Firm Performance in Changing Economic Environments

Inaugural-Dissertation
zur Erlangung des Grades Doctor oeconomiae publicae
(Dr. oec. publ.)
an der Ludwig-Maximilians-Universität München

2020

vorgelegt von

Shuyao Yang

Referent: Prof. Gabriel Felbermayr, PhD

Korreferent: Prof. Dr. Oliver Falck

Promotionsabschlussberatung: 03. Februar 2021

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For my family

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Shuyao Yang, September 2020

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Preface

Firm performance, such as production capacity, growth potential and international activities, is crucial to each firm's success, as well as to economic growth and development. The economic environment, encompassing features of market frictions, trade policies and transport security, in turn, has an impact on the performance of firms. It is therefore of high relevance to gain a better knowledge of firm performance in the context of changing economic environments. A comprehensive understanding of firm performance is then helpful to boost firms' growth, facilitate policy-making and ultimately improve the overall welfare of society.

This dissertation, consisting of four chapters, contributes in diverse ways to a better understanding of firm performance in various economic settings. The common goal of all chapters is to investigate how firms adjust their performance in response to changes in an economic environment. Firm performance, such as production capacity or export activities, and changes in the economic environment, such as labor market frictions or trade reforms, are measured along different dimensions in each chapter. In particular, Chapter 1 explores the universe of firms in an industrialized country, Germany. Chapters 2 to 4 zoom in on internationally active firms in the largest developing and export-oriented country, China. The same firm-level customs data combined with data on trade policies or pirate attacks are used in Chapters 2 to 4 to conduct the empirical investigation. All chapters are self-contained (with their own introductions and appendices) and can be read independently. The bibliography is joint for all chapters at the end of the dissertation.

In a nutshell, Chapter 1, using a unique panel of German firms, investigates how firms adjust their policies on current production and future expansion in response to the shortage of labor supply. Moving from the universe of firms to productive ones involved in trade, Chapters 2 and 3 examine the effects of trade policies on Chinese firms' export performance. More specifically, Chapter 2 investigates the impact of non-tariff barriers on firms' trade

margins and pricing strategy. Chapter 3 studies the effects of partial VAT rebate policy on multi-product firms and their product scopes. Shifting the focus away from trade policies, Chapter 4 looks at the impact of maritime piracy on firms' choice of transport modes. Each chapter is briefly summarized as follows.

Chapter 1 investigates the impacts of manpower constraints on firms' contemporaneous and prospective policies. Manpower constraints refer to a pervasive lack of supply of high-skilled and low-skilled workers. Frictions in financial markets and labor markets are critical as they limit firms' ability to produce efficiently and maximize profits. However, unlike financial constraints, which have been intensively examined, manpower constraints are surprisingly largely understudied. One reason is that they are hard to detect. We overcome this obstacle by using unique panel data, in which we observe directly whether firms declare they face a shortage of specialized workers. The data contains 5,000 German firms, which constitute a representative sample of German businesses from 1980 to 2001.

Our baseline analysis exploits the relationship between manpower constraints and corporate policies. The policies are either contemporaneous ones, measured by firms' capacity utilization and backlog of orders, or prospective ones, measured by firms' hiring plans and investment plans. We find that manpower-constrained firms operate at higher capacity utilization, have a longer backlog of orders, and are more willing to invest in capital and employment in the short term. We confirm these results in an instrumental-variable strategy, which uses the variation in the yearly cumulative inflow of Eastern German immigrants across Western German states to instrument for the share of firms that are subject to manpower constraints in each Western state over time. Lastly, we construct a Manpower Constraint (MPC) Index calibrating the loadings on firm-level financials that are also available in commonly used data sets for US, European, and Asian firms. Our results in this chapter provide, to our best knowledge, the first evidence on manpower constraints and the performance of manpower-constrained firms, which help inform relevant debates such as the reform of immigration policies and the investment in public and private education for low-skilled workers.

Chapter 2 explores the impact of trade policy, the Technical Barriers to Trade (TBTs), on firms' export performance. Instead of looking at the universe of firms as in the previous chapter, I now focus on firms that are engaged in international trade. These firms are on average larger and more productive than pure domestic firms, and are important

contributors of a country's economic growth.[1] It is therefore important to dive deeper into the understanding of the performance of internationally active firms. Moreover, TBTs are key players in modern trade policies and are by far the most commonly used non-tariff measures (UNCTAD, 2013). Despite the widespread use of TBTs, their impact on trade remains ambiguous especially at the firm-level.

To fill this gap, Chapter 2 investigates the impact of restrictive TBTs on firms' extensive margins (firms' decisions to participate or exit a product-destination market), intensive margins (firms' export values on a product-destination combination) and pricing strategy, with a focus on the heterogeneous impacts across firms. For this purpose, firm-level data on Chinese exporters from China customs data and product-level data on TBT specific trade concerns from the WTO are merged at product-country-year level. To identify a causal relationship, an instrumental variable (IV) approach is utilized, which uses TBT concerns raised by any third country rather than China as instrument to predict Chinese firms' export decisions.

The IV estimation shows that, on average, the imposition of restrictive TBTs adversely affect firms' extensive margins (firms are deterred from export participation and forced to exit the TBT-imposed foreign market) and intensive margins (incumbent firms face a loss of export values), but not significantly affect firms' pricing strategy (incumbent firms on average do not adjust prices). By comparing to the IV results, I show that results using ordinary least squares (OLS) approach suffer from underestimation and endogeneity bias.

Moreover, a rich set of firm characteristics is exploited to test the theoretical prediction of heterogeneous impacts across firms. In line with the theories of heterogeneous firms, empirical findings confirm that firms of different types react to restrictive TBTs differently. More specifically, firms that are larger, have more trading partners or have a domestic ownership type can overcome the variable and fixed costs induced by restrictive TBTs, thereby staying in the foreign market and enjoying reduced competition. This findings implies inter-firm resource reallocation (Melitz, 2003). In addition, I find that multi-destination firms in developed countries react differently to ones in developing countries. It is more likely for multi-destination firms in France to exit the market under restrictive TBTs (Fontagné and Orefice, 2018). However, multi-destination firms in China are more willing to overcome the higher trade costs and stay in the market. I also find that firms' pricing strategies vary not only across different firm characteristics but also within the same ownership type. Given

[1] For example Melitz (2003); Helpman et al. (2004); Mayer and Ottaviano (2008); Bernard et al. (2011); Wagner (2012).

the same restrictive TBTs, large and multi-destination firms tend to pass-through part of the increased cost to the final consumers by charging a higher price, whereas domestic-owned firms tend to reduce price by less than cost. By dividing domestic-owned firms into state-owned and private-owned ones, I find that the price-decreasing effect is mainly driven by state-owned rather than private firms. This chapter contributes to the large literature on firm heterogeneity and the role of TBTs on trade. Policy makers should consider the heterogeneous effects of trade agreements across firms during trade negotiations to better enhance social welfare.

Chapter 3 explores the impact of another trade policy, the partial VAT rebate rate, on firms' export performance. Unlike other countries that fully refund VAT on exports, China implements an unusual VAT rebate policy, that is partially refunding VAT on exports. Such trade policy is intensively and frequently used as a trade-promoting tool in China. Despite the uncommon feature and extensive use of VAT rebates in China, evidence regarding the impact of partial VAT rebates on trade remains scarce. Especially the impact on multi-product exporters, who are the key players in international trade and the main contributors of a country's total export revenues, is thus far largely overlooked. To fill the gap, Chapter 3 explores the impact of partial VAT rebates on multi-product firms with heterogeneous product quality.

First theoretically, we present a model of VAT rebates in the context of multi-product exporters, in which the partial rebate of VAT acts as an export tax. The products within each firm are heterogeneous in both physical efficiency and quality. We show that the impact of VAT rebates is heterogeneous across products within multi-product exporters when the products face different elasticity of demand. Specifically, our model predicts that an increase in VAT rebate rate is associated with an increase in the export quantity (a decrease in the export price), and the effect increases (decreases) for products that are closer to a firm's core competence.

Second empirically, we collect detailed data on VAT rebate rate at 8-digit HS product level at a monthly basis, which is the most disaggregated data for the case of China, and combine it with firm-level export data for 2003-2006. To the best of our knowledge, we are the first using such highly disaggregated firm-level and product-level data to explore the performance of multi-product exporters under partial VAT rebates. During our sample period, the VAT rebates are likely to be exogenous as they are part of China's reform and development policy, and are adjusted by the government to modify the economic

structure and solve environmental problems. Nevertheless, a set of fixed effects and a series of robustness checks are conducted to control for our baseline results. We use product rank, an ordering of products based on their destination-specific export values, to differentiate the product quality within a firm.

The empirical findings are in line with our model's predictions. We find that products with better quality within a firm have higher resistance to unfavorable changes of VAT rebate rate. More specifically, our baseline analysis shows that, first, a one percentage point increase in VAT rebate rate is related to 1.1% increase in the export quantity, and the quantity increases more if the product has a better quality. Second, a one percentage point increase in VAT rebate rate is related to 0.75% decrease in the export price, and the price decreases less if the product has a better quality. Moreover, we find that the effects of VAT rebates differ across trade regimes and firm-level productivity. First, the positive effect of VAT rebates on the export quantity is smaller (larger) if the product is closer to the firm's core competence in ordinary (processing) trade. Second, the export price decreases with a rise of VAT rebate rate, and decreases less if the product has a better quality for the case of ordinary trade. Third, baseline patterns appear in both high-productive and low-productive firms, and the two groups do not behave significantly different from each other. This chapter informs the impact of trade policies on firms in China, and sheds light on the reallocation of resources across products within firms.

Chapter 4, shifting the focus away from trade policies, studies the impact of maritime piracy on firms' choice of transport modes. With 180 incidents in 2017 which lead to 166 crew members being taken hostage or kidnapped and three killed, maritime piracy remains a real threat to international merchant shipping (ICC IMB, 2018). Surprisingly, detailed evidence on its economic consequences remains scarce. Most studies are either descriptive or focus on a specific region (Endler et al., 2012), with only two exceptions who study the effects of piracy on transport cost (Bensassi and Martínez-Zarzoso, 2013) or on overall trade (Bensassi and Martínez-Zarzoso, 2012). However, both papers focus on trade between Europe and Asia.

This Chapter extends the scope by considering the universe of Chinese exports to all destination countries to empirically investigate the effects of piracy on firms' export performance. To this end, firm-level Chinese customs data and data on the number of pirate attacks are combined by considering all possible ocean routes between China and the continent to which the destination country belongs. The findings show that, in line with the

literature, pirate activity on a certain trade route induces firms to change transportation mode, shipping some of their goods by plane rather than by ship. The remaining average shipments per firm, however, become larger and average producer prices fall, indicating that exporters absorb parts of the costs. Despite these compensating activities, overall exports from China decline on routes affected by piracy, indicating a dampening impact on trade.

Overall, Chapter 1 uncovers that manpower-constrained firms are more efficient. They operate at higher capacity, have higher backlog of order at current state, and seek for expansions in capital expenditure and employment base in the future. Chapter 2 finds that firms are adversely affected by restrictive TBTs. They are deterred from export participation, induced to exit the foreign market, and facing a loss of export value. However, such negative effects are mitigated for high-productive firms, indicating inter-firm resource reallocation. Chapter 3 discovers that firms skew their export towards their "core" products when facing a partial VAT rebate rate, indicating intra-firm resource reallocation. Chapter 4 finds that firms tend to change their transport modes under the threat of maritime piracy. This dissertation contributes to the empirical literature studying firm performance in changing economic environments and provides insight into factors that affect firm growth. Beyond that, this dissertation aims to enable better-informed and welfare-enhancing policy decisions.

Chapter 1

Manpower Constraints and Corporate Policies*

1.1 Introduction

Frictions in financial markets and labor markets limit firms' ability to invest, produce, and ultimately maximize profits. Manpower constraints—the pervasive lack of high-skilled and low-skilled specialized workers, irrespective of the wages firms might offer—are an important friction whose effects have been largely understudied because they are hard to detect. Any allocation of specialized workers across firms could be an unconstrained or constrained equilibrium in the labor market.

Financial constraints face a similar detection and measurement problem, but can be relaxed more easily than manpower constraints. Money is fungible and can be redistributed across firms and space contrary to people and skills. Building up skills and training infrastructures takes time and skilled people cannot be moved easily where demand for them exists. Workers are surprisingly unwilling to respond to incentives to move (Moretti, 2012). Manpower constraints might therefore represent a large obstacle to firms' activities.[1]

*This chapter is based on joint work with Francesco D'Acunto and Michael Weber. We thank participants at AFA 2019 in Atlanta, ETSG 2017 in Florence, 2017 Annual Congress of the German Economic Association (Verein für Socialpolitik) in Vienna and ifo Lunchtime Seminar in Munich for comments and suggestions.

[1]Gatzer et al. (2014) provide survey evidence that lack of qualified manpower can be an impediment to "execute projects".

The supply of high-skilled and low-skilled specialized workers is also tied to heated policy debates. Immigration policies can restrict or enlarge the supply of specialized workers available in a country. Quotas on H-1B visa availability in the United States are a prime example of an immigration policy that shapes the supply of specialized workers. Moreover, training and education of specialized workers is a public good that firms can barely provide to workers, because workers can leave the firm at any time. The supply of public and private education programs, such as associate degrees, determines the quality of skills that workers build up before joining firms.

We study the effect of manpower constraints on corporate policies with unique data, in which we observe *directly* whether firms declare they face a shortage of specialized workers with the needed skills, and hence cannot hire specialized workers irrespective of the wage they would offer. The data is a proprietary semester-level panel of 5,000 German firms from 1980 to 2001, operating in manufacturing, construction, and trade. These firms constitute a representative sample of German businesses, to which the ifo Institute asked a large set of questions ranging from existing corporate policies and expectations about future economic conditions to expected changes in corporate policies.

In our baseline analysis, we exploit the cross-sectional variation in the likelihood that firms are manpower constrained at any point in time throughout our sample period. Manpower-constrained firms have higher capacity utilization, longer backlog of orders (measured in months), are more willing to increase their capital expenditures in the following year, and are more willing to grow their employment in the following year,[2] after partialling out semester, state, and industry fixed effects, as well as controlling directly for whether firms declare that they are subject to financial constraints. Financial constraints might be related to employment policies, and we need to disentangle the case in which a firm does not hire additional workers because of the lack of capital—a demand-side story—instead of the lack of workers available—our supply-side story.

Because this is the first paper that observes the incidence of manpower constraints, we investigate in detail the characteristics of manpower-constrained firms. In the median industry (*Wood Processing*), 17.6% of firms are manpower constrained at least once throughout our sample period. Large variation in the presence of manpower constraints exists across industries, and manpower constraints are more likely to occur in traditional manufacturing industries and wholesale trade than in specialized and high-tech industries. For instance,

[2]The survey asks firms about their employment policy regarding all employees, and not just specialized workers.

25.7% of the firms in *Printing and coping* are manpower-constrained, but only 7.5% of firms in *Chemical industry*. The incidence of manpower constraints also varies largely over time. In our sample, about 14% of firms were manpower constrained in 1980, 5% in 1985 and 2% in 1996.

Unobservables correlated with the likelihood a firm is manpower constrained might also explain the different corporate policies and performance of manpower-constrained firms compared to other firms. To address these endogeneity concerns, we exploit a natural experiment to obtain quasi-exogenous variation in the relaxation of German firms' manpower constraints. We consider the fall of the Berlin Wall in 1989 and the subsequent mass migrations of Eastern German workers into Western Germany (Fuchs-Schündeln and Schündeln, 2005). Eastern German workers were highly specialized in traditional manufacturing tasks, which is the expertise that manpower-constrained firms in our sample are looking for. Eastern Germans migrated into areas in which relatives and friends had settled before the Berlin Wall was built. The bombings during WWII affected the supply of housing in Germany which determined the settlement of such relatives and friends. Bombings during WWII therefore determined the spatial diffusion of Eastern German refugees during the 1950s and also of Eastern Germans escaping communism after the fall of the Berlin Wall (Burchardi and Hassan, 2013). Consistent with our interpretation of the natural experiment, the share of firms that declare they are manpower constrained decreased from 14% in 1990 to 9% in 1991, 3% in 1992, and stayed below or around 5% until the end of our sample, in 2001.

Our identification strategy is an instrumental-variable approach, which uses the variation in the yearly cumulative inflow of Eastern German immigrants across Western German states (*Bundesländer*) to instrument for the share of firms that are subject to manpower constraints in each Western state over time. We observe immigration fluxes at the state level, and hence to avoid unduly interpreting within-state firm-level observations as independent, we construct our instrument at the state level as opposed to the firm level.

The identifying assumption we make is that the extent of the influx of Eastern German workers after the fall of the Berlin Wall affected firms' policies only through the relaxation of their manpower constraints and not through other channels. The main threat to this exclusion restriction is the fact that the fall of the Berlin Wall created a new free market to which Western firms could supply a large range of products that previously did not exist in the East. The formal political and monetary reunification of Germany followed.

This threat is not relevant to our identification strategy, because *all* Western firms, in any state, were exposed to the opening of the new market to the same extent, whereas we exploit variation in the influx of Eastern immigrants across states. This point is the crucial reason why we do not design a difference-in-differences strategy based on the relaxation of manpower constraints within firms before and after 1989. If we did so, we would be unable to disentangle the effect of the fall of the Berlin Wall on manpower constraints from the effect of the opening of a new market for Western firms.

A related concern with our exclusion restriction might be that the increase in the local population after a large influx of Eastern workers also changed the size and characteristics of the local markets and demand within Western states. This was likely to affect firms in states with a larger influx of immigrants more than firms in other states. This concern is not relevant in our case because, if anything, a larger influx of immigrants would have increased the demand local firms had to satisfy, and hence would have increased their capacity utilization, backlog of orders, willingness to invest in capital expenditures, and of hiring additional workers in the following year even more. To the contrary, if the influx of immigrants relaxed manpower constraints, as our identification strategy assumes, local firms should have decreased their capacity utilization and backlog of orders, and could have finally invested in new machines that the additional workers could operate, hence reducing their willingness to invest in capital expenditures in the following year.

We show in the first stage that our instrument is relevant. In the second stage, we confirm the baseline positive effects of manpower constraints on capacity utilization, backlog of orders, willingness to invest, and willingness to grow employment. The magnitudes of the instrumental-variable estimates are similar to the magnitudes in the baseline analysis. This suggests that the endogeneity concerns when using the survey-based measure do not significantly bias the OLS estimates in one direction.

Observing the incidence of manpower constraints is not possible in commonly used data sets for US, European, and Asian firms. At the same time, progress in the detection and measurement of manpower constraints would allow deeper investigations into the effects of this type of labor-market constraints on firm- and industry-level outcomes, productivity, and ultimately economic growth. We therefore exploit the subsample of firms for which we observe balance-sheet financials to construct a *Manpower Constraint (MPC) Index*.

