpha} K_{i1}^{\alpha-1} + p_s(1-\delta)}{1+r} - p_b \right) \mid A_{i0} \right] = 0$$

Since the budget constraint always binds, $\lambda_i = u'(D_{i0}) > 0$. Because D_{i0} and K_{i1} are in firm i 's time 0 information set, we can take $u'(D_{i0})$ and $K_{i1}^{\alpha-1}$ out of the expectational operator. Given this is a partial equilibrium model and all prices are fixed, we are able to solve for K_{i1} and $\partial K_{i0}/\partial \nu$ as a function of the time 0 productivity

$$K_{i1} = \left(\frac{p_b(1+r) - p_s(1-\delta)}{\alpha(1-\tau)} \right)^{1/(\alpha-1)} e^{\omega_i + \rho b_{i0} - \frac{1}{2}(1-\alpha)\sigma_\epsilon^2}$$

$$\frac{\partial K_{i1}}{\partial \nu} = -\frac{1}{1-\alpha} \left(\frac{p_b(1+r) - p_s(1-\delta)}{\alpha(1-\tau)} \right)^{\frac{2-\alpha}{\alpha-1}} \frac{p_k(1+r - (r+\delta)(1+\tau)p_\nu)}{\alpha(1-\tau)} e^{\omega_i + \rho b_{i0} - \frac{1}{2}(1-\alpha)\sigma_\epsilon^2}$$

The investment rate is

$$\frac{I_{i0}}{K_{i0}} = \frac{K_{i1} - (1-\delta)K_{i0}}{K_{i0}} = \frac{K_{i1}}{K_{i0}} - 1 + \delta$$

Given K_{i0} is predetermined, the response of the investment rate to the VAT rate ν is

$$\begin{aligned} \frac{\partial(I_{i0}/K_{i0})}{\partial \nu} &= \frac{\partial K_{i1}/\partial \nu}{K_{i0}} = -\frac{1}{1-\alpha} \left(\frac{p_b(1+r) - p_s(1-\delta)}{\alpha(1-\tau)} \right)^{\frac{2-\alpha}{\alpha-1}} \\ &\quad \cdot \frac{p_k(1+r - (r+\delta)(1+\tau)p_\nu)}{\alpha(1-\tau)K_{i0}} e^{\omega_i + \rho b_{i0} - \frac{1}{2}(1-\alpha)\sigma_\epsilon^2} \end{aligned}$$

Because this is a partial equilibrium model, all the prices are treated as constants. Therefore, the response of the investment rate to the VAT rate ν is proportional to the productivity to capital ratio in the first period

$$\frac{\partial(I_{i0}/K_{i0})}{\partial \nu} \propto -\frac{e^{\omega_i + \rho b_{i0}}}{K_{i0}}$$

8.2 Frictionless Dynamic Model

Firm i 's problem is

$$\max_{K_{it+1}} E_0 \left[\sum_{t=0}^{\infty} \beta^t \left((1 - \tau) A_{it}^{1-\alpha} K_{it}^\alpha - p_t (K_{it+1} - (1 - \delta) K_{it}) \right) \right]$$

where $p_t \equiv (1 + \nu)(1 - \tau p_\nu)$ and $a_{it} = \log(A_{it}) = \omega_i + b_{it}$. where ω_i is firm-specific heterogeneity and b_{it} is an AR(1) type idiosyncratic transitory shock: $b_{it+1} = \rho b_{it} + \epsilon_{t+1}$. As in the two period model, we assume ϵ_{it+1} follows a normal distribution $\epsilon \sim N(0, \sigma_\epsilon^2)$ to achieve analytical results. p_t is indexed by t because it may change value during the reform when ν changes. The F.O.C. with respect to K_{it+1} is

$$p_t = \beta \mathbb{E} \left((1 - \tau) \alpha A_{it+1}^{1-\alpha} K_{it+1}^{\alpha-1} + p_{t+1} (1 - \delta) \mid A_{it} \right)$$

Because K_{it+1} is in firm i 's time t information set, we can take $K_{it+1}^{\alpha-1}$ out of the expectation operator and solve for K_{it+1} . The VAT rate ν declined from 17% to 0% in the reform. Denote $p^{17\%} = (1 + 17\%)(1 - \tau p_{17\%})$ and $p^{0\%} = (1 + 0\%)(1 - \tau p_{0\%})$. If period t is not the period immediately before the reform, p_t and p_{t+1} are the same. In this case

$$K_{it+1} = \left(\frac{\alpha \beta (1 - \tau)}{p_t (1 - \beta (1 - \delta))} \right)^{1/(1-\alpha)} e^{\omega_i + \rho b_{it} + \frac{1}{2}(1-\alpha)\sigma_\epsilon^2}$$

where $p_t = p^{17\%}$ pre-reform and $p_t = p^{0\%}$ post-reform. If period t is the period immediately before the reform, then $p_t = p^{17\%}$ and $p_{t+1} = p^{0\%}$. In this case

$$K_{it+1} = \left(\frac{\alpha \beta (1 - \tau)}{p^{17\%} - \beta (1 - \delta) p^{0\%}} \right)^{1/(1-\alpha)} e^{\omega_i + \rho b_{it} + \frac{1}{2}(1-\alpha)\sigma_\epsilon^2}$$

We are interested in how the response of the investment rate to ν varies with size K_{it} . Consider four periods in the model, $t - 2, t - 1, t, t + 1$. Suppose the economy is in the pre-reform equilibrium up to period $t - 1$ and the reform occurs at period t

* At period $t - 2$, $p_{t-2} = p^{17\%}$ and $p_{t-1} = p^{17\%}$

$$\frac{I_{it-2}}{K_{it-2}} = \frac{K_{it-1}}{K_{it-2}} - (1 - \delta) = \left(\frac{p^{17\%}}{p^{17\%}} \right)^{1/(1-\alpha)} e^{\rho(b_{it-2}-b_{it-3})} - 1 + \delta$$

* At period $t - 1$, $p_{t-1} = p^{17\%}$ and $p_t = p^{0\%}$

$$\frac{I_{it-1}}{K_{it-1}} = \frac{K_{it}}{K_{it-1}} - (1 - \delta) = \left(\frac{p^{17\%}(1 - \beta(1 - \delta))}{p^{17\%} - \beta(1 - \delta)p^{0\%}} \right)^{1/(1-\alpha)} e^{\rho(b_{it-1}-b_{it-2})} - 1 + \delta$$