The logic of our MPC index is similar to the Kaplan-Zingales index for financial constraints. We use a logit specification to run predictive regressions of the likelihood that firms in our

sample declare they are manpower constrained onto their ages, general and administrative expenses (SG&A), trade accounts payable, trade accounts receivable, and inventories. Once we control for these five dimensions, we find other financials unrelated to the likelihood of manpower constraints. We then interpret the estimated coefficients on each of these variables as the loadings one can apply to different samples of firms to obtain a measure of the extent of manpower-constraints which firms face. Based on this procedure, we compute the MPC Index as follows:

$$MPC\ Index = 0.16 \times Age + 0.23 \times \frac{SG\&A}{Assets} - 0.26 \times \frac{A/P}{Assets} + 0.39 \times \frac{A/R}{Assets} + 0.40 \times \frac{Inventories}{Assets}.$$

We run a comparative analysis of manpower constraints and financial constraints (which we kept constant throughout the main analysis in the paper). We find that, as expected, the factors that predict manpower constraints are different from those that predict financial constraints.

Overall, our results investigate the effect of manpower constraints on corporate policies in a setting which allows us to observe the incidence of manpower constraints directly, and to obtain quasi-exogenous variation in the strictness of manpower constraints based on a natural experiment. We then construct an index, the MPC index, which is based on predicting the manpower-constrained status of firms with financials that are commonly available outside our setting. In this way, the MPC index can hopefully help future research investigate the effects of manpower constraints on other micro-level and macro-level outcomes.

This paper contributes to three strands of literature. First, it belongs to the research that tries to measure the extent and severity of external constraints on corporate decision-making. The problem of measuring financial constraints has produced a large literature in finance (Fazzari et al., 1988; Fazzari et al., 2000; Kaplan and Zingales, 1997; Kaplan and Zingales, 2000; Farre-Mensa and Ljungqvist, 2015). To the best of our knowledge, no paper has tackled the problem of providing proxies for firms' manpower constraints, likely because providing such measures would prove even tougher than for financial constraints. Any labor allocation across firms could be a constrained or unconstrained outcome of the labor market. Our paper contributes to this literature by providing a direct measure of manpower constraints based on firms' survey responses. In order to allow researchers using other data to proxy for the extent of manpower constraints of the firms they study, we

construct a Manpower-constraint (MPC) Index, based on the loadings of a dummy for being manpower constrained on firm-level balance-sheet financials.

To study the effect of financial constraints on firm-level outcomes overcoming the issue of measuring financial constraints, studies on financial frictions usually exploit quasi-exogenous variation in the relaxation of unmeasured financing constraints (e.g., see Jayaratne and Strahan (1996)). Most related to our paper is Chava et al. (2016), who exploit the staggered introduction of Right-to-Work laws across US states on corporate investment. This literature inspires our paper, which similarly documents the baseline effects of manpower constraints arising from inefficiencies in labor markets on corporate policies, and uses a source of quasi-exogenous variation in the relaxation of such friction for identification. Different from earlier work, we do observe directly in the data whether firms declare they face manpower constraints, and we do not need to proxy for constraints using observable information.

Second, this paper contributes to the strand of research that studies the effects of immigration policies on firm-level productivity and labor market equilibria (Borjas, 2014). Recent contribution to this large literature include Peri et al. (2015), who exploit H-1B visa lotteries to estimate the effects of inflows of specialized workers on city-level outcomes. Kerr et al. (2016) discuss the selection of specialized-worker inflows, and their effects on productivity and growth. Our paper uses quasi-exogenous variation in the immigration flows of specialized workers to study the effect of relaxing manpower constraints on corporate policies.

Third, the paper speaks to the literature on the effects of education policies on the quality of the workforce available to firms, both in the short and long term. Gennaioli et al. (2012) use a unique panel data set of regional characteristics worldwide to show that higher education is related to higher development across space, and that the role of the education of managers is particularly relevant to development. D'Acunto (2016) finds that the cross-sectional variation in basic education levels across European regions persisted for centuries, and that firms in regions with a more educated low-skilled workforce innovate and invest more than other regions. This paper shows that the availability of specialized low-skilled workers is a crucial yet neglected source of flexibility in firms' investment and growth plans.

The paper is organized as follows. Section 1.2 describes the data we use. Section 1.3 investigates the characteristics of manpower-constrained firms in detail and provides baseline

results. Section 1.4 discusses the identification strategy based on a natural experiment. Section 1.5 builds up the MPC index. Section 1.6 concludes the paper.

1.2 Data

Our data consist of a panel of German firms we observe from 1980 to 2001. The panel is a representative sample of German firms, which is surveyed each month by the ifo Institute, Munich (DE) under the *Business Expectations Panel* (BEP) project. The panel includes manufacturing, trade, and construction companies. The aim of the ifo Institute is to collect firm-level expectations regarding one-year firm-level policies as well as economy-wide variables, such as the unemployment rate and GDP growth. The ifo Institute uses this information to construct a monthly index of business sentiment in Germany called *ifo Business Climate Survey*, which is a leading macroeconomic indicator in Germany. Parts of the survey are used for the official German Business Sentiment index of the Directorate General for Economic and Financial Affairs of the European Commission. Consistent with ifo Institute's aims, researchers have mainly used the data to address questions in Macroeconomics (e.g., see Bachmann et al. (2013)). We merge information from the BEP with data from the *Business Investment Panel* (BIP), which asks a representative sample of German firms questions about their corporate policies and investment plans every six months. Additional details and characteristics of the data we use are described by Seiler (2012).

Although the ifo Institute has been running the survey continuously up to the present day, we do not use observations after 2001 when the survey stopped asking about manpower constraints. One drawback of the BEP is balance sheet variables are not collected for the vast majority of firms in the panel, because the aim of the ifo Institute is not to use data for research in finance or productivity. Instead, as mentioned above, the ifo Institute uses the survey information to construct a business sentiment index of German firms. Balance sheet variables and financials are only available for 9% of the sample. Therefore, in our baseline analysis, we do not control for financial dimensions, but we find all our results are robust for controlling for financials in the subsample of firms for which we observe them.

The unique question in the BEP we use in our analysis asks whether firms think they face manpower constraints. In the official English translation of the BEP questionnaire, question 3.2.29 is titled *"constraints: lack of manpower".*

The translated question reads as follows:

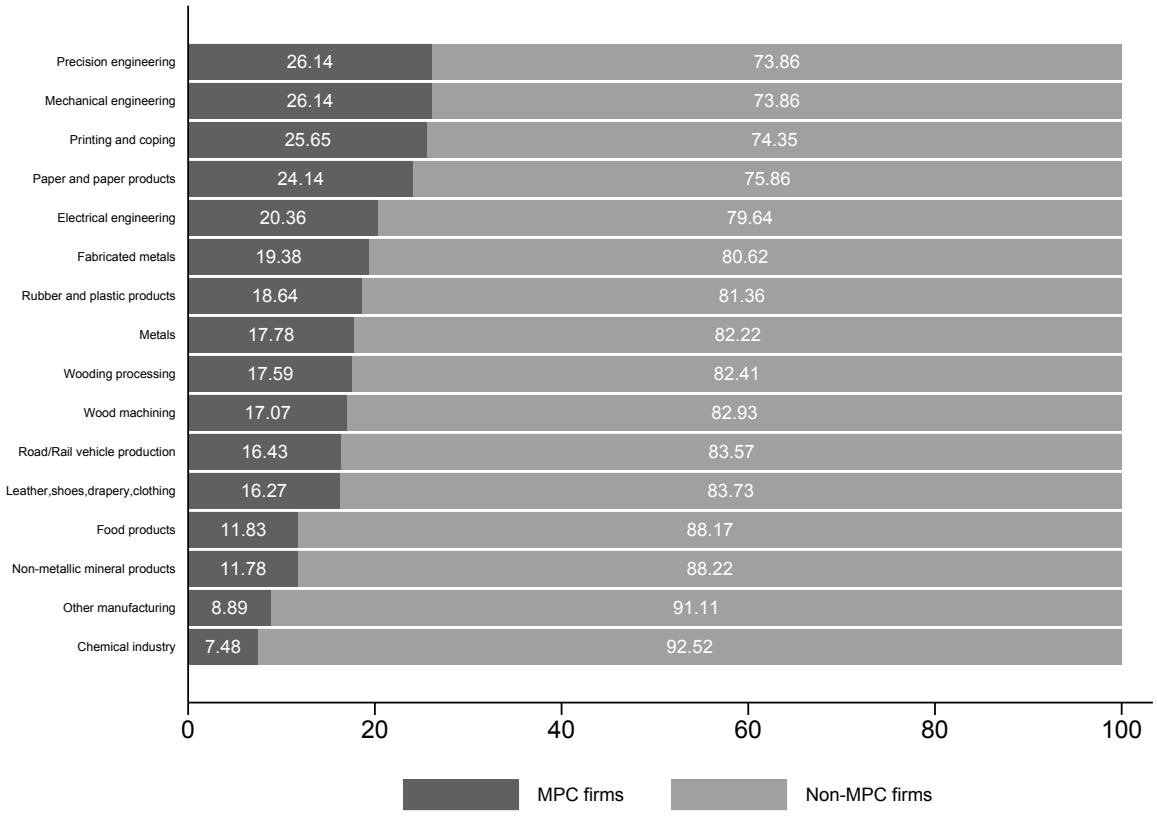
"Our domestic production activities are currently constrained by the lack of skilled labor."

In our analysis, we define a dummy variable that equals one if a firm in the panel responds "Yes" to the question above, and 0 otherwise.

Figure 1.1 describes the variation of manpower constraints across manufacturing subsectors. Note here we show important subsectors that have at least 1000 observations over the whole sample period. In the figure, we define manpower-constrained as a firm that declares they are manpower constrained at any point in time covered by the survey. Substantial heterogeneity in the incidence of manpower constraints exists across manufacturing subsectors. In the median industry, *Wood Processing*, 17.6% of firms declare they are manpower constrained at least once over the sample period. The share of manpower constraints is highest in the *Precision engineering* (26.1%) and lowest in the *Chemical industry* (7.5%).[3] Interestingly, manpower constraints are more common in traditional industries, such as *Mechanical engineering*, *Printing and coping*, and *Paper and paper products* than in high-tech industries, such as *Chemical industry* and *Other manufacturing*. Low-skilled specialized workers, as opposed to high-skilled specialized workers, seem to drive the presence of manpower constraints. This fact is consistent with the results in Labor Economics and Economic Geography (e.g. Eichhorst et al. (2017)) that low-skilled workers are substantially less likely to move across space than high-skilled workers, and the results in Education Economics that building up basic and specialized skills in the broader population takes decades (e.g. Becker (1994)). Apart from variation across industries, the share of manpower-constrained firms changes across industries-time as well. One example is provided by Figure 1.5 in the Appendix. It shows that manpower-constrained firms behave differently in chemical industry and electrical engineering over the years.

[3]The share reaches 100% in the *Mining support service activity* sector, but because we only observe two firms in this sector, we do not use them in the analysis. All results are virtually unchanged when we use these additional two firms in the analysis.

Figure 1.1: Manpower-constrained Firms by Industry



Note: This figure describes the fraction of firms in our sample that declares being manpower-constrained and the share of unconstrained firms in each industry.

Figure 1.2 describes the variation of manpower constraints over time. In the figure, we define manpower-constrained as a firm-year observation that declares they are manpower constrained. The incidence of manpower constraints varies dramatically over time. In our sample period, the fraction of firms that declare they are manpower constrained peaks in 1980 and in 1990, when it equals 14% in the overall population of firms. The fraction reaches its local minimum of 1% in 1983. The fraction of manpower-constrained firms in the German economy stays around 5% in the second half of the 1980s, as well as in the late 1990s/early 2000s. A more detailed relation between the fraction of manpower-constrained firms and the change of unemployment rate in Western Germany is provided in Figure 1.6 in the Appendix. It shows that the decrease in the unemployment rate, which implies a shortage of labor supply, is associated with a increase in the fraction of manpower-constrained firms. The evidence of the raw data is in line with our supply-side story.

Figure 1.2: Manpower-constrained Firms by Year

Note: This figure describes the fraction of firms in our sample that declares being manpower-constrained for each year between 1980 and 2001.

Table 1.1 summarizes the key variables used in the baseline regression for the period 1980-2001. Panel A reports the binary variables. The *manpower constraints* takes the value of 1 if a firm declares that they are manpower constrained at any point in time over the sample period, and 0 otherwise. The *financial constraints* equals one if a firm claims at least once during the sample period that the financial situation has strong negative influence on their domestic investment activities. We choose a strict measure here to ensure that the negative influence of financial situation is strong enough and can be perceived as financial constraints for the corresponding firms. The *want hire more* asks firm's willingness to grow in the following year in terms of employment base, it takes the value of 1 if firms plan to increase their employment, and 0 otherwise. Similarly, the *want investment more* asks firm's willingness to grow in the following year in terms of capital expenditure, it takes the value of 1 if firms plan to increase their investment, and 0 otherwise. Panel B reports

the continuous variables used in the baseline analysis. The *capacity utilization* asks the current utilization of firm's production equipment for producing a certain product. It is measured in percent (full utilization = 100%) and could be larger than 100%, implying over-utilization. The *order backlog* inquires the backlog of orders that firms have not yet fulfilled, measured in months. Detailed formulation of the survey questions are listed in the Appendix 1.7.1.

Table 1.1: Summary Statistics

	N	mean	sd	min	p50	max
Panel A: categorical variables						
Manpower constraints	16113	.0858934	.2802152	0	0	1
Financial constraints	16113	.2953516	.4562148	0	0	1
Want hire more	16113	.0205424	.1418509	0	0	1
Want investment more	16113	.2717681	.4448848	0	0	1
Panel B: continuous variables						
Capacity utilization	16113	.0873229	.9192482	-3.450965	.1531544	25.44752
Order backlog	16113	.056114	1.033232	-1.19448	-.103281	4.261515

Note: Summary statistics for the final data set.

1.3 Baseline Analysis

After having described the characteristics of manpower-constrained firms in our sample, we move on to analyze the effects of manpower constraints on a set of corporate policies.

The baseline analysis exploits the panel structure of the data to measure the correlation between manpower-constrained status at the firm level at each point in time and the firm's contemporaneous and prospective policies. Exploiting the variation in manpower-constrained status within firms over time is crucial to our baseline analysis. If we were only comparing manpower-constrained firms and unconstrained firms in the cross section, unconstrained firms would not represent appropriate counterfactuals for constrained firms. Better-managed and efficient firms—dimensions we cannot detect in the data—might be manpower constrained because they are better at satisfying demand than unconstrained firms, and hence cannot expand more without acquiring unconstrained firms or waiting

for such firms to layoff workers. The panel structure of the data allows us to compare manpower constraints and corporate policies within firms, and use the unconstrained firms as a counterfactual for shocks on the demand side, which will affect both constrained and unconstrained firms similarly.

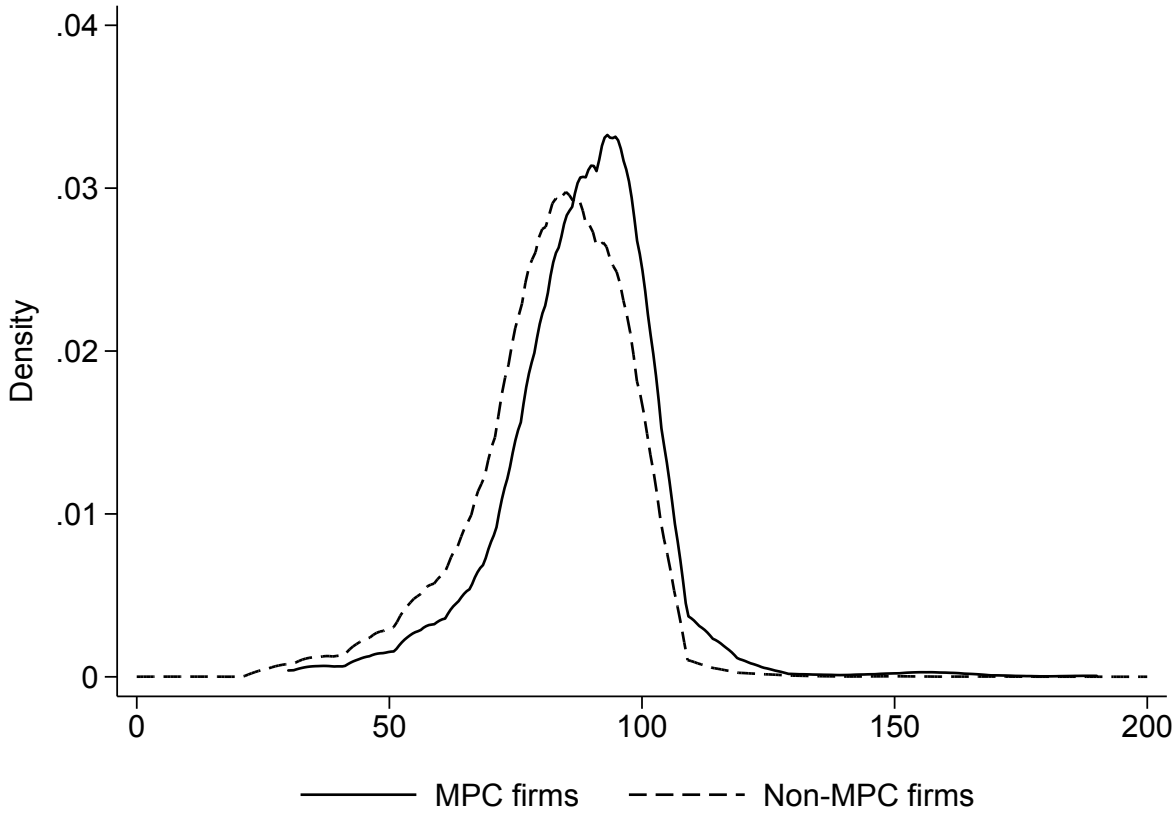
For the corporate policies contemporaneous to the detection of manpower-constrained status, we focus on dimensions that capture the extent of utilization and over-utilization of corporate resources. Specifically, we look at capacity utilization and the backlog of orders that firms have not yet fulfilled, measured in months. Firms in our sample might declare that they are manpower constrained because they are less efficient and productive than other firms, and hence high-skilled and low-skilled specialized workers would obtain higher salaries and bonuses in other firms. In this case, manpower-constrained firms would face lower demand than other firms, and hence should have a shorter backlog of unfulfilled orders and lower capacity utilization. At the same time, manpower-constrained firms might be facing higher demand than they can fulfill, because they are more efficient or produce better products than competitors. In this case, manpower-constrained firms should produce at or above capacity, and should have a longer backlog of orders than other firms.

For the prospective corporate policies, we consider firms' willingness to grow in the following year in terms of both capital expenditures and employment base. If lower efficiency determines manpower constraints, constrained firms should not be willing to invest or grow more in the short term, because they would anyway be unable to use additional resources effectively. If higher efficiency determines manpower constraints, instead, firms are constrained in their growth, and hence should be willing to invest more in capital expenditures and in employment in the short term. Note that employment policies are not tautological. As argued above, being manpower constrained does not necessarily imply that the firm might want or need to hire more workers, and hence to grow.

1.3.1 Univariate Analysis based on Raw Data

Before moving to our multivariate analysis, we look at the raw data in Figure 1.3. This figure focuses on capacity utilization as an example of the four policies described above. We plot the density of capacity utilization separately for firms that declare they are manpower constrained (solid curve) and firms that are unconstrained (dashed curve).

Figure 1.3: Manpower Constraints and Capacity Utilization: Raw Data



Note: This figure plots the densities of capacity utilization in percentage points for two groups of firms in our sample, that is, manpower-constrained firms (solid line) and unconstrained firms (dashed line).

Consistent with the over-utilization notion described above, the average capacity utilization of manpower-constrained firms is 95%, whereas the average of unconstrained firms is 82%. In short, the manpower-constrained firms have higher capacity utilization across the distribution. The figure also shows that the density of capacity utilization is more skewed toward the 100% boundary for constrained firms than for unconstrained ones. An alternative way to see that manpower-constrained firms are more likely to produce at full capacity than other firms consists of comparing the share of firms that hit the 100% boundary in the manpower-constrained and unconstrained distributions. The share of manpower-constrained firms is higher, and the manpower-constrained curve lies above the unconstrained curve for all values above 90%. The raw data described in Figure 1.3

shows that, before excluding any firm-, industry-, time-, or location-characteristic of firms, manpower-constrained firms have higher capacity utilization than unconstrained firms.

The fact that manpower-constrained firms have higher capacity utilization than unconstrained ones also acts as a validation of our measure of manpower constraints. Because the measure is based on corporate executives' answers to a survey in which they have no incentives to tell the truth, one might be worried that our measure captures noise or even false claims. Instead, many firms whose corporate executives declare that they are manpower constrained are indeed working at capacity or above capacity.

1.3.2 Multivariate Analysis

Our baseline multivariate specification is as follows:

$$\begin{aligned} Corporate\ Policy_{i,t,k,s} = \alpha + \beta Manpower\ Constrained_{i,t,k,s} \\ + \gamma Financially\ Constrained_{i,t,k,s} + \eta_t + \eta_k + \eta_s + \eta_i + \epsilon_{i,t,k,s}. \end{aligned} \tag{1.1}$$

The dependent variable, $Corporate\ Policy_{i,t,k,s}$, is one of the two contemporaneous policies or two prospective policies describe above for firm i in semester t in sector k and state s; $Manpower\ Constrained_{i,t,k,s}$ is a dummy that equals one if firm i declares they are manpower constrained in semester t; $Financially\ Constrained_{i,t,k,s}$ is a dummy that equals one if firm i declares they are financially constrained in semester t; and η_t, η_k, η_s, and η_i are full sets of semester, industry, state, and firm fixed effects.

For capacity utilization and backlog of orders, the dependent variable is continuous, and we estimate equation 1.1 by ordinary-least-squares. We cluster standard errors at the firm level. For the prospective willingness to invest in capital and labor, the dependent variable equals one if the firm declares they want to invest, and 0 otherwise. We therefore estimate equation 1.1 in a logit specification, and we report marginal effects estimated at the mean value of the independent variables. Standard errors clustered at the firm level are estimated with the delta method.

Table 1.2 reports the results for estimating equation 1.1 when the outcome variables are two policies contemporaneous to the presence of manpower constraints – order backlog (columns (1)-(3)) and capacity utilization (columns (4)-(6)). The dependent variables are

standardized. Order backlog is the backlog of orders unfulfilled by the company measured in months. Columns (1)-(3) show that manpower-constrained firms have a 0.24 to 0.33 standard deviation higher backlog of orders. The estimates are similar if we include the full set of fixed effects or not. In columns (4)-(6), manpower-constrained firms' capacity utilization is 0.28 standard deviation higher than for unconstrained firms. The magnitude and statistical significance of the estimates are again similar whether or not we absorb systematic shocks that affect all firms equally each semester, systematic time-invariant characteristics across industries and states, and time-invariant firm characteristics.

Results for contemporaneous corporate policies are consistent with the notion that manpower-constrained firms are more efficient, or face a higher demand, than other firms, and hence the lack of specialized workers makes them operate above capacity by over-utilizing their existing resources.

Table 1.2: Contemporaneous Policies and Manpower Constraints

	Order Backlog			Capacity Utilization		
	(1)	(2)	(3)	(4)	(5)	(6)
Manpower constraints	0.329***	0.326***	0.244***	0.280***	0.281***	0.285***
	(7.05)	(7.10)	(10.68)	(4.62)	(4.67)	(11.34)
Financial constraints	-0.0487	-0.0548	-2.467***	-0.0627	-0.0616	-0.0789
	(-0.93)	(-1.03)	(-20.31)	(-1.24)	(-1.20)	(-0.45)
No. of obs.	27190	27190	27190	28836	28836	28836
No. of firms	791	791	791	790	790	790
TimeFE	x	x	x	x	x	x
SectorFE	x	x	x	x	x	x
StateFE		x	x		x	x
FirmFE			x			x
Adjusted R^2	0.282	0.286	0.678	0.0798	0.0871	0.487

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. t-stat reported in parentheses. OLS regressions with time, sector, state and firm fixed effects. Standard errors clustered at the firm level.

Table 1.3 also estimates equation 1.1, but the outcome variables are prospective policies, that is, firms' reported willingness to invest in capital expenditures and to hire new work-

ers in the year following the detection of manpower constraints. All columns report the marginal effects for estimating equation 1.1 with a logit specification. Indeed, the estimated association between manpower-constrained status and prospective policy outcomes are in line with our interpretation of the contemporaneous policy outcomes.

In columns (1)-(3) of Table 1.3, manpower-constrained firms are 2.1-4.2% more likely to declare they want to invest in employment in the following year. In columns (4)-(6), manpower-constrained firms are 2.6-3.4% more likely to declare that they want to invest in capital expenditure in the following year. The association is stable across specifications that restrict the variation differently.

Table 1.3: Prospective Policies and Manpower Constraints

	Want Hire More			Want Investment More		
	(1)	(2)	(3)	(4)	(5)	(6)
Manpower constraints	0.0212***	0.0205***	0.0418***	0.0339**	0.0334**	0.0259*
	(8.52)	(8.89)	(13.02)	(2.37)	(2.32)	(1.74)
Financial constraints	0.00134	0.00106	-0.0151	0.0103	0.0154	-0.161
	(0.74)	(0.60)	(-0.87)	(0.73)	(1.08)	(-1.02)
No. of obs.	29631	29631	12187	22327	22327	20859
No. of firms	799	799	308	774	774	677
TimeFE	x	x	x	x	x	x
SectorFE	x	x	x	x	x	x
StateFE		x	x		x	x
FirmFE			x			x

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. t-stat reported in parentheses. Logit regressions with time, sector, state and firm fixed effects. Marginal effects are reported. Standard errors clustered at the firm level.

Results for prospective corporate policies are also consistent with the notion that manpower-constrained firms are more efficient, or face a higher demand, than other firms, and hence those firms are more willing to invest in capital expenditures and hire additional workers in the near future.

Overall, our baseline results suggest that manpower-constrained firms operate at higher capacity than other firms, they face larger amounts of unfulfilled demand as suggested by their order backlogs, and they want to invest more in capital expenditures and employment in the short term.

1.4 Instrumental-Variable Strategy

The baseline analysis accounts for time-invariant systematic differences across industries and across German states, as well as time-varying and seasonal shocks that affect all German firms in the same semester. At the same time, unobservable firm-level characteristics that vary within states and within industries over time might determine both firms' manpower-constrained status and their contemporaneous and prospective corporate policies, and hence hinder a causal interpretation of our baseline results. For instance, the managers of manpower-constrained firms might be more efficient than other managers. Efficient managers would produce better products at better conditions, absorbing all available specialized workers in their local economy and attracting higher demand, and hence working at higher capacity than other firms.

Reverse causality might also explain our baseline findings. Firms that face higher demand work at higher capacity, and become manpower constrained once they absorb all the specialized workers available in the local economy.

Addressing these identification concerns requires that we find a source of exogenous variation in the extent to which a limited availability of workers constrains firms' production and investment, which is orthogonal to other demand- and supply-side shocks that firms might face.

To obtain a source of quasi-exogenous variation in the extent to which manpower constraints bind, we exploit a natural experiment that resembles a quasi-random influx of specialized workers into Western German states at different levels across space. The natural experiment is the fall of the Berlin Wall in 1989. Fuchs-Schündeln and Schündeln (2005) and Burchardi and Hassan (2013) used the fall of the Berlin Wall and the subsequent reunification of Western and Eastern Germany as a natural experiment to study precautionary savings and the economic impact of social ties.

Although the *Deutsche Demokratische Republik* (DDR), the previous East Germany, had shown signs of economic and social crisis for a few years, the fall of the Berlin Wall and its consequences were largely unexpected by Germans on either side of the Wall, even if the Cold War rhetoric proposed a deterministic view of this event. For instance, the Western press suggested the passionate "Tear Down This Wall!" speech in which US President Ronald Reagan called for the fall of the Berlin Wall in 1987 was a milestone that helped the actual fall of the Wall. Instead, the speech went largely ignored by the German press and politicians on both sides of the Wall, including the West. Three-term German Chancellor Angela Merkel provided another vivid suggestion that the fall of the Berlin Wall was a largely unexpected event when she revealed in 2009 that she was taking a sauna and then having beers in East Berlin while the border was opened on the Eastern side. Even claims that US cultural influences in 1989 directly affected the fall of the Wall seem unrealistic. For instance, many believe that the Scorpion's song "Wind of Change" was crucial to the revolts of East German youngsters conducive to the fall of the Wall. But "Wind of Change" was recorded in Los Angeles in 1990, and released as a single album in 1991, well after the Wall had already fallen.

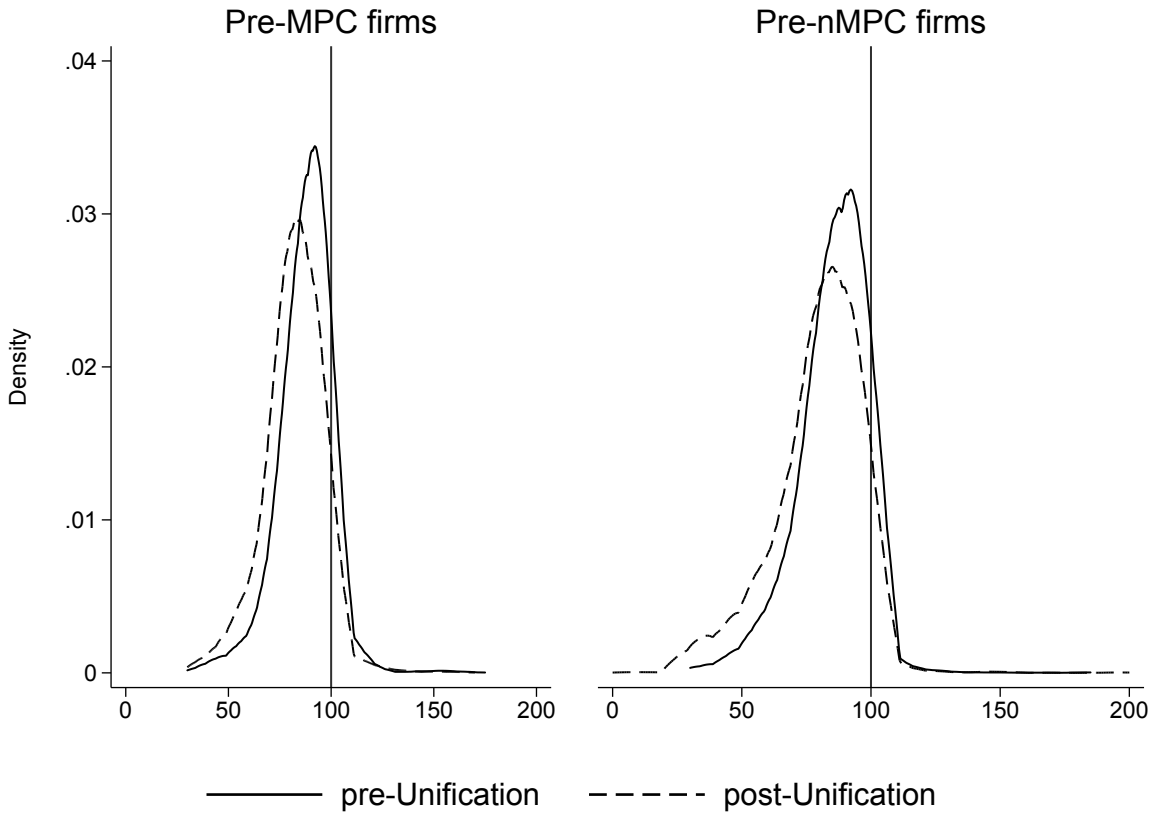
The fall of the Berlin Wall determined mass migrations of Eastern German workers into Western Germany. Eastern German workers were highly specialized in manufacturing jobs, which is the expertise firms in our sample would need most. For our identification, the crucial feature of this shock is that Eastern Germans moved into areas in which relatives and friends had settled before the construction of the Berlin Wall. These relatives and friends could only settle in areas of Western Germany in which the supply of housing was less destroyed during WWII. Bombings during WWII therefore determined the spatial diffusion of Eastern German refugees during the 1950s, and also of Eastern Germans escaping communism after the fall of the Berlin Wall.

Consistent with our interpretation of the natural experiment, the share of firms that declare they are manpower constrained decreased from 14% in 1990 to 4% in 1991, 3% in 1992, and stayed below or around 5% until the end of our sample in 2001. See Figure 1.2 for more details.

In addition, we take capacity utilization as an example and look at the raw data around the German reunification in Figure 1.4. We plot the densities of capacity utilization separately for firms that are manpower *constrained* before German reunification on the left and *unconstrained* before reunification on the right. We limit variation to years around the

reunification shock, that is 1990-1994. The solid curves are the density of capacity utilization before reunification and the dashed curves are after reunification. The vertical lines are set at the 100% capacity utilization distribution for each group. It shows clearly that the average capacity utilization is relaxed after German reunification for pre-constrained firms, but not so obvious for pre-unconstrained firms.

Figure 1.4: Capacity Utilization Before and After German Reunification



Note: This figure plots the densities of capacity utilization for pre-constrained and pre-unconstrained firms around German reunification.

Our identification strategy is an instrumental-variable approach, which uses the variation in the yearly cumulative fluxes of Eastern immigrants across Western German states to instrument for the share of firms that are subject to manpower constraints in each Western state over time. We observe immigration fluxes at the state level, and hence, to avoid unduly interpreting within-state firm-level observations as independent, we construct our

instrument at the state level as opposed to the firm level. Below, we discuss why a difference-in-differences strategy at the firm level would be inappropriate to our setting.

The IV strategy consists of the following equations:

$$\begin{aligned} Share\ Manpower-constrained_{i,k,t,s} = \alpha + \beta Cum\ Inflow\ Immigrants_{t,s} \\ + \gamma Fin\ Constrained_{i,t,k,s} + \eta_t + \eta_k + \eta_s + \epsilon_{i,t,k,s}, \end{aligned} \tag{1.2}$$

$$\begin{aligned} Corporate\ Policy_{i,t,k,s} = \alpha + \beta \widehat{Share\ Manpower-constrained}_{i,k,t,s} \\ + \gamma Fin\ Constrained_{i,t,k,s} + \eta_t + \eta_k + \eta_s + \epsilon_{i,t,k,s}. \end{aligned} \tag{1.3}$$

Equation 1.2 is the first stage, in which we predict the share of manpower-constrained firms in state s and semester t for firm i operating in industry k. Equation 1.3 is the second stage, in which we predict the corporate policies of the same set of firms using the share of manpower-constrained firms instrumented in the first stage.

The identifying assumption (exclusion restriction) is that the extent of the influx of Eastern German workers after the fall of the Berlin Wall affected firms' policies only through the relaxation of their manpower constraints, and not through other channels.

1.4.1 Validity of the Instrument

The main threat to the exclusion restriction underlying our strategy is the fact that the fall of the Berlin Wall created a new free market to which Western firms could supply a large range of products that previously did not exist in the East. The formal political and monetary reunification of Germany followed. This threat is not relevant to our identification strategy, because *all* Western firms, in any state, were exposed to the opening of the new market to the same extent, whereas we exploit variation in the influx of Eastern immigrants across states. This point is also the reason why we do not design a difference-in-differences strategy based on the relaxation of manpower constraints within firms before and after 1989. If we did so, we would be unable to disentangle the effect of the fall of the Berlin Wall on manpower constraints from the effect of the opening of a new market for Western firms.

A related concern is that the increase in local population after a large influx of Eastern workers also changed the size and characteristics of the local markets and demand within

Western states, which was likely to affect firms in states with a larger influx of immigrants more than firms in other states. We believe this concern is not relevant in our case because, if anything, a larger influx of immigrants would have increased the demand for the goods of local firms, and hence would have increased their capacity utilization, backlog of orders, willingness to invest in capital expenditures, and of hiring additional workers in the following year even more. To the contrary, if the influx of immigrants relaxed manpower constraints, as our identification strategy assumes, local firms should have decreased their capacity utilization and backlog of orders, and could have finally invested in new machines which the additional workers could operate, hence reducing their willingness to invest in capital expenditures in the following year.

As we argued above, the influx of Eastern German immigrants after the fall of the Wall followed the patterns of migrations of Eastern migrants that relocated to Western states after WWII, before the construction of the Wall. Because the availability of non-bombed housing stock determined post-WWII migration patterns, we argue that the spatial diffusion of immigrant fluxes was quasi-exogenous. At the same time, one might be concerned that Western German firms that started after WWII might have faced different local market conditions based on the number of immigrants in the areas in which they operated. Firms might have also selected into areas with more or less migrants based on unobservable characteristics that also affected their tendency to become manpower constrained and their corporate policies after 1980. To address this concern, we repeat our IV analysis on the subsample of firms in our sample that were founded before WWII and survived throughout the war. This subsample includes about half of the firms in our sample.[4] Our results are similar if we focus on this subsample of firms. Detailed results are provided in Table 1.6 in the Appendix.

1.4.2 First- and Second-stage Results

Table 1.4 reports the results for estimating equation 1.2 and equation 1.3 by two-stage least squares for the contemporaneous corporate policies (columns (1)-(4)), and by two-stage probit estimation for the prospective corporate policies (columns (5)-(8)). The sample period is all the years between 1990 and 2001. As for the first stage, the results show our

[4]Note German corporations have high survival rates, and high average age. The oldest firm in our sample was founded in 1258 AD.

instrument is relevant, because across all outcomes the first-stage F-statistics are above 10 in each specification.