* At period t , $p_t = p^{0\%}$ and $p_{t+1} = p^{0\%}$

$$\frac{I_{it}}{K_{it}} = \frac{K_{it+1}}{K_{it}} - (1 - \delta) = \left(\frac{p^{17\%} - \beta(1 - \delta)p^{0\%}}{p^{0\%}(1 - \beta(1 - \delta))} \right)^{1/(1-\alpha)} e^{\rho(b_{it}-b_{it-1})} - 1 + \delta$$

* At period $t + 1$, $p_{t+1} = p^{0\%}$ and $p_{t+2} = p^{0\%}$

$$\frac{I_{it+1}}{K_{it+1}} = \frac{K_{it+2}}{K_{it+1}} - (1 - \delta) = \left(\frac{p^{0\%}}{p^{0\%}} \right)^{1/(1-\alpha)} e^{\rho(b_{it+1}-b_{it})} - 1 + \delta$$

The DID estimate of the investment rate's response to ν is

$$\begin{aligned} \text{DID estimate} &= \mathbb{E} \left(\frac{I}{K} \mid \nu = 0\%, t \right) - \mathbb{E} \left(\frac{I}{K} \mid \nu = 17\%, t - 1 \right) \\ &\quad - \left[\mathbb{E} \left(\frac{I}{K} \mid \nu = 0\%, t \right) - \mathbb{E} \left(\frac{I}{K} \mid \nu = 0\%, t - 1 \right) \right] \end{aligned}$$

The term in the square brackets is 0 since the control group are at the same equilibrium pre and post reform. Hence

$$\begin{aligned} \text{DID estimate} &= \left(\frac{p^{17\%} - \beta(1 - \delta)p^{0\%}}{p^{0\%}(1 - \beta(1 - \delta))} \right)^{\frac{1}{1-\alpha}} \mathbb{E} (e^{\rho(b_{it}-b_{it-1})}) \\ &\quad - \left(\frac{p^{17\%}(1 - \beta(1 - \delta))}{p^{17\%} - \beta(1 - \delta)p^{0\%}} \right)^{\frac{1}{1-\alpha}} \mathbb{E} (e^{\rho(b_{it-1}-b_{it-2})}) \end{aligned}$$

Part III

Productivity Losses from Three Channels of USA Housing Boom in the early 2000s

1 Introduction

After the 1997 Asian financial crisis, many Asian countries started to raise USD denominated foreign reserve. As a result, a large amount of credit became available to USA households, many of which came in the form of sub-prime mortgages and led to the prolonged USA housing boom during the early 2000s. During the housing boom, the housing price growth rate ranges from the bottom 6.58% in 2000 to the peak 10.52% in 2005 according to the Federal Housing Finance Agency (The comparison of housing price growth and GDP growth is shown in Figure 9 below). In addition to the well known fact that the housing boom caused the 2007-2009 Great Recession, it might also caused misallocation of capital and labor in firms' production and generated an efficiency loss for the aggregate economy.

Xiong et al. (2017) documented three potential channels of productivity loss from housing boom in the Chinese housing market over the last decade. In addition to the traditional beneficial collateral channel, which provides credit to land holding firms' business and operation and stimulates firms' productivity growth, they proposed two additional channels: speculation channel and crowding out channel. For the speculation channel, it describes the hypothesis that the rate of return from investing in housing market is larger than that of investing in capital, R&D and other

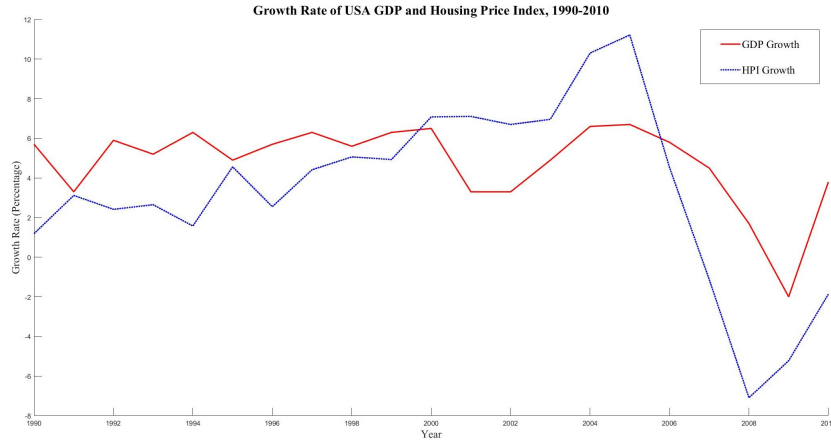


Figure 9: Growth Rate of USA GDP and Housing Price Index, 1990-2010

productive activities so that firms sacrifice normal productive investment and transfer the funds to speculate in the housing market. As a result, the speculation channel generates productivity loss. For the crowding out channel, it describes the hypothesis that banks and other financial institutions reduce financing to non-land holding firms and their investments. Because young firms such as start-ups usually do not hold land or properties and are mostly more productive than older firms, the crowding out channel therefore generates productivity loss as well. During the last decade, the average housing price has increased by about 400% in China. Hence firms have strong incentive to speculate in the housing market. Wei Xiong and this co-authors found all three proposed channels are significant during this period and overall there is significant productivity loss.

In the short paper, I use the same identification specifications of Xiong et al. (2017) and investigate the loquacity or silence of the three channels during the early 2000s USA housing boom. I find that the collateral channel was very significant as documented by Chaney, Sraer and Thesmar (2012) and Adelino, Schoar and Severino (2015). Specially I use compustat data to look at how changes of a firm's value of land and properties not related to its own business affect the firm's future capital in-

vestment, short and long term security investment and R&D investment. For the two other channels, I find both the speculation channel and the crowding out channel were silent. Specially I supplement the compustat data with Housing Price Index (HPI) data from the Federal Housing Finance Agency to look at how changes of regional HPI and whether a firm holds lands or properties affect its productive investment. Finally I run a reduced form regression of productivity loss on changes in HPI to look at the effect of the housing boom on productivity loss for US economy during the early 2000s. The productivity loss is measured by misallocation of capital as in Hsieh and Klenow (2009). To solve the potential endogeneity problem of changes in HPI, I apply the housing supply elasticity measure suggested by Saiz (2010) interacted with oil price index or national short term mortgage rate as in Chaney, Sraer and Thesmar (2012) to instrument for the changes in HPI. By running this instrumented regression, I find the housing boom had a overall positive effect on productivity growth over the early 2000s, which means the collateral channel dominates the other two negative channels in the US economy over this period.