Table 1.4: Firm Outcomes on Instrumented Manpower Constraints (State-level Variation)

	Order Backlog		Capacity Utilization		Want Hire More		Want Investment More	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Relative MPC	0.0090***	0.0060***	0.0077***	0.0077***	0.034***	0.036***	0.0043***	0.0048***
	(5.26)	(3.71)	(4.67)	(4.75)	(13.88)	(14.59)	(3.43)	(3.77)
Financial constraints	0.035	-0.058	-0.10*	-0.094*	-0.0024	-0.0090	0.047***	0.055***
	(0.51)	(-1.04)	(-1.79)	(-1.68)	(-0.05)	(-0.18)	(2.85)	(3.28)
StateFE	x	x	x	x	x	x	x	x
SectorFE		x		x		x		x
No. of obs.	14,781	14,781	15,315	15,315	16,175	16,017	31,805	31,805
F-Stat	2606.63	2533.25	3228.96	3181.23	3502.94	3464.03	2451.57	2452.55

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. t-stat reported in parentheses. IV regressions with state and sector fixed effects.

As for the second stage, the IV results confirm our baseline multivariate analysis across all corporate policies. Manpower-constrained firms operate at higher capacity utilization, have longer backlogs of orders, and are more willing than unconstrained firms to invest in capital expenditures and in employment in the short run. The magnitude of the effects cannot be directly compared with the baseline multivariate analysis, because in the baseline analysis, the main independent variable is a dummy that equals one if the firms is manpower-constrained, whereas in the IV analysis, the main independent variable—the share of manpower-constrained firms in each Western German state instrumented with the cumulative influx of Eastern German immigrants after the fall of the Berlin Wall—is continuous.

Our sample covers the period 1980-2001. The fluxes of Eastern German immigrants were substantial in the first few years after the fall of the Wall, but lower in the subsequent years. We therefore repeat our IV analysis limiting the sample between 1990 and 1994, so that we capture only the few years in which Eastern German migration was at its spike, and our migration fluxes are not driven by dimensions possibly different from the fall of the Berlin Wall. We show the results for this estimation in Table 1.5, and we confirm our IV results in this subsample.

Table 1.5: Firm Outcomes on Instrumented Manpower Constraints
(State-level Variation, around Reunification)

	Order Backlog		Capacity Utilization		Want Hire More		Want Investment More	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Relative MPC	0.0050***	0.0050***	0.0098***	0.0098***	0.016***	0.017***	0.0019***	0.0019***
	(9.18)	(10.66)	(20.77)	(21.06)	(11.94)	(12.05)	(3.59)	(3.62)
Financial constraints	-0.0092	-0.080***	-0.15***	-0.13***	-0.11	-0.11	0.015	0.018
	(-0.33)	(-3.30)	(-6.48)	(-5.41)	(-1.51)	(-1.56)	(0.58)	(0.69)
StateFE	x	x	x	x	x	x	x	x
SectorFE		x		x		x		x
No. of obs.	6,394	6,394	6,890	6,890	7,142	6,859	12,776	12,776
F-Stat	34790.93	34751.16	36837.17	36751.55	8039.68	8029.29	14733.22	14729.20

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. t-stat reported in parentheses. IV regressions with state and sector fixed effects.

1.5 Manpower-Constraint Index

Our analysis so far focused on the effects of manpower constraints on the corporate policies of German firms between 1980 and 2001. This setting allows us to observe which firms are manpower constrained directly, as well as to obtain quasi-exogenous variation in the likelihood firms are manpower-constrained across Western German states in an internally-consistent identification strategy.

To the best of our knowledge, this is the first paper that observes directly whether firms declare they face manpower constraints. We are also unaware of other survey- or administrative-based evidence that includes this information in the US, other European countries, or Asia. At the same time, progress in the detection and measurement of manpower constraints would allow deeper investigations into the effects of this type of labor-market constraints on firm- and industry-level outcomes, productivity, and ultimately economic growth.

To allow scholars to proxy for the incidence of manpower constraints in settings different from the one we study, we therefore exploit the subsample of firms in our sample for which we observe balance-sheet financial variables to construct a *Manpower Constraint (MPC) Index*.

Our MPC index is inspired by the Kaplan-Zingales (KZ) index for financial constraints. Similar to KZ, we run predictive logistic regressions of a dummy that equals one if the firms

declares it is manpower constrained on a set of financials that are available in databases scholars in Finance and Accounting commonly use. We estimate the marginal effects of each financial on the likelihood of manpower constraints, and propose these marginal effects as loads on the same financials that scholars can use to proxy for the likelihood of manpower constraints at the firm level.

Specifically, we estimate the following specification with a logit regression:

$$\begin{aligned} Pr(MPC == 1)_{i,t,k,s} = \Phi(\alpha \times Age_{i,t,k,s} + \beta \times \frac{SG\&A}{Assets}_{i,t,k,s} + \gamma \times \frac{A/P}{Assets}_{i,t,k,s} \\ + \delta \times \frac{A/R}{Assets}_{i,t,k,s} + \zeta \times \frac{Inventories}{Assets}_{i,t,k,s}), \end{aligned} \tag{1.4}$$

where Age is the firm's age at time t, $\frac{SG\&A}{Assets}$ is SG&A expenses scaled by total assets, $\frac{A/P}{Assets}$ and $\frac{A/R}{Assets}$ are the firm's accounts payable and accounts receivable scaled by total assets, and $\frac{Inventories}{Assets}$ is the amount of inventory scaled by total assets. We focus on these five firm-level financials, because we find that after controlling for these five dimensions, no other observable financials of the firms in our sample are associated significantly with their manpower-constrained status.

We then interpret the estimated coefficients on each of these variables as the loads which one can apply to different samples of firms in order to obtain a measure of the extent of manpower constraints that firms face. Based on this procedure, the following expression is the MPC Index, where we report the loadings associated with each financial variable, with stars that indicate the significance level of the test-statistic for the null hypothesis that the marginal effect from equation 1.4 equals zero:

$$\begin{aligned} MPC\ Index = 0.16^{**} \times Age + 0.23^{***} \times \frac{SG\&A}{Assets} - 0.26^{**} \times \frac{A/P}{Assets} \\ + 0.39^{***} \times \frac{A/R}{Assets} + 0.40^{***} \times \frac{Inventories}{Assets}. \end{aligned} \tag{1.5}$$

Financial constraints have been heavily studied over the last two decades. Financial constraints and manpower constraints should not be highly correlated, because dimensions like the supply of finance that firms can access, the amount of collateral they can pledge, and the uncertainty of firms' investment projects should determine the likelihood of whether firms face financial constraints. Instead, under our interpretation, manpower constraints

depend on the supply of specialized workers in the economy, which individual firms can barely control.

To assess the extent to which financial constraints and manpower constraints capture different concepts, we exploit the logit setup in equation 1.4 to obtain a similar index for financial constraints. Our aim is to compare the loads of financial constraints to the financials that explain manpower constraints with the loadings of manpower constraints on the same financials. Below are the loadings for financial constraints:

$$\begin{aligned} Financial\ Constraints = 0.10 \times Age - 0.13 \times \frac{SG\&A}{Assets} + 0.11 \times \frac{A/P}{Assets} \\ - 0.05 \times \frac{A/R}{Assets} + 0.23^{*} \times \frac{Inventories}{Assets}. \end{aligned} \tag{1.6}$$

As expected from the fact that financial constraints are a different economic object from manpower constraints, all the loadings in equation 1.6 are not statistically different from zero, and the signs of three of the five loadings are different from the ones we estimated for manpower constraints, as reported in equation 1.5.

1.6 Conclusions

We exploit a unique panel of German firms from 1980 to 2001, in which we observe *directly* whether firms declare they face manpower constraints—the pervasive lack of high-skilled or low-skilled specialized workers, whatever the wage firms might offer—to describe the characteristics of manpower-constrained firms, as well as the effects of manpower constraints on a set of contemporaneous and prospective corporate policies.

In our baseline analysis, we find that manpower-constrained firms operate at higher capacity utilization, have a longer backlog of orders, and are more willing to invest in capital and employment in the short term. We confirm these results using an instrumental-variable strategy that exploits the quasi-exogenous fluxes of Eastern German specialized workers across Western German states after the fall of the Berlin Wall in 1989. The IV results confirm the baseline positive effects of manpower constraints on firms' current policies (capacity utilization and backlog of orders) and future plans (willingness to invest and hire).

Manpower constraints constitute a crucial factor affecting firm performance. However, observing the incidence of manpower constraints is not always possible in other data sets for US, European and Asian firms. To fill the gap, we use a logic analogous to the Kaplan-Zingales index for financial constraints, and propose a Manpower Constraint (MPC) Index, which proxies for the likelihood that a firm is manpower constrained. This MPC index is readily applicable to firms in data sets that include balance sheet financial variables.

The results in this paper are a first step towards our understanding of the prevalence of manpower constraints, the characteristics of manpower-constrained firms, and the effects of manpower constraints on corporate policies. Future research in Finance and Accounting should delve deeper into this important yet neglected friction to firm-level operations.

1.7 Appendix

1.7.1 Survey Questions

This section lists the official English translation of the survey questions.

Manpower Constraints: Our domestic production activities with regard to XY are currently constrained by the lack of skilled labor: Yes or No

Financial Constraints: Our domestic investment activities were influenced by the financing situation:

- strong inducement
- slight inducement
- no influence
- slight negative influence
- strong negative influence

Capacity Utilization: The utilization of our production equipment for producing XY (customary full utilization = 100) currently amounts to:

30	40	50	60	70	80	90	100	more than 100%, namely:

Backlog of Order: At the moment, our backlog of orders for shipments of XY corresponds to a production period of:

no orders	up to about _ month(s):											if more than 10, please state number of months:
	1/2	1	2	3	4	5	6	7	8	9	10	

Want Investment More: As compared to this year, we probably will invest... next year:

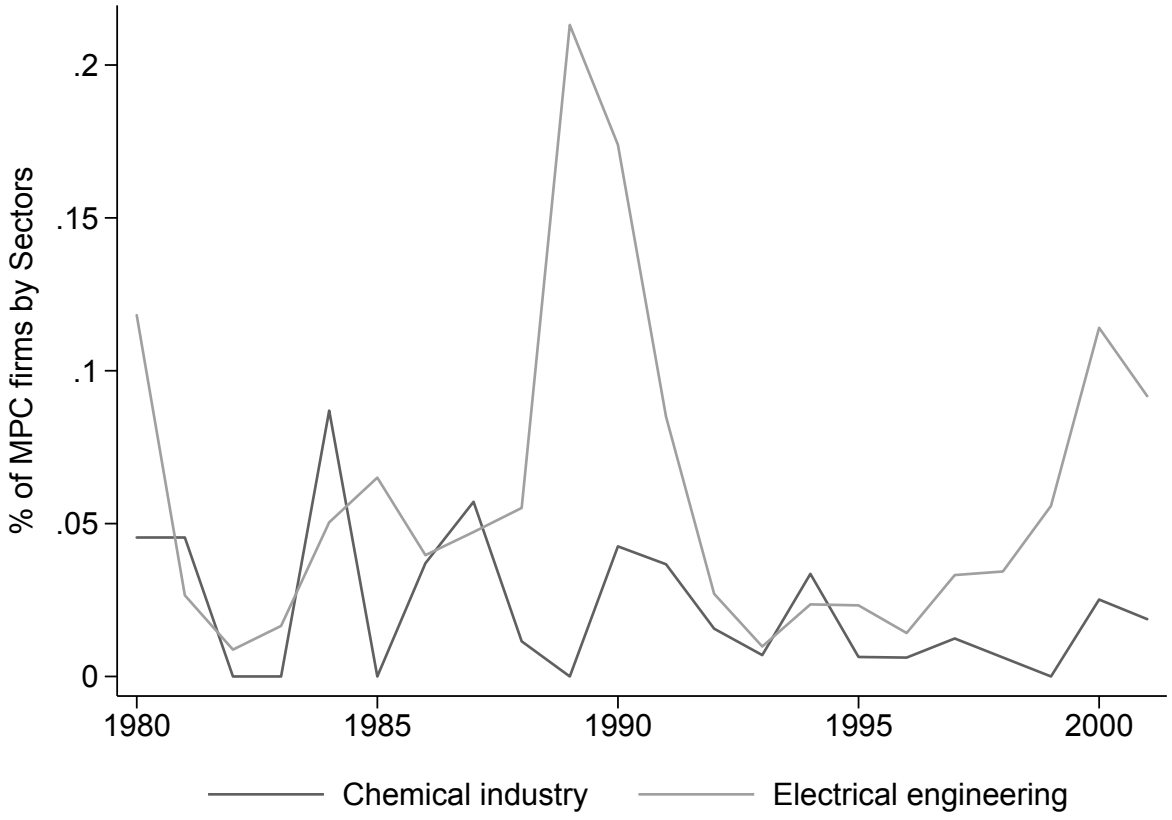
- more
- the same amount
- less

Want Hire More: During the next 3 months, the number of employees involved in the production of XY will:

- increase
- remain about the same
- decrease

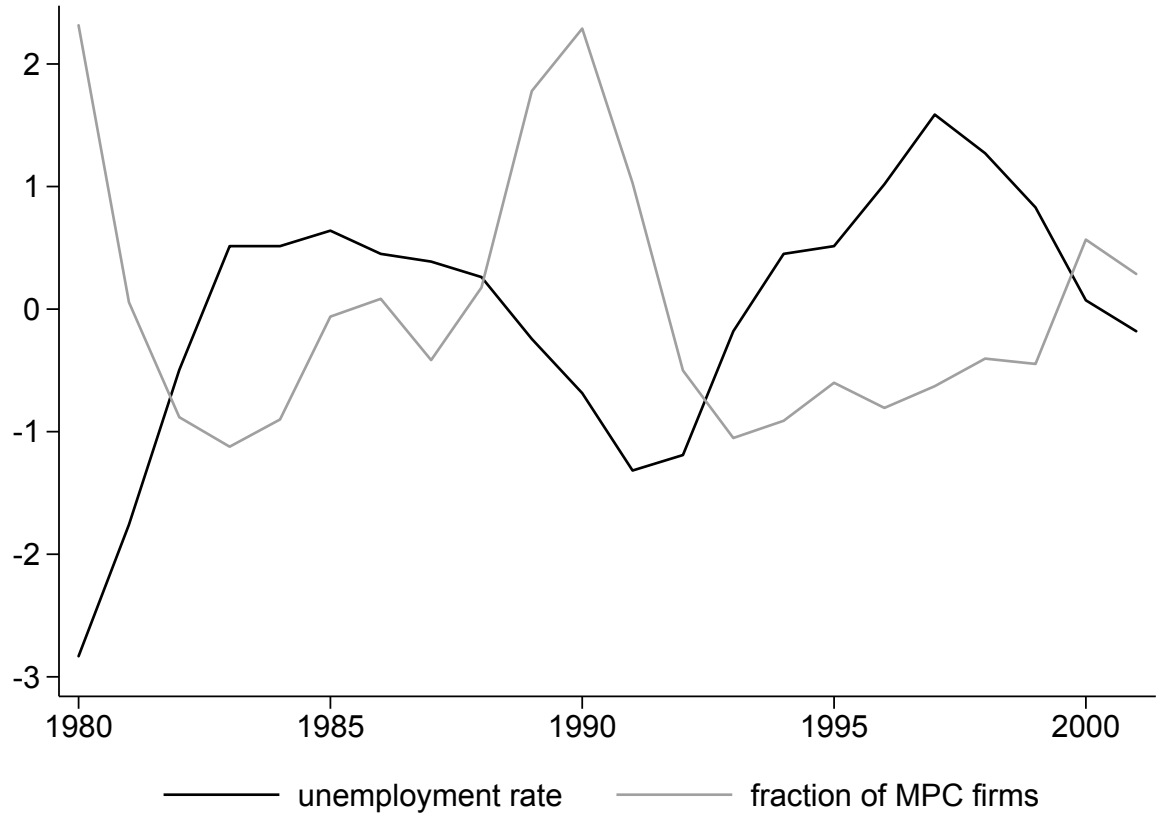
1.7.2 Additional Figures and Tables

Figure 1.5: Manpower Constraints across Industries and over Time



Note: This figure shows the variation of manpower constraints across industries (chemical industry and electrical engineering) and over time (1980-2001).

Figure 1.6: The Unemployment Rate and the Fraction of Manpower-constrained Firms



Note: This figure describes the unemployment rate and the fraction of manpower-constrained firms in Western Germany.

Table 1.6: Firm Outcomes on Instrumented Manpower Constraints
(Subsample of Firms Founded before WWII, around Reunification)

	Order Backlog		Capacity Utilization		Want Hire More		Want Investment More	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Relative MPC	0.0042***	0.0043***	0.010***	0.010***	0.017***	0.018***	0.0020**	0.0020***
	(5.31)	(6.40)	(15.08)	(15.41)	(8.70)	(8.81)	(2.53)	(2.62)
Financial constraints	-0.030	-0.099***	-0.13***	-0.13***	-0.064	-0.091	0.055	0.066*
	(-0.76)	(-2.82)	(-3.89)	(-3.79)	(-0.65)	(-0.89)	(1.47)	(1.69)
StateFE	x	x	x	x	x	x	x	x
SectorFE		x		x		x		x
No. of obs.	3,011	3,011	3,394	3,394	3,495	3,388	5,974	5,973
F-Stat	17492.54	17405.15	18777.99	18689.85	19010.11	18925.59	33257.99	33165.55

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. t-stat reported in parentheses. IV regressions with state and sector fixed effects.

Chapter 2

Technical Barriers to Trade and Firms' Export Decisions

2.1 Introduction

Over the last decades, modern trade policies such as non-tariff measures (NTMs) are gaining prevalence. One of the key players among NTMs is Technical Barriers to Trade (TBTs). TBTs require exporters' quality, labelling, testing and certification procedures to fulfill the standards in the importing country. TBTs are by far the most commonly used NTMs, with countries imposing them on average on about 30% of trade (UNCTAD, 2013).

Despite the widespread use of TBTs, their impact on trade remains ambiguous, especially at the firm-level. Most studies use aggregate data to analyse the impact of TBTs on trade. They find that TBTs are trade restrictive in general and trade promoting in certain sectors or products.[1] However, studies using firm-level data are relatively scarce. Theoretically, firm heterogeneity models predict that the effect of TBTs on firms' export is both positive and negative; nonetheless, the net effect is unclear. Empirically, exporters in the U.S., France and Egypt have been examined.[2] Yet, little work has been done for the case of China, one of the world's largest exporters and targets of NTMs (Lu et al., 2013). To the best of my knowledge, there are two papers exploring the impact of TBTs on Chinese

[1]For example Fontagné et al. (2005); Disdier et al. (2008); Jiang (2009); Bao and Qiu (2010); Uprasen (2014).