The paper is organized as follows. Section I gives a general introduction. Section II describes the data. Section III describes the identification methodology. Section IV presents the empirical results. Section V describes the aggregate effect of the housing boom on capital misallocation and section VI concludes.

2 Data

My data for different categories of firm investment and value of a firm's land or property are drawn from Compustat. Compustat is a database of financial, statistical and market information on active and inactive global companies throughout the world. I use the data from Compustat North America -Fundamental Annual and look at US firms only. The sample ranges from 1998 to 2007 and encompasses 9382 firms.

Because compustat report the location of the headquarter of each firm only and many manufacturing firms have their plants and factories in other Metropolitan Statistical Areas (MSA) from their headquarters, I exclude tradable sectors as in Mian and Sufi (2014) from my sample to make all identifications local to each MSA. Land and property value of a firm that is not related to its own business is reported in Compustat but there is not a land and property investment variable in Compustat. To construct this variable, I use the fact that change of land and property value of a firm at a given year has two components: change of value of existing land and property and purchase of new land and property. Hence I subtract the land and property value of a firm at year $t - 1$ multiplied by housing price index growth from $t - 1$ to t from the land and property value of the same firm at year t as the land and property investment of the firm at year t . In formula it is $LandInvestment_t = LandValue_t - LandValue_{t-1} \cdot \frac{HPI_t}{HPI_{t-1}}$.

Table 9 lists summary statistics of main variables from compustat used in my analysis.

Table 9: Sample Summary Statistics (All Quantities in Logs)

Variable	# of Obs	Mean	Std. Dev.	p10	p50	p90
Security Investment	22080	2.56	2.82	-0.90	2.56	6.03
Capital Investment	35854	1.91	2.95	-2.01	2.04	5.60
R&D Investment	4896	1.13	2.30	-1.73	1.10	3.95
Land & Property Value	8272	1.78	2.44	-1.35	1.79	4.88
Tobin's Q	23956	8.87	27.25	0.48	2.69	15.05
Cash Holding	44955	2.24	2.75	-1.25	2.44	5.41
Total Sales	44920	4.92	2.66	1.76	5.01	8.16
Total Assets	30906	3.75	2.81	0.06	4.10	6.99

The Housing Price Index (HPI) data is from the Federal Housing Finance Agency and is available at MSA level and at quarterly frequency. To construct HPI at annual frequency, I compute simple average of HPI for each year at each MSA. The Housing Supply Elasticity (HSE) is drawn from Saiz (2010). The HSE measures the flexibility

of new housing construction in response to rising housing demand based on geographic characteristics and is available at MSA level. For MSAs on plains, when housing demand rises, new houses are built in suburbs of cities in response to the rising demand and the local housing price rises moderately. For MSAs on hills or mountains, it is hard to build new houses in response to the rising housing demand and as a result the local housing price rises sharply. The firm data from Compustat is panel data and the HSE is available at the cross section only since it is constructed using geographic characteristics. To generate time variation, I interact the HSE with aggregate shock to the US economy using either oil price index or national short term mortgage rate as in Chaney, Sraer and Thesmar (2012). The national short term mortgage rate is from the Federal Reserve Economic Data (FRED). The interacted variables are used as instruments for changes in HPI. Since the instruments are based on geographic characteristics, they are not correlated to other shocks in the residue of the regression and should serve as good instruments.

3 Empirical Methodology

This section introduces the identification methodologies I use in measuring the effects of the three channels (Collateral, Speculation and Crowding Out) of housing boom on US economy during the early 2000s. I follow the methodologies used in Xiong et al. (2017) and focus on the effect of the housing boom on different categories of investments taken by firms. Specially for the collateral channel, I look at when the land value of a firm increases, whether the firm invests more on capital investment, R&D investment or land and property investment, given a set of control variables. For the speculation channel, I look at when the local housing price index increases, how a firm adjusts its capital, R&D and land and property investments, given the presence of land and property value change and other controls. For the crowding out

channel, I look at when a firm does not hold land or property, whether the firm will reduce its capital and R&D investment due to this factor. In what follows, I describe the three channels respectively in detail.

3.1 Collateral Channel

For the collateral channel, I follow the identification strategy used in Chaney, Sraer and Thesmar (2012) and use the following regression specification:

$$\log(I_{i,t}) = \alpha + \beta \log(LandValue_{i,t-1}) + \theta X_{it} + u_i + \delta_t + \epsilon_{it} \quad (13)$$

Here the subscript i denotes firm and t denotes year. The dependent variable is the log of firm i 's investment. I test this specification using short and long term security investment, capital investment and research and development investment respectively. On the right hand side, $\log(LandValue_{i,t-1})$ denotes the log land and property value of firm i at year $t - 1$ that is not related to the firm's main business. X_{it} is a set of control variables that consist of a firm's Tobin's Q (market value/total asset), cash flow, total sales and total assets. u_i is firm level fixed effect and δ_t is year level time fixed effect. In this specification, β is the parameter of interest and measures given 1% increase of firm's land and property value from last year, how much % will firm increase (decrease) its investment in security market, capital and research and development. The hypothesis of the collateral channel says $\beta > 0$ in our specification and we will see in the next empirical result section that indeed the collateral channel was very significant during the early 2000s period.

3.2 Speculation and Crowding Out Channels

For the speculation and crowding out channel, I follow the identification strategy

used in Xiong et al. (2017) and use the following regression specification:

$$\begin{aligned}
I_{i,t} = & \alpha + \gamma\Delta HPI_{msa,t} + \beta\log(LandValue_{i,t-1}) + \eta\log(LandValue_{i,t-1}) \times \Delta HPI_{msa,t} \\
& + \kappa_0 1(non - owner) + \kappa_1 1(non - owner) \times \Delta HPI_{msa,t} + \theta X_{it} + u_i + \delta_t + \epsilon_{it}
\end{aligned}
\tag{14}$$

Again the subscript i denotes firm and t denotes year. In addition to the variables in equation (1) for the collateral channel, here I introduce two new variables: $\Delta HPI_{msa,t}$ and $1(non - owner)$. $\Delta HPI_{msa,t}$ is the change of housing price index from year $t-1$ to year t at the MSA where the firm i locates. $1(non - owner)$ is an indicator variable that equals 1 if firm i does not hold any land or property not related to its main business. In this specification, $\log(LandValue_{i,t-1})$ is included in the regressors to represent the availability of financing and the collateral channel. After including $\log(LandValue_{i,t-1})$, the coefficient η in front of $\log(LandValue_{i,t-1}) \times \Delta HPI_{msa,t}$ should measure the net effect of the speculation channel. According to the speculation channel hypothesis, we would expect $\eta < 0$ for security and capital investment and $\eta > 0$ for land and property investment. In addition, After including $\log(LandValue_{i,t-1})$, the coefficient κ_1 in front of $1(non - owner) \times \Delta HPI_{msa,t}$ should measure the net effect of the crowding out channel. According to the crowding out channel hypothesis, we would expect $\kappa_1 < 0$ for all categories of investment.