[2]See Reyes (2011); Fontagné and Orefice (2018); Kamal and Zaki (2018) respectively.

exporters, but they are limited in either the type of firms (Hu et al., 2019) or the range of firm characteristics (Gulotty et al., 2017).

To quantify TBTs with trade-restrictive nature (henceforth restrictive TBTs) is another challenge. TBT is one of the most difficult NTMs to quantify (Bao and Qiu, 2012). Researchers use different approaches to measure TBTs based on TBT notifications and still face limitations.[3] Even if data on TBT notifications can be estimated, it is often impossible to distinguish between discriminatory and non-discriminatory measures. In the spirit of WTO's TBT Agreement, TBTs should be non-discriminatory and "do not create unnecessary obstacles to trade" (WTO, 2012). However, TBTs might be over utilized by the governments and become trade protectionism (Kang and Ramizo, 2017). Moreover, such restrictive TBTs might be systematically, though unintentionally, biased against developing countries (UNCTAD, 2013). It is thus important to scrutinize TBTs that are applied in a discriminatory or trade-restrictive way.

This paper aims to fill the aforementioned gaps by analyzing the impacts of restrictive TBTs on Chinese firms' export decisions. Specifically, I investigate the impacts of restrictive TBTs on firms' extensive margins (firms' decisions to export or to exit a product-destination market), intensive margins (firms' export values on a product-destination combination) and pricing strategy, with a focus on the heterogeneous impacts across firms.

To this end, two major databases are used: the first is firm-level data on the universe of Chinese exporters from the China customs data. The second is product-level data on restrictive TBTs from a novel WTO database on TBT specific trade concerns. This database records all the TBT-related concerns raised by exporting countries to the TBT Committee. Considering the time and cost involved in the procedure, a TBT concern will only be raised if exporters regard it as a "sizeable" barrier for their export activities (Fontagné et al., 2015).[4] In other words, a concern will only be raised if exporters perceive it as more trade restrictive than necessary. Therefore, the TBT concerns are suitable measures for restrictive TBTs. In this paper, the two terms, restrictive TBT and TBT concerns will be used interchangeably. Exporter data and restrictive TBTs are combined at HS4 product

[3]Though WTO members are required to report the new or changed TBTs through the WTO, they normally have no incentive to do so. And some TBT notifications fail to provide specific product codes and descriptions (Bao and Qiu, 2012; Crivelli and Groeschl, 2016).

[4]A WTO member wishing to raise a TBT-specific trade concern (raising country) has to inform both the TBT Committee and the country imposing the corresponding TBT (maintaining country) at least two weeks before the next TBT Committee meeting. The TBT-specific trade concern will be listed in the agenda and discussed in the forum (Holzer, 2019).

level over the 2002-2009 period. China offers an ideal setting here, as Chinese firms are frequently and widely targeted by TBTs and have substantial inter- and intra-industry differentiation (Hu et al., 2019).

The identification strategy is an instrumental-variable (IV) approach. I regress firms' outcome variables (firms' extensive margins, intensive margin and pricing strategy) on TBT concerns and a group of interaction terms between TBT concerns and firms characteristics (firm size, multi-destination status and ownership types). By linking product-level TBTs and firm-level exports, the interaction terms are able to shed light on the heterogeneous effects of TBTs across firms. Crucially, in the first stage of the IV strategy, I instrument for the TBT concerns raised by China using the TBT concerns raised by any third country, and the interaction terms between China-raised TBT concerns and firm characteristics using the interaction terms between third-country-raised TBT concerns and firm characteristics. The rational is that TBT concerns raised by third country rather than China are likely to be exogeneous to Chinese firms' exporting behavior. In the second stage of the IV strategy, I predict firms' export decisions on instrumented TBT concerns and instrumented interaction terms.

This paper finds that restrictive TBTs have negative effects on firms' extensive and intensive margins and a null average effect on price, with the effect varying across heterogeneous firms. First, the imposition of restrictive TBTs prevents firms from export participation and inducing higher exit rates. However, the negative effect is attenuated for firms that are large, have multiple destinations (henceforth multi-destination firms) or domestic ownership type (henceforth domestic-owned firms).[5] Interestingly, I find that multi-destination firms in China and France react oppositely to the restrictive TBTs. Fontagné and Orefice (2018) find that it is more likely for multi-destination firms in France to exit the market with restrictive TBTs. However, I find that multi-destination firms in China are willing to overcome the higher trade costs and stay in the market. Second, incumbent firms face a loss of export values in general. But large, multi-destination or domestic-owned firms enjoy reduced competition and larger market share. Third, a null average effect on firms' pricing strategy is discovered. But firms of different types set their export price differently. Given the same restrictive TBTs, large and multi-destination firms tend to pass-through part of the increased cost to the final consumers by charging a higher price, whereas domestic-owned firms tend to reduce price by less than cost. By dividing domestic-owned firms into

[5]In this paper, domestic-owned firms are not firms serving the domestic market, but rather exporters with domestic ownership type.

state-owned and private-owned ones, I find that the price-decreasing effect is mainly driven by state-owned rather than private-owned firms.

The contribution of this paper is threefold: First, I exploit a rich set of firm characteristics to uncover interesting firm-level heterogeneity. I find that multi-destination firms in a developing country react differently to the ones in developed countries,[6] and firms' pricing strategies vary not only across different firm characteristics but also within the same ownership type. Second, two types of measurements are used to estimate restrictive TBTs. Beyond the traditional dummy variable, TBTs are also measured by the number of years that a TBT concern remains unresolved (TBT duration). The empirical results are consistent in both measures. Third, by applying an IV approach, I show that simple OLS approach suffers from endogeneity bias.

The remainder of the paper is organized as follows: Section 2.2 reviews the literature on TBTs. Section 2.3 introduces the data sets. Section 2.4 summarizes the theoretical predictions and presents the empirical strategies. Section 2.5 reports and discusses the main results. Section 2.6 extends the main results and provides a series of robustness checks. Section 2.7 concludes the paper.

2.2 Literature Review

This paper relates to several strands of literature. First, the "New New" trade theory initiated by Melitz (2003) assumes that firms within an industry are heterogeneous in productivity. Incorporating variable and fixed costs of trade into the model, he shows that large and more productive firms enter the export market and simultaneously force less productive firms to exit. Based on the Melitz framework, researchers (Chaney, 2008; Helpman et al., 2008; Melitz and Ottaviano, 2008; Lawless, 2009) develop theoretical models to investigate the effect of trade cost as well as firm-level trade on both intensive and extensive margins. For example, Chaney (2008) extends the Melitz model with the influence of trade barriers on the two trade margins. He shows that a drop of trade barriers increases export volume of incumbent exporters (intensive margin) as well as the set of exporters (extensive

[6] Fontagné and Orefice (2018) find that the driving-out effect of TBTs is stronger for multi-destination firms in France. However, this paper finds that multi-destination firms in China expand export under restrictive TBTs.

margin). Mayer and Ottaviano (2008) reveal that exporters outperform non-exporters in several aspects: they are bigger, more productive and generate higher added value.

Second, a rich set of literature uses aggregate data to analyse the trade effect of NTMs in general. Kee et al. (2009) provide three indicators of trade restrictiveness for 78 developing and developed countries. They find that the restrictiveness of NTMs takes a large share across countries, especially in developed ones, and sometimes even outweigh the restrictiveness of tariffs. Building on Kee et al. (2009)'s work, Hoekman and Nicita (2011) find that tariff and non-tariff measures continue to be trade impediments for developing countries; Niu et al. (2018) estimate the ad valorem equivalents of NTMs for 97 countries over 1997-2015 and conclude that NTMs are rising as dominant components of trade protection over the years. Similar trade dampening impact of NTMs are revealed by Bratt (2017) and Kinzius et al. (2019).

Some scholars narrow down the types of NTMs and explore the trade effect of TBTs in particular. Most of the work find that TBTs are trade restrictive in most cases and trade promoting in a few sectors or products. For instance, Fontagné et al. (2005) estimate the impact of SPS and TBT measures for 161 product groups and find that the impacts of NTMs vary across products. In particular, it is trade promoting for very few manufacturing products and trade hindering for the majority of products. Disdier et al. (2008) estimate the impact of SPS and TBT measures in agricultural trade. The results show that these measures dampen OECD imports on the whole, whereas foster trade in some sectors. Bao and Qiu (2010) investigate the effect of TBTs on China's import during 1998 to 2006. They find that China's TBTs are overall trade restrictive while trade promoting for some manufacturing goods.

More specifically, a branch of literature focuses on one large, emerging and export-oriented country - China - and investigates the impact of TBTs on China's export at aggregate level. Examining all industries, Uprasen (2014) discovers that TBTs in the EU market play dual roles in Chinese exports: encouraging exports when TBTs are regarding product quality or performance requirements (B700) and conformity assessments (B800); whereas hindering exports when TBTs are about the restrictions of products (B100). Exploring one industry, Jiang (2009) look at TBTs raised by the U.S., the European Union, and Japan aiming at China's textile products. He finds both positive influence in the long run (quality upgrading) and negative influence in the short run (export reduction).

Third, while most of the NTMs-related research relies on aggregate trade data, firm-level analyses are relatively scarce. Analysing different NTMs and their relationship with firms' export performance, defined as export propensity and market diversification (Chen et al., 2006) or as the number of export markets and products (Chen et al., 2008), researchers find that NTMs adversely affect firms' export (Chen et al., 2006), or the effects vary across standards, which can be either positive (quality standards, labelling requirements) or negative (certification procedure) (Chen et al., 2008).

Some scholars investigate the impact of one specific type of NTMs on the export performance of firms in developed countries: Reyes (2011) find that U.S. manufacturing firms with higher productivity increase entry to the EU market following a reduction of one NTM.[7] For firms located in France, Fontagné et al. (2015) find a negative effect of SPS concerns on both extensive and intensive margins, but such negative effects are attenuated in larger firms. Similar negative effects of TBT concerns on export are revealed by Fontagné and Orefice (2018). Moreover, those negative effects are stronger for multi-destination firms, which tend to divert to destinations without TBTs.

Looking at developing countries, Kamal and Zaki (2018) analyse the impact of TBT concerns on Egyptian firms. The results indicate a negative effect of TBT concerns on the intensive margin but no clear cut-off effect on the extensive margin unless taking firm size into consideration. Combining data on pesticide standards and firms' export in 42 developing countries, Fernandes et al. (2019) find that restrictive standards adversely affect firms' export, but firm size and network can partially compensate such negative effects.

Though China is one of the world's largest exporters and targets of NTMs (Lu et al., 2013), limited work has been done to investigate the impact of NTMs, particularly TBTs, on Chinese firms. To my best knowledge, there are two papers in this field. Hu et al. (2019) investigate the impact of TBT notifications on firm-level export using the Children-Resistance Act as a quasi-natural experiment. They explore cigarette lighter firms from 2004 to 2008. Compared to Hu et al. (2019), this paper has a broader range of firm types (the universe of Chinese firms) and a longer time span (from 2002 to 2009). Gulotty et al. (2017) exploit the influence of TBT concerns on Chinese firms from 2000 to 2007. Their specification considers firm size. Compared to Gulotty et al. (2017), this paper enriches the analysis of firm characteristics by including firms' multi-destination status and ownership types as well.

[7] the harmonization of European product standards to international norms in the electronics sector

2.3 Data on Restrictive TBTs and Exporters

The data consists of two important databases: a recently available database on TBT specific trade concerns (STCs) from WTO and a database of Chinese firm exports.

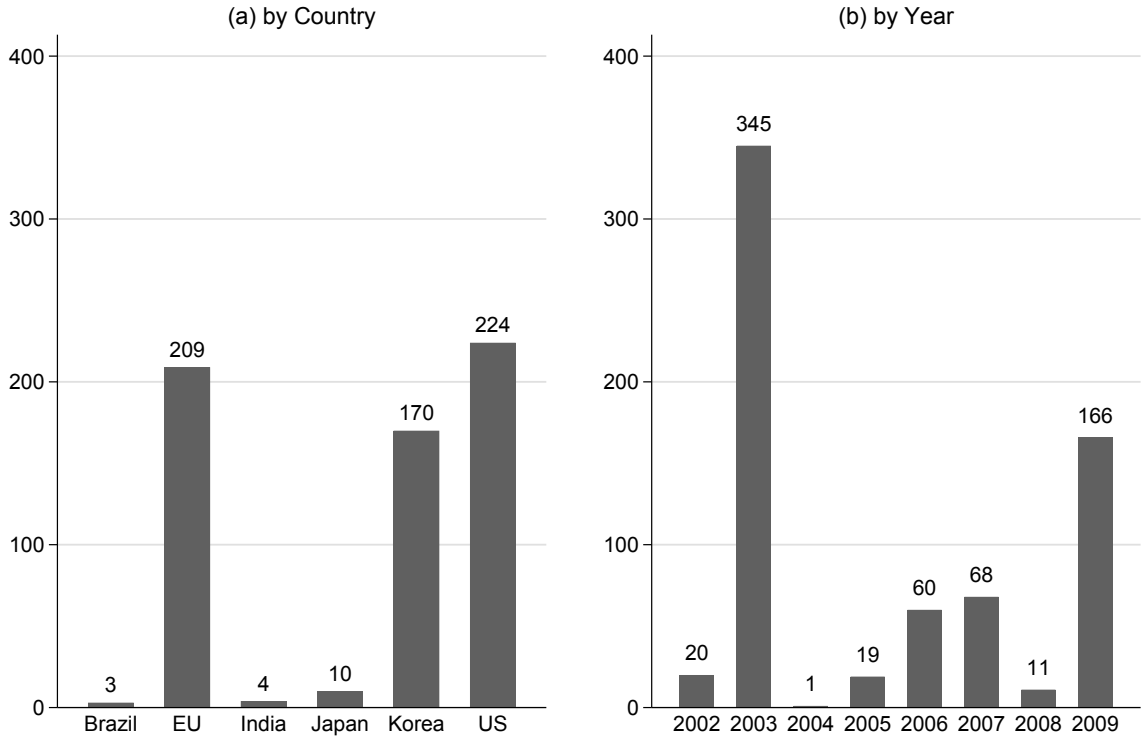
TBTs are measures widely adopted to regulate markets, protect human health and safety, preserve natural resources and protect consumers. It is required that exporters' product quality, labelling and technical standards fulfill the TBTs imposed by the importing countries. Ideally, TBTs should be transparent and unbiased. However, they can also be used to discriminate against imported products and protect domestic ones. If a WTO member thinks that another member's TBTs may unfavorably impact their particular goods, they are entitled to raise their specific trade concerns (STCs) on that TBT measure to the WTO Committee. For example, the United States notified a new TBT measure on the standards for the flammability of clothing textiles from China in 2007. Considering the requirement to be more trade restrictive than necessary, the representative of China raised an STC to the WTO Committee (Ngobi, 2016).

By compiling all the TBT concerns issued by WTO members, WTO builds up a comprehensive database on TBT STCs over the period of 1995-2011.[8] This new database has in total 318 STCs and each STC entry contains information on: (1) product code, at the Harmonized System (HS), Revision 2, four-digit level, (2) years that STCs are raised at the first time and subsequently, (3) WTO members that raise the STC on a specific TBT measure (raising country), (4) WTO members that impose the TBT measure (maintaining country).

As this paper intends to investigate the impact of restrictive TBTs on Chinese exporters, my analysis focuses on STCs raised by China against certain importing countries over the period of 2002-2009. An overview of the products under TBT concerns raised by China is provided in Figure 2.1. Panel (a) shows the total number of products under TBT concerns by the maintaining country. China raised most TBT concerns targeting the United States, the European Union and South Korea, followed by Japan, India and Brazil. The number of products under TBT concerns by year is reported in Panel (b). 2003 and 2009 have the highest number of products under TBT concerns, whereas 2004 has only one case. Figure 2.1 reveals a substantial variation of product numbers under TBT concerns across maintaining countries and time.

[8]The database on TBT STCs is retrieved 9 October 2019, from `https://www.wto.org/english/res_e/publications_e/wtr12_dataset_e.htm`.

Figure 2.1: The Number of Products under TBT Concerns by Country and Year



Note: Panel (a) shows the total number of products under TBT concerns from 2002-2009 by country. Panel (b) shows the total number of products under TBT concerns against all maintaining countries by year.

Traditional TBT notifications provide no information on whether the TBTs are restrictive or not. However, this newly available database on TBT STCs solves this issue as it only focuses on restrictive TBTs. Considering the time and effort needed to raise a concern, a WTO member will only raise an STC on a certain TBT measure if they think that the TBT is over restrictive and will potentially become a trade barrier for them (Fontagné et al., 2015). Based on this data set, I am able to proxy the restrictive TBTs, in other words, TBT concerns, using two different measurements.

TBT Dummy: The first measurement is broadly used in the literature. It equals one if China raises a TBT concern against country c on product p in year t, and zero otherwise.

TBT Duration: The second measurement is the number of years that a TBT concern remains unresolved. The data set provides information on the first year of raising a STC but no information on the year of resolution. I circumvent this problem by using the information on the date of TBT concerns that have been subsequently raised. Research

shows that the average duration of a TBT concern is two years (WTO, 2012; Fontagné and Orefice, 2018). I therefore set TBT concern to be resolved after two years if the concern is not raised again in WTO committee. For instance, if a STC was raised by China against South Korea in 2002, subsequently raised in 2004, and not re-raised in any following year, the STC is assumed to be "resolved" in 2006. After estimating the resolution year, I am able to construct the second measure, TBT duration. 50% of the TBT concerns last for two years, which is also the shortest duration of a TBT concern, while the longest duration is ten years.

The second data set used in this paper is annual China export data at firm-product(HS8)-destination-year level for the period 2000-2009. This analysis focuses on the period 2002-2009 during which the data on TBT STCs is also available. The china export data contains information on unique firm identification, product code at the 8-digit HS level, the trading year and destination country. The free-on-board value in U.S. dollars and export quantities are reported directly, from which unit values can be approximated using producer price. It also provides information on firm characteristics, such as firm size proxied by total export value, the number of firms' destination countries in each product-year combination, and firms' ownership types.

This data set directly provides the key outcome variables capturing firms' intensive margins and pricing strategy; however, firms' extensive margins (firms' decisions to participate or exit a market) cannot be directly obtained. In order to generate variables on firms' export participation and exit probability, I need to expand the data set so that each firm-product-destination combination has an observation in all years. Export value is set to zero when exports do not happen in that year by that firm-product-destination combination. The expanded data set allows me to define the following firm outcome variables $Y_{c,p,f,t}$:[9]

Firm's export participation: a dummy equals one if firm f exports a positive value of product p to country c at time t, and zero otherwise.

Firm's exit probability: a dummy equals one if firm f does not export product p to country c at time t but did so at time $t-1$, and zero if firm f does export product p to country c in both years.