4 Empirical Result

This section presents the empirical results using the methodologies described in the last section. I present the results for testing of collateral channel firstly and the results for the testing of speculation and crowding out channels follows.

4.1 Collateral Channel

Table 10 presents the results for regression (1) for short and long term security investment, capital investment and R&D investment respectively.

Table 10: The Collateral Channel on Firm Investment

Investment (in logs)	(1) Security	(2) Capital	(3) R&D
$\log(Land\ Value_{i,t-1})$	0.0615*** (2.71)	0.231*** (28.61)	-0.202*** (-5.15)
Tobin's Q	0.00496 (0.60)	0.0241*** (12.62)	0.0661*** (4.46)
$\log(Cash\ Flow)$	-0.0734** (-1.98)	0.147*** (13.42)	0.0795* (1.72)
$\log(Total\ Sale)$	-0.521*** (-10.94)	0.596*** (30.37)	-0.213*** (-2.93)
$\log(Total\ Asset)$	1.443*** (23.65)	0.0835*** (3.81)	1.168*** (12.30)
N	1993	5856	679
R^2	0.575	0.800	0.754
F	367.1	3657.6	223.1

t statistics in parentheses

We see the collateral channel was very significant for all categories of firm investment. Through column 1 to 3, the results say after controlling for Tobin's Q , cash flow, total sales, total assets and two fixed effects, 1% increase in a firm's land and property value from last year will increase the firm's short and long term security investment by 0.0615%, will increase the firm's capital investment by 0.231% and will decrease the firm's R&D investment by 0.202%. It is consistent with our expectation that increase in the land and property value of a firm will loosen the firm's financial constraint and contribute to its security and capital investment. However, we see the regression coefficient of land and property value on R&D investment is negative. A possible explanation is that R&D investment takes relatively long time to realize return, when the land and property value of a firm increases, myopic managers may

use newly available credit and even reduce R&D investment to increase capital investment to enlarge short term production scale and achieve larger output. We will see this more clearly in the next subsection when we introduce speculation and crowding out channels explicitly.

4.2 Speculation and Crowding Out Channel

Table 11 presents the results for regression (2) for short and long term security investment, capital investment and land and property investment respectively. The variable land and property investment is constructed using the method described in the data section.

We see from Table 11 (next page) that the collateral channel was still very significant for all categories of firm investment after including the speculation channel and the crowding out channel. However, in this regression specification, our focus are the coefficient η and κ_1 in equation (2). We should expect $\eta < 0$ for column (1) and (2) and $\eta > 0$ for column (3). We see this is not the case in the data because the speculation channel was silent during the early 2000s: η was not significant through column (1) to (3). We should also expect $\kappa_1 < 0$ if the crowding out channel is active. From the data, we see the crowding out channel was not significant as well. If a firm does not hold any land or property, its capital investment will decrease by around 1% and its land investment will almost not change relative to a firm holding land or property and with all other characteristics the same. According to our hypothesis, the collateral channel loosens firms' financial constraints, stimulates capital investment and contributes to aggregate productivity growth. The crowding out channel generates misallocation of capital (directs capital to large and inefficient land and property holding firms) and harms aggregate productivity growth. The aggregate effect of the three channels is clear from my analysis that only the collateral channel was active during early 2000s. In the next section, I compute the aggregate TFP loss

and confirms its relation with the three channels combined.

Table 11: The Speculation and Crowding Out Channels on Firm Investment

Investment (in logs)	(1) Security	(2) Capital	(3) Land
$\Delta HPI_{i,t}$	-0.00617 (-0.65)	0.000858 (0.29)	0.0000147 (0.07)
$\log(LandValue_{i,t-1})$	0.0790** (2.01)	0.225*** (17.93)	-0.00269*** (-3.16)
$\log(LandValue_{i,t-1}) \times \Delta HPI_{i,t}$	0.000890 (0.37)	0.00107 (1.41)	-0.0000892* (-1.71)
<i>Non – Owner</i>	-0.592 (-1.00)	-0.281 (-1.49)	-0.0880*** (-7.09)
<i>Non – Owner</i> \times $\Delta HPI_{i,t}$	0.0335 (1.05)	-0.0108 (-0.83)	-0.000485 (-0.56)
Tobin’s <i>Q</i>	0.00228 (0.20)	0.0141*** (6.91)	0.000122 (0.88)
$\log(Cash\ Flow)$	-0.157*** (-3.02)	0.160*** (11.19)	0.00125 (1.28)
$\log(Total\ Sale)$	-0.375*** (-5.23)	0.566*** (20.79)	0.00539*** (3.00)
$\log(Total\ Asset)$	1.351*** (15.27)	0.0897*** (3.05)	-0.00192 (-0.98)
<i>N</i>	1140	3482	3495
<i>R</i> ²	0.554	0.801	0.0404
<i>F</i>	88.98	1152.7	18.28

t statistics in parentheses

5 Resource Misallocation

This section presents the aggregate effect of the three channels of housing boom on the aggregate productivity loss during the early 2000s. The way I compute aggregate productivity loss follows from Heish and Klenow (2009). The data I use here is the same Compustat data I used in Section IV. Specially I compute the TFP loss at the MSA level by computing the weighted average of industry level TFP losses in each MSA. The weight is the total revenue of a industry in a MSA divided by the total

revenue of all industries in that MSA. Within each MSA, industry level TFP losses are computed using each firm’s total revenue, capital stock and labor employment. To study the aggregate effect of the three channels of housing boom on aggregate productivity loss, I specify the following regression as in Xiong et al. (2017).

$$TFPLoss_{msa,t} = \alpha + \beta \Delta HPI_{msa,t} + u_{msa} + \delta_t + \epsilon_{it} \quad (15)$$

In equation (3), $TFPLoss_{msa,t}$ is the TFP loss computed at MSA level. $\Delta HPI_{msa,t}$ is the change of housing price index of MSA i at year t . u_{msa} is MSA fixed effect and δ_t is year fixed effect. In this specification, because the dependent variable is TFP loss, if the beneficial collateral channel dominates, we should expect $\beta < 0$ and if the other two harmful channels dominates, we should expect $\beta > 0$. We will see below the simple regression of equation (3) says $\beta > 0$ and the speculation and crowding out channels dominate the collateral channel. However, there is endogeneity problem with $\Delta HPI_{msa,t}$. $\Delta HPI_{msa,t}$ may be correlated with unobserved shocks to TFP loss and the estimation might be biased. To attack this endogeneity problem, I draw the housing supply elasticity (HSE) in Saiz (2010) as an instrument for $\Delta HPI_{msa,t}$. The variable $\Delta HPI_{msa,t}$ is available in panel form but the HSE is available at the cross section only since it is constructed using geographic characteristics. To generate time variation, I interact the HSE with aggregate shock to the US economy using either oil price index or national short term mortgage rate as in Chaney, Sraer and Thesmar (2012). As I explained in the data section, these interacted variables should serve as good instruments to $\Delta HPI_{msa,t}$. Table IV lists the results of the simple regression of equation (3) and the two instrumented versions using the two instruments: HSE \times Oil Price Index and HSE \times Mortgage Rate.

From Table 12 we see the simple regression of equation (3) says $\beta > 0$ and the speculation and crowding out channels dominate the collateral channel. However,

Table 12: Aggregate Productivity Loss from Three Channels of Housing Boom

	(1)	(2)	(3)
	TFP Loss	TFP Loss	TFP Loss
$\Delta HPI_{i,t}$	0.0977*** (12.68)		
HSE \times Oil Price		-0.384*** (-2.65)	
HSE \times Mortgage Rate			-0.278*** (-5.98)
N	6219	6219	6219
R^2	0.884	0.810	0.839
F	160.8	7.042	35.77

t statistics in parentheses

using the IV estimation, we see the result is reversed and the two IV estimation gives similar estimates that $\beta > 0$ and the collateral channel dominates the speculation and crowding out channels. Therefore, the USA housing boom during the early 2000s contributes to productivity growth at the aggregate level.

6 Conclusion

In this short paper, I use Compustat data and housing price index data to study the effects of the three channels of housing boom proposed by Xiong et al. (2017) on the USA economy over the early 2000s period. I find the traditional collateral channel was very significant during this period as documented by the literature. The speculation channel and the crowding out channel were silent. At the aggregate level, using the IV estimation backed by the housing supply elasticity in Saiz (2010), I find the housing boom had a positive effect on productivity growth and the collateral channel dominates the speculation channel and the crowding out channel. This is consistent with my expectation. Xiong et al. (2017) finds a negative effect of housing boom on productivity growth in China over the last decade. This is because the rate

of return in the housing market has been so large (2 to 3 times of GDP growth rate and quantitatively ranges from 17% to 30%) that the speculation channel dominates the collateral channel. In USA, the housing market return at the maximum was about 10% only in 2005 and was not very different from GDP growth rate. As a result, the speculation channel was silent during the early 2000s and overall the housing boom had a positive effect on productivity growth.

Part IV

Labor Market Frictions and Productivity Losses in Portugal

1 Introduction

Over the past 25 years, Portugal has gone through a boom, a slump, a sudden stop and now a slow recovery. Among the four south European countries: Spain, Portugal, Italy and Greece, Portugal has had the worst economic performance to date. A natural question is what is driving the poor performance of the Portuguese economy over the years, compared to other south European countries?

Reis (2013) argues that it was credit and capital misallocation that caused the 2000-2007 Portuguese slump: productive firms were collateral constrained, could not borrow and expand. Unproductive firms had access to bank credit and expanded. Productivity distribution became more dispersed and aggregate total factor productivity declined. Using firm level data from the Portuguese statistics institute, Dias et al (2016) confirmed Reis (2013)'s argument that capital misallocation was the most important factor of productivity losses in Portugal in the lead up to the Eurozone crisis. In this article, I focus on the period of the Portuguese economy after the slump (2008–2017): the sudden stop and the slow recovery period, mainly due to data availability. Using the framework of Hsieh and Klenow (2009), I document the fact that labor market misallocations (dispersion in MRPL) have become increasingly important to the severity of resource misallocation (dispersion in TFPR) in Portugal after the slump. The Portuguese economy has many size dependent labor market laws that favor small and medium sized firms, five of which were enacted during the 2012-2013

sudden stop years. In later sections of the article, I try to identify the sources of labor market frictions in Portugal. Specially, I implement difference in difference study and construct measure of labor market friction using the gap between average labor cost between small and large firms within the same NACE 4-digit industry to address the effect of the new size dependent labor market laws on labor market misallocation and reallocation. I find the new size dependent labor market laws can reduce unemployment temporarily but exacerbated within industry labor misallocation.

1.1 Relation to Literature

Blanchard (2007) was one of the early articles which document the poor economic performance of Portugal. Blanchard examined various policy choices, from reforms increasing productivity growth, to coordinated decreases in nominal wages, and the use of fiscal policy to alleviate the Portuguese situation. Reis (2013) proposes “financial intergration does not lead to financial deepening” might be the culprit of Portuguese slump. He proposed an open economy two sector model, where most of the inefficiencies come from the misallocation within the non-tradable sectors. However, due to lack of micro level data analysis, to what extent this Portuguese slump can be explained by the so called “financial intergration does not lead to financial deepening” channel was unsettled. Dias et al. (2016) fill this gap by looking at the Portuguese firm level data from 1996–2011 and shows that capital misallocation was important to explain the productivity loss in the lead up to the crisis for Portugal. Service sectors’ capital misallocation was especially severe.