[9]Note that considering firms' exit decision in year 2000 is problematic, as no information is given regarding to firms' export status in year 1999. It is arbitrary to assume that a firm does or does not export in year 1999. Thus I have to exclude the starting year of the data set and look at the extensive margin from 2001 onwards.

Apart from the aforementioned two main data sets, the tariff data at product(HS4)-year-country level are included as control variables.[10] Theoretically, the tariff and non-tariff measures can be used as substitutes or complements (Fontagné et al., 2015). In order to isolate the trade effect of restrictive TBTs from traditional tariffs, the focus of this paper, I control for bilateral tariffs between China and destination countries at HS4 product level. Note that tariffs are provided in percentage points, for example 12% tariff will be listed as 12 in the data set, I first divide tariffs by 100 (denoted as Tariff) and then calculate the logarithmic form $ln(Tariff + 1)_{c,p,t}$. The summary statistics of $ln(Tariff + 1)_{c,p,t}$ are given in Table 2.1.

Before combining the product-level TBT concerns and firm-level export data, several steps of data preparation are needed. First, data cleaning. As I want to obtain a consistent measure on firm's participation and exit, I drop occasional exporters, who export the same product to the same destination less than 4 times within the sample period. Second, product code harmonization. The China export data reports the HS1996 classification for the year 2000-2001, HS2002 classification for the year 2002-2006 and HS2007 classification for the year 2007-2009. The TBT STCs data set reports the HS2002 classification. The tariff data uses HS1992 classification. All the product codes are converted to the HS1992 classification using the concordance tables provided by UN Trade Statistics.[11] Third, exclusion of trade intermediaries. This paper aims to investigate firms' direct decisions on export, so trade intermediaries are excluded as they might behave differently when facing restrictive TBTs (Beestermöller et al., 2018). Lastly, I aggregate all exports by firm-year-destination to the HS4 level, and merge trade data with TBT concerns at this level using year, product code and destination country.

Table 2.1 reports the descriptive statistics of the sample.[12] The final data set covers the period of 2002 to 2009, with the unit observation of firm-product-destination-year. There are around 199,000 Chinese firms in total, who export 1,200 products (HS4) to 69 countries.

[10] The tariff data come from Teti (2020). The author cordially thank Teti (2020) for collecting and sharing the data set.

[11] The concordance tables are retrieved 1 November 2019, from `https://unstats.un.org/unsd/trade/classifications/correspondence-tables.asp`

[12] $ln(value)$ denotes export value of firm f exporting product p to country c at time t. $ln(price)$ denotes export price of firm f exporting product p to country c at time t. $ln(size)$ denotes firm size proxied by export value. $ln(visibility)$ denotes firm visibility proxied by sector-county-year specific export value. $ln(Tariff + 1)$ denotes tariffs in logarithmic form between China and trading countries at product level. The five variables will be described in details in the following section.

Over the sample period, China raised TBT concerns on 356 products, taking a 30% share of total exported products.

Table 2.1: Summary Statistics

	N	Mean	SD	Min	p50	Max
$ln(value)$	5,401,899	10.72	2.34	0.69	10.80	22.64
$ln(price)$	5,393,194	1.50	2.01	-9.71	1.27	18.61
$ln(size)$	17,648,240	0.16	8.42	-15.02	0.00	22.76
$ln(visibility)$	17,624,677	0.00	0.02	-0.69	0.00	0.69
$ln(Tariff+1)$	15,599,358	0.05	0.08	0.00	0.03	3.16
# Firms			198,957			
# Products			1,210			
# Products under TBT concerns			356			
# Destination countries			69			
# Product-firm pairs			848,393			
# Product-firm-destination pairs			2,238,156			

Note: Summary statistics for the final data set.

2.4 Estimation Strategy

The main objective of this paper is to explore how restrictive TBTs affect firms' extensive margins (export participation and exit probability), intensive margins (export value) and pricing strategy. To this end, I first present theoretical predictions based on the Melitz (2003) model, then test those predictions empirically using product-level TBT data and firm-level export data.

2.4.1 Theoretical Predictions

The key feature of the Melitz (2003) model is that firms are heterogeneous in productivity and face both variable (iceberg) cost and fixed entry cost in order to export. Based on the Melitz (2003) model, the impacts of restrictive TBTs on firms' export performance involve two steps.

First, the imposition of restrictive TBTs in importing country increases both fixed and variable costs of firms exporting to that country. An increased fixed cost can be initial investments in production process, packaging and labeling requirements in compliance with importing countries' standards. An increased variable cost can be due to the fact that exporters have to adapt their production, use better inputs or upgrade their products' quality to fulfill the standards of the importing country (Reyes, 2011; Bao and Qiu, 2012; Kamal and Zaki, 2018; Hu et al., 2019; Fontagné and Orefice, 2018). Maskus et al. (2005) find that TBTs raise the variable production cost by 0.06 and 0.13 percent, and raise the fixed cost by 4.7 percent, which are statistically significant increase.

Second, the increased trade costs induced by restrictive TBTs will impact firms' trade margins and pricing strategy. Specifically, firms' extensive margins are adversely affected by the rise of variable and fixed costs induced by restrictive TBTs. However, the effect on firms' intensive margin is ambiguous. A higher variable cost can reduce firms' export value to the TBT imposing country. But a higher fixed cost can drive less productive firms out of the market and reduce competition, thereby raising export value of more productive firms remaining in the market (Bernard et al., 2012). The effect on firms' export price is similarly ambiguous. The Melitz (2003) model demonstrates that a higher variable cost increases firms' export price. But more productive firms may charge a lower price, as they can comply to higher standards at lower cost (Bloom et al., 2010; Fontagné et al., 2015). But a higher fixed entry cost can drive less productive firms out of the market and reduce competition in foreign market. More productive firms remaining in the market can therefore charge a higher price.

In addition, the Melitz (2003) model emphasizes firm heterogeneity in productivity even within narrowly defined industries, and the heterogeneity is closely associated with firms' trade patterns. A more productive firm will have larger output and revenues, charge a lower price and earn higher profits than a less productive firm. Trade liberalization will induce more productive firms to enter the export market and simultaneously force the least productive firms to exit, leading to resources reallocations across firms within an industry.

Overall, the Melitz (2003) model predicts that restrictive TBTs have: (1) negative impact on firms' extensive margin, (2) both negative and positive impacts on firms' intensive margin and pricing strategy, (3) heterogeneous impacts across firms. The net effect of restrictive TBTs on firms' intensive margin and pricing strategy is theoretically ambiguous, it is therefore necessary to exploit this issue empirically.

2.4.2 Empirical Estimation

Against the aforementioned theoretical background, the aim of this section is to empirically estimate the impacts of restrictive TBTs on all firms' extensive margins as well as on incumbent firms' intensive margin and pricing strategy. There are two steps to set up the empirical specification: First, an ordinary least squares (OLS) approach is presented to illustrate the key variables and coefficients of interest. Second, an instrumental-variable (IV) strategy is employed to solve potential endogeneity issues.

Following Fontagné et al. (2015) and Fontagné and Orefice (2018), the point of departure is a simple OLS model,[13] regressing firm outcome variables on restrictive TBTs and firm characteristics:

$$\begin{aligned} Y_{c,p,f,t} =& \beta_1 TBT_{c,p,t-1} + \beta_2 ln(size)_{f,t-1} + \beta_3 (TBT_{c,p,t-1} * ln(size)_{f,t-1}) \\ &+ \beta_4 ln(visi)_{f,HS2,p,t-1} + \beta_5 (TBT_{c,p,t-1} * ln(visi)_{f,HS2,p,t-1}) \\ &+ \beta_6 ln(Tariff+1)_{c,p,t-1} + \nu_f + \nu_p + \nu_{k,c,t} + \epsilon_{c,p,f,t}. \end{aligned} \tag{2.1}$$

The firm outcome variables $Y_{c,p,f,t}$ are: (1) firm's export participation: a dummy equals 1 if firm f exports a positive value of product p to country c at time t, and 0 otherwise. (2) firm's exit probability: a dummy equals 1 if firm f does not export product p to country c at time t but did so at time $t-1$, and 0 if firm f does export product p to country c in both years. (3) export value (in logs) for firm f exporting product p to country c at time t. (4) firm's export price proxied by unit value.

The explanatory variables are restrictive TBTs, a group of firm characteristics and interaction terms between the two. Specifically, $TBT_{c,p,t-1}$ is TBT concerns raised by China against county c for product p at time $t-1$. It is measured by a TBT dummy or TBT duration. $ln(size)_{f,t-1}$ is firm size proxied by export value of firm f at $t-1$. The interaction term between firm size and TBTs is included in the regression. By doing so, I am able to link product-level TBTs and firm-level export to investigate the possible heterogeneous effect of TBTs across firm size. Based on trade theory, I expect that bigger firms, most likely more productive, should react differently to the restrictive TBTs. The coefficient of the interaction term will be the main focus of this specification. In addition, Fontagné

[13] OLS model with high-dimensional fixed effect is estimated using the STATA command "reghdfe" provided by Correia (2016).

et al. (2015) point out that large and more visible firms, in terms of export value in a certain sector and destination, may be targeted by partner countries by means of raising specific TBTs. If it were the case, highly visible firms should suffer more from the restrictive TBTs. To address this possible reverse causality, firm visibility ($ln(visi)_{f,HS2,p,t-1}$) proxied by sector(HS2)-county-year specific export value at $t-1$ and its interaction with TBTs are included.

As tariff and non-tariff measures can be either substitutes or complements, it is necessary to separate the tariff effect from the specification. Therefore the tariffs between China and country c of product p at time $t-1$ is included. Recall that the tariffs are provided in percentage points in the data set. I divide tariffs by 100 (denoted as Tariff in the equations) and calculate the logarithmic form $ln(Tariff+1)_{c,p,t-1}$, so that β_6 gives a direct estimates of the trade elasticity of tariffs.

All the explanatory variables are lagged by one year to address endogeneity bias. Indeed, the presence of a TBT concern and additional variables at $t-1$ are likely to be exogenous to firm's export decisions at t (Fontagné et al., 2015; Fontagné and Orefice, 2018; Fernandes et al., 2019; Kamal and Zaki, 2018; Kinzius et al., 2019).

A set of fixed effects are applied to absorb unobserved variations. Firm fixed effects (ν_f) are used to control for time-invariant firm-specific unobserved characteristics that might affect exporters' performance. Product fixed effects (ν_p) are used to control for time-invariant product-specific unobservable features. Sector(HS2)-destination-time fixed effects (ν_{kct}) are used to control for sector-destination-time level unobserved characteristics, such as exchange rate fluctuation, business cycle and shocks in the foreign markets. Given that both the dependent variables and main variables of interest (the interaction terms between TBTs and firm characteristics) vary at the firm-product-destination-time level, the standard errors are clustered at the product-destination-time level. ϵ_{cpft} is the error term.

Trade theory predicts that the impacts of TBTs are likely to be heterogeneous across firms. To test this prediction empirically, firm size and its interaction with TBTs are included. Moreover, the comprehensive data set enables me to further enrich the analysis by considering another two characteristics: firms' multi-destination status and ownership types.

First, the inclusion of firms' multi-destination status is inspired by Fontagné and Orefice (2018), who find that multi-destination exporters in France tend to exit the market under TBTs and look for new markets that have no TBTs (TBT-free markets) as a result of restrictive TBTs. To investigate whether such an effect holds for multi-destination ex-

porters in China, I include a multi-destination dummy ($multi_{f,p,t-2}$), which equals 1 if the number of TBT-free destinations for each firm-product-year combination is above the 90$^{\text{th}}$ percentile, and 0 otherwise. The threshold corresponds to 13 TBT-free destinations in the data set. The dummy is lagged by 2 years to circumvent potential reverse causality and ensure that its interaction with TBTs has clear indication.

Second, existing literature reveals that Chinese firms' productivity, financial access and export performance vary dramatically across ownership types (Manova et al., 2009; Song et al., 2011; Khandelwal et al., 2013; Tao et al., 2012; Brandt et al., 2012; Girma et al., 2009). It is therefore worthwhile to consider heterogeneity within ownership structure as a result of restrictive TBTs. Firms' ownership types are grouped into two categories: domestic-owned firms and foreign-owned firms. Domestic-owned firms include State-owned Enterprises (SOEs), collective and private enterprises. Foreign-owned firms contain 100% foreign-owned enterprises and joint ventures. I include a domestic dummy ($domestic_{f,t-1}$), which equals 1 if firm f is domestic at $t-1$, and 0 otherwise. Similar to previous exercise, the interaction term between domestic dummy and TBTs is also introduced.

Therefore, the OLS regressions with various firm characteristics (firm size, multi-destination status and ownership types) are given as following:

$$\begin{aligned} Y_{c,p,f,t} =& \beta_1 TBT_{c,p,t-1} + \beta_2 ln(size)_{f,t-1} + \beta_3 (TBT_{c,p,t-1} * ln(size)_{f,t-1}) \\ &+ \beta_4 ln(visi)_{f,HS2,p,t-1} + \beta_5 (TBT_{c,p,t-1} * ln(visi)_{f,HS2,p,t-1}) \\ &+ \beta_6 multi_{f,p,t-2} + \beta_7 (TBT_{c,p,t-1} * multi_{f,p,t-2}) \\ &+ \beta_8 ln(Tariff+1)_{c,p,t-1} + \nu_f + \nu_p + \nu_{k,c,t} + \epsilon_{c,p,f,t}, \end{aligned} \tag{2.2}$$

$$\begin{aligned} Y_{c,p,f,t} =& \beta_1 TBT_{c,p,t-1} + \beta_2 ln(size)_{f,t-1} + \beta_3 (TBT_{c,p,t-1} * ln(size)_{f,t-1}) \\ &+ \beta_4 ln(visi)_{f,HS2,p,t-1} + \beta_5 (TBT_{c,p,t-1} * ln(visi)_{f,HS2,p,t-1}) \\ &+ \beta_6 domestic_{f,t-1} + \beta_7 (TBT_{c,p,t-1} * domestic_{f,t-1}) \\ &+ \beta_8 ln(Tariff+1)_{c,p,t-1} + \nu_f + \nu_p + \nu_{k,c,t} + \epsilon_{c,p,f,t}. \end{aligned} \tag{2.3}$$

Though the aforementioned OLS approach can largely control the reverse causality (by adding firm visibility and using lagged explanatory variables) and unobserved variables (by adding a rich set of fixed effects), one might still worry about potential endogeneity.

For instance, unobservables might determine TBTs and firms' export decisions, or past changes in exporters' performance might determine TBTs.

To address these endogeneity concerns, an IV strategy is employed. I instrument for the TBT concerns raised by China ($TBT_{c,p,t-1}$) using the TBT concerns raised by any third country ($TBT_{j,p,t-1}$). Similarly, I instrument for the interaction terms between China-raised TBT concerns and firm characteristics ($TBT_{c,p,t-1} * Character_{f,t-1}$) using the interaction terms between third-country-raised TBT concerns and firm characteristics ($TBT_{j,p,t-1} * Character_{f,t-1}$). Note that firm characteristics includes firm size ($ln(size)_{f,t-1}$), multi-destination status ($multi_{f,p,t-2}$) and domestic ownership ($domestic_{f,t-1}$).

I argue that the third-country-raised TBT concerns and their interactions with firm characteristics constitute a valid set of instruments. First, instead of using TBT concerns raised by China over product p at time $t-1$, I use TBT concerns raised by any third country (neither China nor China's allies) over the same product p at the same time $t-1$. The rationale is that a TBT concern raised by a third country over product p at time $t-1$ is likely to be exogenous to Chinese firms' exporting behavior regarding to that product p at time t. Second, the third country should not be China's allies. If it were the case, China might collude with its ally to pursue protectionist policies by allowing its ally to raise TBT concerns that are actually in favor of Chinese firms. Therefore China's allies are excluded from the third country cohort to ensure the exogeneity of the instrument.

Similar to the previous exercise, the third-country-raised TBT concerns are measured by TBT dummy or TBT duration, and are further interacted with firm characteristics (firm size, multi-destination dummy and domestic dummy).

In the first stage, TBT concerns raised by third countries rather than China ($TBT_{j,p,t-1}$) and the interaction terms with firm characteristics ($TBT_{j,p,t-1} * Character_{f,t-1}$) are used to predict the instrumented TBT concerns ($\widehat{TBT}_{c,p,t-1}$) and instrumented interaction terms ($TBT_{c,p,t-1} * \widehat{Character}_{f,t-1}$). In the next section, first-stage coefficients and F-statistic are reported to check the relevance of the instruments.

In the second stage, I use the instrumented TBT concerns ($\widehat{TBT}_{c,p,t-1}$) and instrumented interaction terms ($TBT_{c,p,t-1} * \widehat{Character}_{f,t-1}$) predicted in the first stage to estimate the same set of firms' outcome variables. Note that firms' ownership types are rather stable over time, which implies that the domestic dummy varies largely at firm level. Thus, firm fixed effects are excluded from the IV regression when TBT concerns are interacted with domestic dummy, as illustrated in equation 2.6.

The second stage of the IV strategy consists of the following equations:

$$\begin{aligned} Y_{c,p,f,t} =& \beta_1 \widehat{TBT}_{c,p,t-1} + \beta_2 ln(size)_{f,t-1} + \beta_3 (\widehat{TBT_{c,p,t-1} * ln(size)}_{f,t-1}) \\ &+ \beta_4 ln(Tariff+1)_{c,p,t-1} + \nu_f + \nu_p + \nu_{k,c,t} + \epsilon_{c,p,f,t}, \end{aligned} \tag{2.4}$$

$$\begin{aligned} Y_{c,p,f,t} =& \beta_1 \widehat{TBT}_{c,p,t-1} + \beta_2 ln(size)_{f,t-1} + \beta_3 (\widehat{TBT_{c,p,t-1} * ln(size)}_{f,t-1}) \\ &+ \beta_4 multi_{f,p,t-2} + \beta_5 (\widehat{TBT_{c,p,t-1} * multi}_{f,p,t-2}) \\ &+ \beta_6 ln(Tariff+1)_{c,p,t-1} + \nu_f + \nu_p + \nu_{k,c,t} + \epsilon_{c,p,f,t}, \end{aligned} \tag{2.5}$$

$$\begin{aligned} Y_{c,p,f,t} =& \beta_1 \widehat{TBT}_{c,p,t-1} + \beta_2 ln(size)_{f,t-1} + \beta_3 (\widehat{TBT_{c,p,t-1} * ln(size)}_{f,t-1}) \\ &+ \beta_4 domestic_{f,t-1} + \beta_5 (\widehat{TBT_{c,p,t-1} * domestic}_{f,t-1}) \\ &+ \beta_6 ln(Tariff+1)_{c,p,t-1} + \nu_p + \nu_{k,c,t} + \epsilon_{c,p,f,t}. \end{aligned} \tag{2.6}$$

2.5 IV Estimation Results

This section presents the main findings regarding the impact of restrictive TBTs on firms' margins of trade: all firms' extensive margins (export participation and exit probability), incumbent firms' intensive margins (export values) and pricing strategy. The results obtained from the IV strategy (equations 2.4, 2.5 and 2.6) are the main results of interest. While the results from the OLS strategy (equations 2.1, 2.2 and 2.3) are used as comparisons.