In a companion paper García-Santana et al. (2016), the authors documented the growth in Spain was mainly driven by factor accumulation rather than productivity growth. Within industry input misallocation was the main reason why the productivity growth has been slow in Spain during 1995–2007. Gopinath et al. (2017) uses Amadeus data as well, documents increase in the dispersion of MRPK and MRPL for

south European countries but not for north European countries and uses a size dependent financial constraint to explain the patterns. However, Gopinath et al. (2017) lacks quasi-experimental study providing evidence of its causal channel. Blattner et al. (2019) fills this gap. Using loan level data from Banco de Portugal, the authors shows that credit reallocation could lead to a reallocation of production factors across firms. Its partial equilibrium exercise suggests that the resulting increase in factor misallocation accounts for 20% of the decline in productivity in Portugal in 2012. Finally Castillo-Martinez (2018) shows that entry and exit was important to understand the productivities dynamics during the recent sudden stops experienced by the south European countries. To date, there has not been work addressing the role of labor market frictions on productivity loss in south Europe. This project explores this area and strives to contribute to the understanding of productivity loss in south Europe.

2 Data

My data come from the European subset of the ORBIS database, the Amadeus data set, which contains financials, stock prices, ownership and subsidiaries information for European firms. The advantage of Amadeus data set is that it covers small and medium sized private firms, in contrast to the US Compustat or Compustat global database which contains publicly listed firms only. In the Portuguese subsample I study, 99.87% of the firms are private firms. Amadeus also has good data coverage. Kalemli-Ozcan (2015) shows the Amadeus coverage of manufacturing activities in Portugal accounts for 96-97% of the total manufacturing activities in Portugal since 2006 measured by Eurostat.

The literature on resource misallocation in south Europe (e.g. Gopinath et al. (2017)) has mainly focused on manufacturing sectors due to less challenges related

to production function estimation. Because manufacturing output accounts for only about 20% of the total output in the Portuguese economy over the last 20 years and as Dias et al. (2016) shows, resource misallocation is more severe in service sectors in Portugal, at the cross section, my study covers tradable sectors, non-tradable sectors and construction sectors defined by Mian and Sufi (2014) and analyze each of the three broad categories separately. Tradable sectors consists of agriculture, mining and manufacturing sectors (NACE revision 2 code 01-33). Non-tradable sectors consists of wholesale, retail, accommodation and food service sectors (NACE revision 2 code 45, 47, 55, 56). Construction sectors consists of NACE revision 2 code 41-43 sectors. All sectors combined accounts for about 40-45% of total Portuguese output over the years I study. The coverage statistics are conservative because I drop observations with missing, zero or negative values for gross output, the wage bill, capital stock and material cost, which are the variables necessary for computing productivity at the firm level. Table 13 summarizes the share of economic activity belonging to the three broadly defined industry categories relative to the total Portuguese economy in 2017.

Table 13: Share of Economic Activity by Industry Category (2017)

	Employment	Wage Bill	Gross Output
Tradable	0.23	0.22	0.21
Non-Tradable	0.18	0.12	0.12
Construction	0.08	0.07	0.04

In terms of time span, my sample ranges from 2006 – 2017. Due to the fact that Amadeus retains firm financial information for a rolling period of 8 years, the coverage for firms in 2006 and 2007 is poor and I neglect these observations in many of the later analysis.

Amadeus database categories firms into four categories: small, medium, large and very large based on operating revenue, total assets and number of employees. In terms of the number of employees, the size definition is small (1–14), medium (15 – 149),

large (150-1000) and very large (more than 1000)¹. Table 14 summarizes the share of economic activity accounted for by firms belonging in the size category defined by Amadeus in 2017.

Table 14: Share of Economic Activity by Size Category (2017)

	Employment	Wage Bill	Gross Output
Small	0.32	0.25	0.19
Medium	0.45	0.46	0.41
Large	0.19	0.25	0.32
Very Large	0.04	0.04	0.08

The sample is mainly composed of small and medium sized firms. We see in 2017 the small and medium sized firms combined account for 77% of total employment, 71% of the wage bill and 50% of the operating revenue.

3 Empirical Analysis

In this section, I employ the framework developed by Hsieh and Klenow (2009) to show that labor market frictions and misallocation are important to understand the poor performance of the Portuguese economy.

In Hsieh and Klenow (2009) framework, final output $Y = \prod_s Y_s^{\theta_s}$, where industry s output Y_{st} is given by $Y_{st} = \left(\sum_i (y_{ist})^{\epsilon/(\epsilon-1)} \right)^{1-\epsilon}$. y_{ist} denotes individual firm i 's real output at time t and ϵ denotes the elasticity of substitution between varieties. Individual firm's production technology is assumed to follow Cobb-Douglas form: $y_{ist} = A_{ist} k_{ist}^{\alpha_s} l_{ist}^{1-\alpha_s}$, where α_s is the elasticity of output with respect to capital in

¹The category standard is listed at <https://wrds-www.wharton.upenn.edu/pages/support/support-articles/bvd/amadeus-company-size-categories/#detail>

industry s . MRPK, MRPL and TFPR in this framework are defined as:

$$MRPK_{ist} = \alpha_s \left(\frac{\epsilon - 1}{\epsilon} \right) \left(\frac{p_{ist} y_{ist}}{k_{ist}} \right) \quad (16)$$

$$MRPL_{ist} = (1 - \alpha_s) \left(\frac{\epsilon - 1}{\epsilon} \right) \left(\frac{p_{ist} y_{ist}}{l_{ist}} \right) \quad (17)$$

$$TFPR_{ist} \equiv p_{ist} A_{ist} = \frac{p_{ist} y_{ist}}{k_{ist}^{\alpha_s} l_{ist}^{1-\alpha_s}} = \frac{\epsilon}{\epsilon - 1} \left(\frac{MRPK_{ist}}{\alpha_s} \right)^{\alpha_s} \left(\frac{MRPL_{ist}}{1 - \alpha_s} \right)^{1-\alpha_s} \quad (18)$$

Efficient allocations are marked by equalized MRPK and MRPL and hence equalized TFPR. The more dispersed TFPR is, the less efficient the industry. To measure the impact of MRPK and MRPL dispersions on the dispersion of TFPR, we need estimates of TFPR and the elasticities of value added with respect to inputs, which I now turn to.