2.5.1 Extensive Margin of Trade

Table 2.2 reports the impact of restrictive TBTs on firms' export participation, estimated using equations 2.4, 2.5 and 2.6. First-stage coefficients and F statistics are presented to show the relevance of the instrument. Specifically, the coefficient of $IVTBT$ is estimated using TBT as a dependent variable in the first stage. Similarly, the coefficient of $IVTBT \times Size$ is estimated using $TBT \times Size$ as a dependent variable in the first stage.

Table 2.2: The Impact of Restrictive TBTs on Firms' Export Participation

	TBT Dummy			**TBT Duration**		
	(1)	(2)	(3)	(4)	(5)	(6)
Second-stage Results						
IV TBT	-0.0054**	-0.0073***	-0.0184***	-0.0003	-0.0004**	-0.0013***
	(0.0021)	(0.0022)	(0.0029)	(0.0002)	(0.0002)	(0.0002)
IV TBT × Size	0.0011***	0.0011***	0.0021***	0.0001***	0.0001***	0.0001***
	(0.0003)	(0.0003)	(0.0003)	(0.0000)	(0.0000)	(0.0000)
IV TBT × Multi		0.0143***			0.0010***	
		(0.0021)			(0.0002)	
IV TBT × Domestic			0.0178***			0.0014***
			(0.0032)			(0.0002)
ln(tariff+1)	0.0013	0.0014	0.0028	0.0015	0.0015	0.0034
	(0.0102)	(0.0102)	(0.0099)	(0.0101)	(0.0101)	(0.0098)
First-stage Coefficients						
IV TBT	0.968***	0.968***	0.972***	0.983***	0.982***	0.985***
IV TBT × Size	0.990***	0.990***	0.991***	0.992***	0.993***	0.993***
IV TBT × Multi		0.988***			0.992***	
IV TBT × Domestic			0.979***			0.989***
First-stage F-stat	183217	183217	183217	183217	183217	183217
Observations	5,314,977	5,314,457	4,785,877	5,314,977	5,314,457	4,785,877
Firm FEs	Yes	Yes		Yes	Yes	
Product FEs	Yes	Yes	Yes	Yes	Yes	Yes
HS2-destination-time FEs	Yes	Yes	Yes	Yes	Yes	Yes
Clusters	71375	71375	71375	71375	71375	71375

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. IV regressions with firm, product and sector(HS2)-destination-time fixed effects. Robust standard errors clustered by product(HS4)-destination-time in parenthesis. TBT is measured by TBT dummy in column (1) to (3) and by TBT duration in column (4) to (6). Firm size, multi-destination dummy and domestic dummy are included but not reported when interacted with TBT.

Looking at the second stage of Table 2.2, the negative and significant coefficient of $IVTBT$ confirms the first theoretical prediction: restrictive TBTs have negative impact on firms' extensive margin. They reduce the probability of firms' export participation by approximately 0.5% (column(1)). The third theoretical prediction is also verified when the interaction terms between TBTs and firm characteristics are considered. In particular, the positive and significant coefficient of $IVTBT \times Size$ suggests that the probability of export participation increases with firm size. As firm size is measured as the deviation from the

median, the effect can be decomposed to small firms (below median size) and large firms (above median size). Namely, the negative effect of TBTs on export participation is lower for large firms. Similarly, the probability of export participation increases by 1.4% (column (2)) when the firms are multi-destination exporters and by 1.8% (column (3)) when the firms are domestic-owned exporters. Similar results are obtained when TBTs are measured by TBT duration in column (4)-(6). In short, TBTs have on average a negative effect on firms' export participation, but this negative effect is dampened for large, multi-destination and domestic-owned firms.

Table 2.3 reports the impact of restrictive TBTs on firms' exit probability. The second-stage results show that, in general, restrictive TBTs increase the probability of exit of Chinese exporters (by 1.9%, an average coefficients in column (1)-(3)). The coefficient of the interaction term between firm size and TBTs is negative, implying that big firms are less likely to exit than small firms. This finding is in line with the large literature on heterogeneous firms. Further, negative coefficients are found on the interaction terms between TBTs and multi-destination dummy as well as domestic dummy. The probability of exit decreases by 0.99% (column (2)) when the firms are multi-destination exporters and by 2.2% (column (3)) when the firms are domestic-owned exporters. Similar results are obtained when TBTs are measured by TBT duration in column (4)-(6). In short, restrictive TBTs trigger a higher exit probability but this negative effect is mitigated for large, multi-destination and domestic-owned firms.

Table 2.3: The Impact of Restrictive TBTs on Firms' Exit Probability

	TBT Dummy			**TBT Duration**		
	(1)	(2)	(3)	(4)	(5)	(6)
Second-stage Results						
IV TBT	0.0148***	0.0160***	0.0266***	0.0010***	0.0011***	0.0019***
	(0.0026)	(0.0026)	(0.0030)	(0.0002)	(0.0002)	(0.0002)
IV TBT × Size	-0.0025***	-0.0024***	-0.0020***	-0.0002***	-0.0002***	-0.0001***
	(0.0003)	(0.0003)	(0.0003)	(0.0000)	(0.0000)	(0.0000)
IV TBT × Multi		-0.0099***			-0.0006***	
		(0.0025)			(0.0002)	
IV TBT × Domestic			-0.0222***			-0.0017***
			(0.0027)			(0.0002)
ln(tariff+1)	0.0013	0.0012	-0.0032	0.0006	0.0006	-0.0040
	(0.0117)	(0.0117)	(0.0101)	(0.0117)	(0.0117)	(0.0101)
First-stage Coefficients						
IV TBT	0.949***	0.949***	0.957***	0.973***	0.973***	0.978***
IV TBT × Size	0.998***	0.998***	0.996***	0.997***	0.997***	0.997***
IV TBT × Multi		0.982***			0.990***	
IV TBT × Domestic			0.967***			0.983***
First-stage F-stat	99550	99550	99550	99550	99550	99550
Observations	2,144,810	2,144,701	2,063,220	2,144,810	2,144,701	2,063,220
Firm FEs	Yes	Yes		Yes	Yes	
Product FEs	Yes	Yes	Yes	Yes	Yes	Yes
HS2-destination-time FEs	Yes	Yes	Yes	Yes	Yes	Yes
Clusters	60650	60650	60650	60650	60650	60650

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. IV regressions with firm, product and sector(HS2)-destination-time fixed effects. Robust standard errors clustered by product(HS4)-destination-time in parenthesis. TBT is measured by TBT dummy in column (1) to (3) and by TBT duration in column (4) to (6). Firm size, multi-destination dummy and domestic dummy are included but not reported when interacted with TBT.

Both Table 2.2 and Table 2.3 show a null effect of tariffs. It is not surprising, as tariff means a rise of variable cost and affect trade mainly through the intensive margins rather than extensive margins (Fontagné and Orefice, 2018). Similar findings are confirmed by Reyes (2011), who finds that tariffs do not significantly affect firms' extensive margin.

One interesting feature is found on multi-destination firms. The behavior of multi-destination exporters in China is in sharp contrast to the ones in France. Fontagné and Orefice (2018) find that the driving-out effect of TBTs on firms' extensive margins is stronger for multi-

destination firms in France, who exit the TBT-imposed markets and divert trade to TBT-free markets. They state that this is due to low diversion cost of multi-destination firms, i.e. the cost of diverting to existing (fixed entry cost already paid) or new (need to pay fixed entry cost) TBT-free markets is lower than the cost of complying with restrictive TBTs. So the strategy for multi-destination firms in France is simply to exit the TBT-imposed markets and relocate towards TBT-free markets.

On the contrary, Chinese multi-destination firms stick to the TBT-imposed markets and continue exporting. This may due to two reasons. One reason can be that the "high productivity" feature dominates the "low diversion cost" feature of multi-destination firms in China.[14] Multi-destination exporters, being more productive, are able to overcome the higher variable and fixed costs induced by restrictive TBTs, thereby staying in the export markets, enjoying reduced competition and gaining larger market share. Another reason can be due to the feature of TBT-imposed markets. Most of the TBT concerns raised by China are targeting the US, the EU and South Korea. Those destinations, though impose restrictive TBTs, are all important trading partners of China. The benefits (large sale, high demand, stable institutions, etc.) of staying in the TBT-imposed markets can compensate or even outweigh the cost of fulfilling the restrictive TBTs. Either way can explain the different behavior between French and Chinese multi-destination firms. This empirical evidence contributes to the literature showing that developing and developed country could be affected by the same TBTs differently (Bao and Qiu, 2012).

Overall, the effects of restrictive TBTs on firms' extensive margins (Tables 2.2 and 2.3) are in line with the Melitz (2003) model. The rise of variable and fixed costs of trade induced by restrictive TBTs adversely affect firms' extensive margins. Restrictive TBTs increase the productivity cut-off below which firms exit. Least productive firms are prevented from export participation and forced to exit. Whereas big players, with respect to productivity, size, the number of export destinations and ownership types, are less affected by restrictive TBTs. Resources are reallocated from low-productive firms towards high-productive ones.

[14]Heterogeneous-firm models predict a positive relationship between a firm's productivity and the number of its export destinations (Melitz, 2003; Bernard et al., 2011). This prediction is empirically verified by Bernard et al. (2011) and Wagner (2012) using data on exporting firms in the U.S. and Germany respectively.

2.5.2 Intensive Margin of Trade

Table 2.4 reports the impact of restrictive TBTs on the value exported by incumbent firms (firms present in years $t-1$ and t). The first-stage coefficients and F statistics confirm the relevance of the instrument.

A negative effect of tariffs is revealed in the second stage, which supports the findings in Tables 2.2 and 2.3. Tariffs, as a type of extra variable cost, affect mainly the intensive margins instead of extensive margins. A ten percentage points increase in tariffs reduces export values by an average of 1.3% (column(1)-(3)). The findings are in line with Fontagné et al. (2015), who find that a ten percentage points increase in tariffs reduces export values by 1.4%, and with Fontagné and Orefice (2018) by 1.5%. Note that tariff is included as a control variable and its coefficients have to be interpreted with caution. As tariffs are normally defined at 8-, 10- or even 12-digit product level, the analysis on the 4-digit level may suffer from aggregation bias, leading to an underestimation of the tariff effect (Felbermayr et al., 2019; Fontagné et al., 2015; Fontagné and Orefice, 2018).

The negative and significant coefficients of $IVTBT$ imply that restrictive TBTs have a negative impact on the intensive margins of incumbent firms in general. Firms staying in the market lose export values by an average of 4% (column(2)-(3)). The positive and significant coefficients of interaction terms between TBTs and firm characteristics indicate heterogeneous impacts of TBTs across firms. Large, multi-destination or domestic-owned firms are less affected by restrictive TBTs. Large firms staying in the market benefit from reduced competition and gain export values by an average of 1.26% (column(1)-(3)). Multi-destination and domestic-owned firms gain export values by 11.77% (column(2)) and 7.94% (column(3)) respectively. Similar conclusion can be drawn from the results of TBT duration in column(4)-(6).

Firm heterogeneity theory predicts that restrictive TBTs have both negative and positive impact on firms' intensive margin. The empirical results show that on average the negative impact dominates the positive one, the net effect of TBTs is negative for incumbent firms. Moreover, empirical evidence is in support of the prediction of heterogeneous impacts across firms. Exporters with higher productivity suffer less from the restrictive TBTs. Specifically, large, multi-destination and domestic-owned firms are able to overcome the variable and fixed costs induced by restrictive TBTs, continue staying in the foreign market, benefit from reduced competition and gain a larger export value.

Table 2.4: The Impact of Restrictive TBTs on Firms' Export Value

	TBT Dummy			**TBT Duration**		
	(1)	(2)	(3)	(4)	(5)	(6)
Second-stage Results						
IV TBT	-0.0144	-0.0293**	-0.0538***	-0.0020*	-0.0032***	-0.0042***
	(0.0141)	(0.0144)	(0.0169)	(0.0012)	(0.0012)	(0.0014)
IV TBT × Size	0.0114***	0.0101***	0.0164***	0.0009***	0.0008***	0.0012***
	(0.0016)	(0.0016)	(0.0018)	(0.0001)	(0.0001)	(0.0001)
IV TBT × Multi		0.1177***			0.0092***	
		(0.0178)			(0.0014)	
IV TBT × Domestic			0.0794***			0.0058***
			(0.0146)			(0.0011)
ln(tariff+1)	-0.1271*	-0.1259*	-0.1476*	-0.1267*	-0.1256*	-0.1470*
	(0.0753)	(0.0753)	(0.0768)	(0.0753)	(0.0753)	(0.0768)
First-stage Coefficients						
IV TBT	0.949***	0.949***	0.957***	0.974***	0.974***	0.978***
IV TBT × Size	0.998***	0.998***	0.996***	0.997***	0.997***	0.997***
IV TBT × Multi		0.982***			0.990***	
IV TBT × Domestic			0.967***			0.984***
First-stage F-stat	99312	99312	99312	99312	99312	99312
Observations	1,732,342	1,732,280	1,666,994	1,732,342	1,732,280	1,666,994
Firm FEs	Yes	Yes		Yes	Yes	
Product FEs	Yes	Yes	Yes	Yes	Yes	Yes
HS2-destination-time FEs	Yes	Yes	Yes	Yes	Yes	Yes
Clusters	57362	57362	57362	57362	57362	57362

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. IV regressions with firm, product and sector(HS2)-destination-time fixed effects. Robust standard errors clustered by product(HS4)-destination-time in parenthesis. TBT is measured by TBT dummy in column (1) to (3) and by TBT duration in column (4) to (6). Firm size, multi-destination dummy and domestic dummy are included but not reported when interacted with TBT.

2.5.3 Pricing Strategy

Table 2.5 reports the impact of restrictive TBTs on the pricing strategy of incumbent firms (firms present in years $t-1$ and t). The price is approximated by the unit value. The coefficient of $IVTBT$ is small, suggesting an average null effect of restrictive TBTs on the export price of incumbent firms. This is not surprising, as trade theory predicts both negative and positive impacts of TBTs on firms' pricing strategy. It turns out that

neither side dominates empirically. The coefficient of interaction term between TBTs and firm size is positive and significant, meaning that large firms increase the export price by an average of 0.7% (column(1)-(3)) when facing restrictive TBTs. Similarly, multi-destination firms increase their export price by 6.7% (column(2)). The price increase of large or multi-destination firms indicates that more productive firms tend to pass-through part of the cost to their export price when facing higher cost induced by TBTs. The coefficient on the interaction term between TBTs and domestic dummy is, however, negative and significant, meaning that domestic-owned firms reduce their export price by 3.8% (column(3)) due to restrictive TBTs. Comparable results are presented using TBT duration in column(4)-(6).

Contrary pricing strategies are found among large or multi-destination firms and domestic-owned firms. It can be due to the different features of those firms. On the one hand, large or multi-destination firms belong to the highly productive group (Melitz, 2003; Mayer and Ottaviano, 2008; Bernard et al., 2011; Wagner, 2012). In the model of heterogeneous firms, more productive firms are able to cope with higher variable and fixed costs of restrictive TBTs. They enter the international markets and simultaneously drive the least productive firms out, thereby enjoying a reduced competition and larger market share. Besides, those firms have a lower demand elasticity, it is possible for them to pass-through part of the increased cost to the customers by charging a higher export price. On the other hand, domestic-owned firms are less productive than the other two. Their demand elasticity is higher than for more efficient firms. It is more likely for them to reduce the price by less then the cost, in order to survive in the international competition and capture some market share (Manova and Zhang, 2012).

Firm heterogeneity theory predicts both positive and negative impact of TBTs on firms' pricing strategy. In fact, neither side dominates the final effect, as an average null effect is obtained from the empirical results. In addition, empirical evidence is in line with the prediction of heterogeneous impacts across firms. Given the same TBTs, the most productive firms (large and multi-destination firms) charge a higher price, whereas the less productive ones (domestic-owned firms) charge a lower price.

Table 2.5: The Impact of Restrictive TBTs on Firms' Pricing Strategy

	TBT Dummy			**TBT Duration**		
	(1)	(2)	(3)	(4)	(5)	(6)
Second-stage Results						
IV TBT	0.0113	0.0027	0.0123	-0.0001	-0.0007	0.0004
	(0.0104)	(0.0106)	(0.0139)	(0.0008)	(0.0008)	(0.0011)
IV TBT × Size	0.0060***	0.0053***	0.0099***	0.0005***	0.0004***	0.0007***
	(0.0009)	(0.0009)	(0.0012)	(0.0001)	(0.0001)	(0.0001)
IV TBT × Multi		0.0675***			0.0049***	
		(0.0080)			(0.0006)	
IV TBT × Domestic			-0.0375***			-0.0032***
			(0.0103)			(0.0008)
ln(tariff+1)	0.0171	0.0178	0.0411	0.0166	0.0171	0.0407
	(0.0410)	(0.0410)	(0.0502)	(0.0411)	(0.0411)	(0.0503)
First-stage Coefficients						
IV TBT	0.949***	0.949***	0.957***	0.974***	0.974***	0.978***
IV TBT × Size	0.998***	0.998***	0.996***	0.997***	0.997***	0.997***
IV TBT × Multi		0.982***			0.990***	
IV TBT × Domestic			0.967***			0.984***
First-stage F-stat	99569	99569	99569	99569	99569	99569
Observations	1,729,202	1,729,140	1,664,038	1,729,202	1,729,140	1,664,038
Firm FEs	Yes	Yes		Yes	Yes	
Product FEs	Yes	Yes	Yes	Yes	Yes	Yes
HS2-destination-time FEs	Yes	Yes	Yes	Yes	Yes	Yes
Clusters	57331	57331	57331	57331	57331	57331

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. IV regressions with firm, product and sector(HS2)-destination-time fixed effects. Robust standard errors clustered by product(HS4)-destination-time in parenthesis. TBT is measured by TBT dummy in column (1) to (3) and by TBT duration in column (4) to (6). Firm size, multi-destination dummy and domestic dummy are included but not reported when interacted with TBT.

To wrap up, the IV results support the theoretical predictions and reveal the heterogeneous impacts of restrictive TBTs across firms. Restrictive TBTs have a negative average impact on firms' extensive and intensive margins: firms are deterred from export participation and suffer higher exit rates; incumbent firms face a loss of export values. However, more "able" firms, that are larger, have more export destinations or domestic ownership, can dampen the negative impact of restrictive TBTs on firms' export decisions. They are able to overcome the higher variable and fixed costs induced by restrictive TBTs, survive in the

international markets, enjoy reduced competition and gain higher export values. Lastly, a null average effect of TBTs on firms' pricing strategy is discovered. More specifically, given the same restrictive TBTs, large and multi-destination firms (most productive ones) tend to pass-through part of the increased cost to their consumers by charging a higher price, while domestic-owned firms (less productive ones) tend to decrease their export price by less than cost.