3.1 Production Function Estimation

To estimate firm level productivity and the elasticities of value added with respect to inputs, I use the two-step generalized method of moments (GMM) implementation of Levinsohn and Petrin (2003) developed in Wooldridge (2009). I allow the elasticities of value added with respect to inputs to vary at the NACE 3-digit industry level. Specially for each NACE 3 digit industry, I estimate

$$\log(y_{ist}) = \alpha + \beta_t(s) + \beta_l(s) \log(l_{ist}) + \beta_k(s) \log(k_{ist}) + \epsilon_{ist}$$

where i denotes firm, s denotes the NACE 3-digit industry and t denotes time. $\beta_t(s)$ is time fixed effect for each industry. I measure firm nominal value added by $p_{ist} y_{ist}$, defined as the difference between operating revenue *opre* and material cost *mate*. y_{ist} is the real output, as nominal value added divided by an output price deflator. Given that firm level price is not observable, I use industry output price deflators from Eurostat at the two digit industry level. For industries that the

Eurostat output price deflators are not available, I deflate the nominal value added by the GDP price deflator. l_{ist} is the wage bill or the cost of labor inputs deflated by the same industry output price deflator. As is standard in the literature, I use the wage bill instead of employment to measure l_{ist} to control for differences in the quality of the workforce across firms. k_{ist} is the book value of fixed asset deflated by the price of investment goods. $\beta_l(s)$ is the elasticity of value added with respect to labor and $\beta_k(s)$ is the elasticity of value added with respect to capital. Because firm level price is not observable, the productivity measure $\log(z_{ist}) = \log(y_{ist}) - \beta_l(s)\log(l_{ist}) + \beta_k(s)\log(k_{ist})$ is defined as revenue productivities or TFPR.

Below are the plots of the time series aggregates of NACE 4-digit industry TFPR, MRPK and MRPL dispersions. Each industry is given a time invariant weight equal to its average share in total value added. This is to make sure all my estimates reflect purely variation within four-digit industries over time. As we can see from the plots, the shape of TFPR dispersion resemble more to the shape of MRPL dispersion. I formalize this argument in the next section.

3.2 Sources of Labor Market Misallocation and Frictions

After establishing the importance of labor market frictions in explaining Portuguese economic performance, in this subsection I try to identify the sources of labor market frictions in Portugal.

Labor market size dependent laws might be the driver of increased MRPL dispersion after the outbreak of the 2009-2013 Portuguese sudden stop. In Portuguese economy, small and medium sized firms enjoy many government sponsored benefits that large firms don't have access. During the 2009-2013 sudden stop, five laws granting less labor cost for small and medium sized firms were passed. From the appendix B of Dias et al. (2016), I list two of the examples:

* Portaria 229/2012 (modified by Portaria 3-A/2013, Portaria 97/2013 and Por-

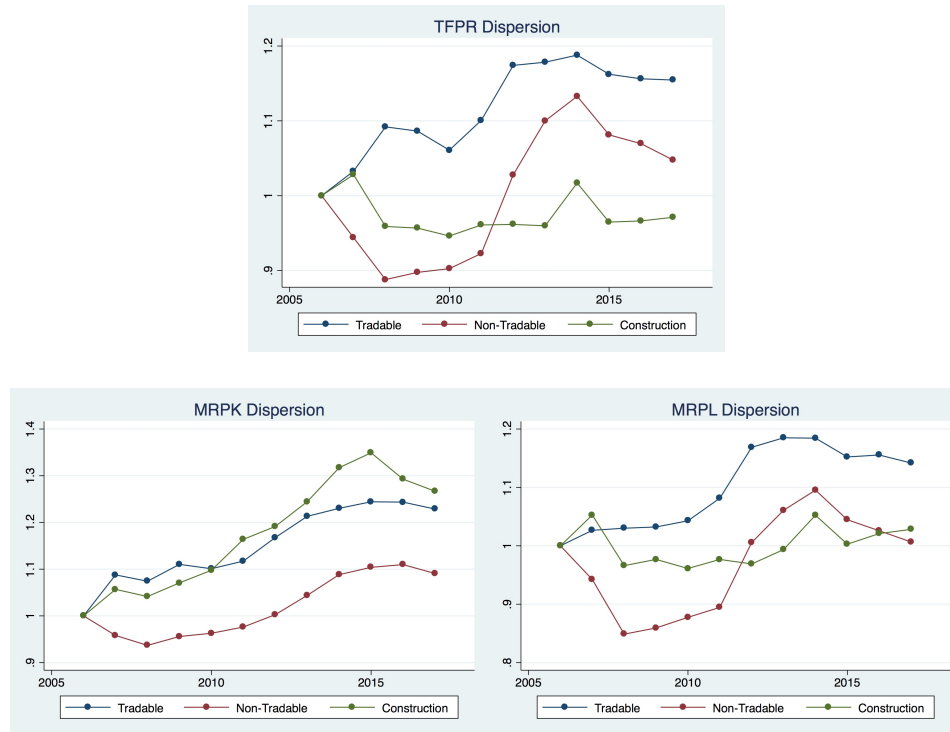


Figure 10: TFPR, MRPK and MRPL Dispersions

taria 106/2013): creates incentives for hiring unemployed workers (reduction of social contributions) up to a maximum of 20 workers (Art° 4), which benefits small and medium-sized firms in relative terms.

- * Portaria 106/2013 (modified by Portaria 149-A/2014): creates incentives for hiring unemployed workers (reduction of social contributions) up to a maximum of 25 workers with temporary contracts (the number of workers with permanent contracts is unlimited) (Art° 3), which benefits small and medium-sized firms in relative terms.

3.3 Difference in Difference evaluation of size dependent labor market laws

Four out of the five laws were passed during 2012–2013, when the unemployment

rate reached historical high (2012 15.5% and 2013 16.2%). I argue these laws alleviated unemployment temporarily but reduced labor reallocation and exacerbated labor misallocation. Inspired by the study of minimum wage law on employment by Card and Krueger (1994), I implement a difference in difference regression to study the effect of these laws on MRPL, MRPK and TFPR in NACE 4-digit industries for small and large firms. Specially the treatment group are small and medium sized firms defined by Amadeus because they benefit from the labor market laws and the control group are large and very large firms defined by Amadeus. To implement DID regression, I estimate

$$Y_{it} = \beta_0 + \beta_1 1(\text{Small or Medium}) \times 1(\text{Year} \geq 2013) + \alpha_i + \eta_{st} + \epsilon_{it} \quad (19)$$

where Y_{it} is takes the form of MRPL, MRPK or TFPR of firm i in year t , $1(\text{Small or Medium})$ is an indicator for small and medium sized groups and $1(\text{Year} \geq 2013)$ is an indicator for the years after 2013. α_i are firm fixed effects and η_{st} are NACE 2-digit industry year fixed effects. The results are summarized in Table 15.

Table 15: Difference in Difference

	MRPL	MRPK	TFPR
$1(\text{Small or Medium}) \times 1(\text{Year} \geq 2013)$	0.0122** (0.00461)	0.216*** (0.0117)	-0.0422*** (0.00379)
N	241255	241051	241051
Adjusted R^2	0.795	0.757	0.907

We see the difference in difference effect is positive and significant for both MRPL and MRPK, with the capital misallocation taking a more prominent role. In addition, we see productivity after the introduction of these labor market laws decreased by about 4.2%. This result strengthen my argument that the size dependent labor market laws exacerbated labor misallocation, although capital misallocation still played the major role.

3.4 Labor Reallocation and Misallocation

There is possibility that the difference in difference term is correlated with the error term, i.e. the parallel trend assumption is violated. To address the concern and to look at labor market frictions more directly, I use the ratio of the average labor cost (ACE) of small and medium sized firms to the average of the ACE of large firms within each NACE 4-digit industries as the measure of labor market friction, and test how the evolution of this measure affects the dispersion of MRPL and (Gross and Excess) labor reallocation over time. This is based on the observation that the wage rate should be equalized within a narrowly defined NACE 4-digit industry in a given year and the observation that the average cost of labor for small and medium sized firms are constantly smaller than those of large firms, which is documented in the figure below.

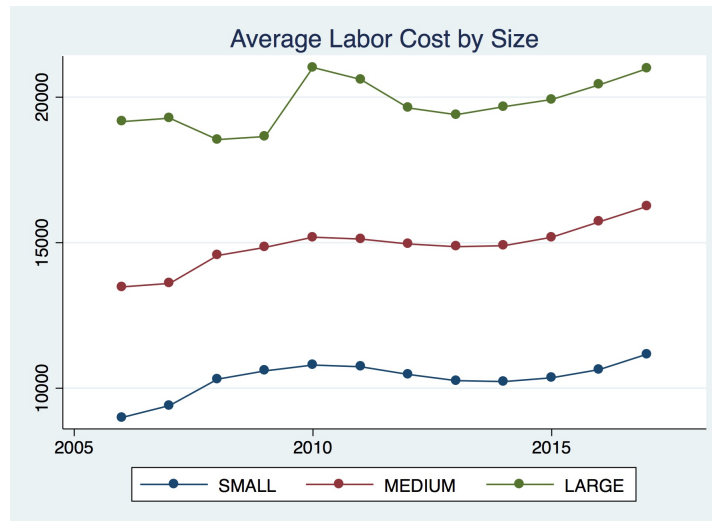


Figure 11: TFPR Distributions - Tradable and Non-Tradable Sectors

Specially, to construct the measure of labor market friction, I compute the ratio of the ACE of small firms to the average of the ACE of very large firms within each NACE 4-digit industry-year group. If there are no very large firms within a NACE 4-digit industry-year group, I use the average of the ACE of large firms instead. If

there are no large firms within a NACE 4-digit industry–year group, I use the average of the ACE of medium sized firms instead. To aggregate the firm level measure into NACE 4-digit industry level and draw inference with MRPL dispersion, I weight within industry ratios with its value added and call the aggregated labor friction measure as labor efficiency in equation (6).

Dispersion of MRPL within a NACE 4-digit industry continue to use the definition in section 3.2. To construct the measure of gorss labor reallocation, I follow the gorss labor reallocation definition by Davis, Haltiwanger, and Schuh (1996) as the sum of job creation and job destruction rate. To construct the measure of excess labor reallocation, I follow the excess labor reallocation definition by Eisfeldt and Rampini (2006) as the minimum of job creation and job destruction rate. Formally, I estimate

$$y_{st} = \beta_0 + \beta_1 \text{Labor Efficiency}_{st} + \gamma_s + \epsilon_{st} \quad (20)$$

where γ_s is industry fixed effect. y_{st} stands for dispersion of MRPL, gross labor reallocation and excess labor reallocation. The results are summarized in table 16.

Table 16: Misallocations and Reallocations

	Sd(MRPL)	Gross Labor Reallocation	Excess Reallocation
Labor Efficiency	-0.0487** (0.0211)	0.153*** (0.0185)	-0.0153*** (0.00251)
Cons	0.669*** (0.0170)	0.0551*** (0.0152)	0.0483*** (0.00207)
N	3122	3400	3376
Adjusted R^2	0.399	0.107	0.404

From Table 16, we see an increase in the labor efficiency, that is a decrease of wage gap between small and large firms will reduce TFPR dispersion, boost gorss labor reallocation and reduce excess labor reallocation. Reduction in MRPL dispersion and increase in gross labor reallocation signal more efficient labor market allocations. The

reason for negative coefficient for excess labor reallocation is probably as wage rates converge within an industry, workers have less incentive to deviate to high paying jobs and stay at their current positions.

4 Conclusion

In this study of Portuguese labor market and resource misallocations, I have documented the relative more important role of labor market frictions in explaining the resource misallocation and the productivity loss in Portugal for recent years than before the Great Recession and tried to identify several sources of labor market frictions.

Part V

Conclusion

My dissertation studies how firm investments respond to market frictions such as corporate taxation, housing booms and how productivities and misallocations evolve in the adjustment processes. In the first chapter, I ask what factors contributed to the heterogeneous investment behavior of small and large firms in China's 2009 Value Added Tax (VAT) reform. I find it is the investment adjustment costs induced higher marginal benefit of investing, rather than financial frictions that caused small firms to invest more.

In the second chapter of my dissertation, I study how the three channels of housing boom: the collateral, the speculation and the crowding out channels affected US manufacturing firms' investment and misallocation over the early 2000s period. I find the collateral channel was active while the other two channels were silent. At the aggregate level, the housing boom had a positive effect on productivity growth.

In the last chapter of my dissertation studies how labor market frictions in Portugal contributed to its productivity slowdown and misallocation. I find the size-dependent labor market laws reduced unemployment temporarily but exacerbated within industry labor misallocation in the long run.

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Biography

This is Xiaoyu (Elessar) Chen from the Department of Economics at Duke University. Before coming to Duke, I worked as a senior research specialist for one year with the Bendheim Center for Finance faculty at Princeton University.

My master's study was at Columbia University's financial mathematics program. I received my undergrad training at Central University of Finance and Economics in Beijing, China.