2.6 Extensions and Robustness Checks

2.6.1 Alternative Estimation: OLS

The previous section discusses the main results using IV estimation. This section presents a number of robustness checks using OLS estimation based on equations 2.1, 2.2 and 2.3. The key results are summarized in Table 2.6 and details are reported in Tables 2.9 - 2.12 in the Appendix.

First, panel A and panel B show that the impact of restrictive TBTs on firms' extensive margins remain negative and significant, with the effect being attenuated for large, multi-destination and domestic-owned firms. Interestingly, the coefficients on the TBTs and interaction terms using OLS estimation are somewhat smaller than the main results, suggesting that the negative effect on firms' extensive margins are underestimated in OLS.

Interesting results are found for firms' visibility. Recall that firms' visibility and its interaction with TBTs are added to control for reverse causality. If a firm were highly visible, in the sense that its export value is large in a sector-destination-year combination, it could be targeted by the importing country via purposed TBTs. If it were the case, a reverse causality should arise and a significant (positive or negative depending on the firm outcome variables) coefficient on the interaction term between visibility and TBTs is expected. Luckily, the estimation on export participation (panel A) does not suffer from reverse causality. The coefficient on the interaction term between visibility and TBTs is insignificant using TBT dummy (column (1)-(3)) and positive using TBT duration (column (4)-(6)), which means that highly visible firms are not purposely targeted. Otherwise those firms should be prevented from export participation - negative and significant coefficient. However, estimation on exit probability (panel B) suffers from an endogeneity problem, as the coefficient between visibility and TBT dummy is positive and significant (column (1)-(3)), implying

that highly visible firms are strongly affected by TBTs and tend to exit the foreign market. In this case, it is especially necessary to utilize IV strategy as the main method to settle a clean causal relationship.

Second, panel C of Table 2.6 shows the impact of restrictive TBTs on incumbent firms' export values. The OLS estimation fails to capture the negative average impact of TBTs, as the coefficient on TBT is insignificant (except for column(5)-(6)). However, it indeed captures the heterogeneous impacts of restrictive TBTs across firms. Same as the IV results, firms with larger size, more export destinations or domestic ownership have higher export value when facing restrictive TBTs. These findings are in line with the theoretical predictions. Moreover, the positive and significant coefficient between visibility and TBTs is favorable, as it indicates that highly-visible firms are not targeted more by restrictive TBTs, thereby suggesting that the OLS estimation does not suffer from endogeneity bias.

Third, panel D of Table 2.6 shows the impact of restrictive TBTs on incumbent firms' pricing strategy. Crucially, the OLS estimation fails to capture the key feature of the domestic-owned firms. The main results using the IV strategy (Table 2.5) find that domestic-owned firms tend to reduce the export price when facing restrictive TBTs. Thus a negative and significant coefficient on the interaction term between domestic dummy and TBTs is expected. However, the OLS results in Table 2.6 show that the coefficient is insignificant using TBT dummy and positive using TBT duration, indicating an estimation bias of OLS. In addition, the OLS estimation suffers from endogeneity as a significant coefficient on the interaction term between visibility and TBT duration (column (4)-(6)) is discovered.

Table 2.6: Alternative Estimation: OLS

	TBT Dummy			**TBT Duration**		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Export Participation						
TBT	-0.0044**	-0.0058***	-0.0123***	-0.0003*	-0.0005***	-0.0010***
	(0.0020)	(0.0020)	(0.0027)	(0.0002)	(0.0002)	(0.0002)
TBT × Size	0.0006**	0.0005*	0.0013***	0.0001***	0.0001***	0.0001***
	(0.0003)	(0.0003)	(0.0003)	(0.0000)	(0.0000)	(0.0000)
TBT × Visibility	0.0605	0.0488	0.0165	0.0220***	0.0206***	0.0184***
	(0.0580)	(0.0577)	(0.0582)	(0.0058)	(0.0058)	(0.0058)
TBT × Multi		0.0116***			0.0009***	
		(0.0020)			(0.0002)	
TBT × Domestic			0.0133***			0.0010***
			(0.0031)			(0.0002)
Panel B: Exit Probability						
TBT	0.0113***	0.0123***	0.0187***	0.0010***	0.0010***	0.0015***
	(0.0022)	(0.0023)	(0.0027)	(0.0002)	(0.0002)	(0.0002)
TBT × Size	-0.0025***	-0.0024***	-0.0027***	-0.0002***	-0.0002***	-0.0002***
	(0.0003)	(0.0003)	(0.0003)	(0.0000)	(0.0000)	(0.0000)
TBT × Visibility	0.0706*	0.0771*	0.0810*	0.0029	0.0035	0.0039
	(0.0427)	(0.0426)	(0.0428)	(0.0040)	(0.0040)	(0.0040)
TBT × Multi		-0.0087***			-0.0005***	
		(0.0024)			(0.0002)	
TBT × Domestic			-0.0123***			-0.0009***
			(0.0024)			(0.0002)
Panel C: Export Value						
TBT	-0.0051	-0.0161	-0.0242	-0.0018	-0.0027**	-0.0045***
	(0.0134)	(0.0135)	(0.0154)	(0.0012)	(0.0012)	(0.0013)
TBT × Size	0.0087***	0.0076***	0.0084***	0.0006***	0.0005***	0.0006***
	(0.0015)	(0.0015)	(0.0015)	(0.0001)	(0.0001)	(0.0001)
TBT × Visibility	2.2363***	2.1525***	2.0894***	0.3398***	0.3306***	0.3261***
	(0.5002)	(0.4993)	(0.4993)	(0.0515)	(0.0514)	(0.0514)
TBT × Multi		0.0987***			0.0074***	
		(0.0168)			(0.0014)	
TBT × Domestic			0.0416***			0.0062***
			(0.0159)			(0.0013)
Panel D: Pricing Strategy						
TBT	-0.0005	-0.0074	0.0017	-0.0003	-0.0009	-0.0010
	(0.0090)	(0.0091)	(0.0093)	(0.0008)	(0.0008)	(0.0008)
TBT × Size	0.0062***	0.0055***	0.0054***	0.0005***	0.0004***	0.0004***
	(0.0009)	(0.0009)	(0.0009)	(0.0001)	(0.0001)	(0.0001)
TBT × Visibility	0.2395	0.1873	0.2363	0.0355**	0.0295*	0.0345**
	(0.1546)	(0.1552)	(0.1546)	(0.0172)	(0.0173)	(0.0172)
TBT × Multi		0.0621***			0.0048***	
		(0.0077)			(0.0006)	
TBT × Domestic			-0.0053			0.0015**
			(0.0091)			(0.0008)

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. For details see Tables 2.9 - 2.12 in the Appendix.

2.6.2 Decomposition of Firm Characteristics

Table 2.7 reports a number of heterogeneity when firm characteristics are decomposed. Each panel shows the coefficients on the interaction terms between restrictive TBTs and one type of firm characteristics that is decomposed. Restrictive TBTs are measured by TBT dummy (column(1)-(4)) or TBT duration (column(5)-(8)). In each case, four outcome variables are considered: firms' export participation, exit probability, export value and pricing strategy.

Small vs. Large Firms First, Panel A of Table 2.7 decomposes firm size into small (below the median) and large (above the median) firms. IV regression is implemented for each of the size category based on equation 2.4. Columns (1) and (2) of Panel A estimate firms' extensive margins. I find that compared to small firms, large firms can strongly mitigate the negative impact of restrictive TBTs on firms' extensive margins. Column (3) shows that the effects of restrictive TBTs on export value differ across firm size: small firms have lower, whereas large firms have higher export values. Price effects reported in Column(4) are insignificant for small firms while positive and significant for large firms, indicating that large firms charge a higher price. Similar patterns are found using TBT duration to measure restrictive TBTs in Columns (5)-(8). The results in Panel A are in line with the main IV results: the negative impacts of restrictive TBTs decline with firm size. Contrary to small firms, large firms are able to stay in the market, increase export value and charge a higher price.

Based on the literature observing the correlation between firm size and productivity, the results in Panel A imply that given the same restrictive TBTs, more productive firms (larger firms) increase export participation and expand export value relative to less productive ones (smaller ones), they also pass-through part of the cost to consumers by charging a higher price.

The 95^{th} vs. 85^{th} Percentile of Multi-destination Dummy Second, Panel B changes the measure of the multi-destination dummy. In the main specification, the multi-destination dummy equals 1 if the number of TBT-free destinations served by a firm-product combination at $t-2$ is above the 90^{th} percentile. As a robustness check, I change the thresholds to both above and below the main setting: the 95^{th} and 85^{th} percentiles are used as alternative thresholds to define the multi-destination dummy. The 95^{th} percentile is stricter than the other one, implying that the defined multi-destination firms export to "exceptionally

many" countries, they can be seen as *super* multi-destination firms. An IV regression is implemented for each of the measure based on equation 2.5. The results reported in Panel B suggest that the main IV results remain robust to different measures of multi-destination dummy. If anything, the magnitude of the coefficient is larger for *super* multi-destination firms (above 95^{th} percentile). Similar patterns are found using TBT duration in Column (5)-(8).

According to the literature observing the correlation between firms' productivity and the number of destinations, the results in Panel B imply that given the same restrictive TBTs, *super* multi-destination firms, being more productive, have a higher probability to participate in the export market, a lower probability to exit, and a larger increase in export value and price.

State- vs. Private-owned Firms Third, Panel C decomposes domestic-owned firms into two categories: State-owned enterprises (SOEs) and private-owned enterprises (private).[15] An IV regression is implemented for each of the category based on equation 2.6. In line with the main results, Columns (1)-(3) show that domestic-owned firms, both SOEs and private ones, suffer less from the negative impact of restrictive TBTs on firms' extensive and intensive margins. Both types of firms participate in the export market and increase their export value. Interestingly, however, price effects reported in Column(4) is significant and *negative* for SOEs whereas *positive* for private firms, indicating that the main results (Table 2.5) of a negative price effect on domestic-owned firms is mainly driven by SOEs rather than private firms. Similar patterns are found using TBT duration in Column (5)-(8).

A growing body of literature reveals that SOEs in China are often inefficient and unproductive, while at the same time, they receive more support from the government and have better financial access (Khandelwal et al., 2013; Tao et al., 2012; Song et al., 2011). Against this background, the results in Panel C indicate that given the same TBTs, more productive firms (private firms) pass-through part of the increased cost to their export price, whereas less productive firms (SOEs) reduce their export price by less than cost to remain competitive in the international market. This indication in turn confirms my explanation on the different pricing strategies in section 2.5.

[15]private-owned firms consist of collective-owned and private-owned ones. Collective-owned firms, owned by a certain number of individuals, are also a type of private ownership.

Table 2.7: Decomposition of Firm Characteristics (Second-stage IV)

	TBT Dummy				TBT Duration			
	(1) Export Participation	(2) Exit Probability	(3) Export Value	(4) Pricing Strategy	(5) Export Participation	(6) Exit Probability	(7) Export Value	(8) Pricing Strategy
Panel A: Firm Size								
IV TBT × Small firms	-0.0005	-0.0011	-0.0193**	-0.0040	-0.0000	-0.0000	-0.0016***	-0.0003
	(0.0004)	(0.0013)	(0.0080)	(0.0042)	(0.0000)	(0.0001)	(0.0006)	(0.0003)
IV TBT × Large firms	0.0036***	-0.0018***	0.0120***	0.0051***	0.0003***	-0.0001***	0.0009***	0.0004***
	(0.0003)	(0.0003)	(0.0018)	(0.0010)	(0.0000)	(0.0000)	(0.0001)	(0.0001)
Panel B: Multi-destination Dummy								
IV TBT × Multi (95th percentile)	0.0224***	-0.0165***	0.1082***	0.0681***	0.0016***	-0.0011***	0.0083***	0.0048***
	(0.0027)	(0.0028)	(0.0216)	(0.0100)	(0.0002)	(0.0002)	(0.0017)	(0.0008)
IV TBT × Multi (85th percentile)	0.0116***	-0.0068***	0.0681***	0.0534***	0.0009***	-0.0004**	0.0050***	0.0039***
	(0.0019)	(0.0022)	(0.0156)	(0.0071)	(0.0001)	(0.0002)	(0.0012)	(0.0005)
Panel C: Domestic Dummy								
IV TBT × SOEs	0.0053**	-0.0148***	0.0611***	-0.1611***	0.0006***	-0.0012***	0.0043***	-0.0128***
	(0.0026)	(0.0025)	(0.0149)	(0.0113)	(0.0002)	(0.0002)	(0.0012)	(0.0009)
IV TBT × Private	0.0148***	-0.0143***	0.0425***	0.0818***	0.0010***	-0.0011***	0.0032***	0.0060***
	(0.0025)	(0.0030)	(0.0151)	(0.0107)	(0.0002)	(0.0002)	(0.0012)	(0.0008)

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. IV regressions with firm, product and sector(HS2)-destination-time fixed effects in panel A and B, product and sector(HS2)-destination-time fixed effects in panel C. Robust standard errors clustered by product(HS4)-destination-time in parenthesis. TBT is measured by TBT dummy in column (1) to (4) and by TBT duration in column (5) to (8). Firm size, multi-destination dummy and domestic dummy are included but not reported when interacted with TBT.

2.6.3 Exclusion of Big Firms

Endogeneity bias may arise if big firms are powerful enough to push government to raise TBT concerns in favor of their needs. I therefore exclude big firms to address the potential endogeneity. Big firms are defined as those whose export value of product-destination combination is above the 99^{th} percentile. They account for 16% of the total firms. Main results are reported in Table 2.8. Panel A and panel B show that the impact of restrictive TBTs on firms' extensive margins remain negative and significant, with the effect being compensated for large, multi-destination and domestic-owned firms. Panel C reveals that excluding big firms fails to capture the negative average impact of restrictive TBTs on export value, but it is able to capture the heterogeneous impacts of TBTs across firms. Panel D reports the impact of restrictive TBTs on incumbent firms' pricing strategy. The results show a null average effect on price and heterogeneous impacts across firms, which is in line with the main findings.

Table 2.8: Exclusion of Big Firms (Second-stage IV)

	TBT Dummy			TBT Duration		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Export Participation						
IV TBT	-0.0041**	-0.0060***	-0.0172***	-0.0002	-0.0003*	-0.0012***
	(0.0021)	(0.0021)	(0.0029)	(0.0002)	(0.0002)	(0.0002)
IV TBT × Size	0.0011***	0.0011***	0.0020***	0.0001***	0.0001***	0.0001***
	(0.0003)	(0.0003)	(0.0003)	(0.0000)	(0.0000)	(0.0000)
IV TBT × Multi		0.0140***			0.0010***	
		(0.0021)			(0.0002)	
IV TBT × Domestic			0.0178***			0.0015***
			(0.0033)			(0.0002)
First-stage F-stat	188005	188005	188005	188005	188005	188005
Panel B: Exit Probability						
IV TBT	0.0142***	0.0153***	0.0254***	0.0010***	0.0010***	0.0018***
	(0.0026)	(0.0026)	(0.0030)	(0.0002)	(0.0002)	(0.0002)
IV TBT × Size	-0.0026***	-0.0025***	-0.0019***	-0.0002***	-0.0002***	-0.0001***
	(0.0003)	(0.0003)	(0.0003)	(0.0000)	(0.0000)	(0.0000)
IV TBT × Multi		-0.0097***			-0.0006***	
		(0.0025)			(0.0002)	
IV TBT × Domestic			-0.0225***			-0.0018***
			(0.0028)			(0.0002)
First-stage F-stat	102456	102456	102456	102456	102456	102456
Panel C: Export Value						
IV TBT	0.0088	-0.0056	0.0085	0.0001	-0.0010	0.0008
	(0.0128)	(0.0131)	(0.0151)	(0.0011)	(0.0011)	(0.0012)
IV TBT × Size	0.0139***	0.0127***	0.0108***	0.0011***	0.0010***	0.0008***
	(0.0014)	(0.0014)	(0.0015)	(0.0001)	(0.0001)	(0.0001)
IV TBT × Multi		0.1127***			0.0087***	
		(0.0160)			(0.0012)	
IV TBT × Domestic			0.0785***			0.0063***
			(0.0128)			(0.0010)
First-stage F-stat	102887	102887	102887	102887	102887	102887
Panel D: Pricing Strategy						
IV TBT	0.0123	0.0036	0.0140	0.0002	-0.0004	0.0007
	(0.0104)	(0.0105)	(0.0136)	(0.0008)	(0.0008)	(0.0011)
IV TBT × Size	0.0062***	0.0055***	0.0083***	0.0005***	0.0005***	0.0006***
	(0.0009)	(0.0009)	(0.0012)	(0.0001)	(0.0001)	(0.0001)
IV TBT × Multi		0.0679***			0.0050***	
		(0.0082)			(0.0006)	
IV TBT × Domestic			-0.0237**			-0.0020**
			(0.0102)			(0.0008)
First-stage F-stat	103169	103169	103169	103169	103169	103169

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. For details see Tables 2.13 - 2.16 in the Appendix.

2.7 Conclusion

This paper investigates the impact of restrictive TBTs on firms' export decisions, with heterogeneous trade effects across firms. A rich set of firms' outcome variables is exploited: firms' decisions on whether participate or exit the product-destination market (extensive margins), firms' export values on a product-destination market (intensive margins) and firms' pricing strategy. Crucially, the analysis accounts for the heterogeneous effects of restrictive TBTs on a number of firm characteristics: firm size, multi-destination status and ownership types.

The empirical results are estimated using an IV approach. First, the empirical results on firms' extensive margins are in line with theoretical predictions. Restrictive TBTs deter firms from export participation and induce higher exit rate. These negative effects are mitigated for large, multi-destination and domestic-owned firms. Interestingly, the behavior of multi-destination firms in China is in sharp contrast to the ones in France. Instead of diverting trade to TBT-free markets, multi-destination firms in China stick to the TBT-imposed markets and continue exporting.

Second, for the intensive margins, trade theory predicts both negative and positive impacts of restrictive TBTs. The empirical results show that the negative impact dominates. In line with the prediction of heterogeneous impacts across firms, I find that large, multi-destination and domestic-owned firms that remain in the market can benefit from reduced competition and gain larger export values.

Lastly, for the pricing strategy, trade theory predicts both negative and positive impacts, while the empirical results show that neither side dominates, as an average null effect is discovered. In line with the prediction of heterogeneous impacts, I find that the price strategies vary across firms. For firms remaining in the market, the most productive firms (large and multi-destination ones) charge a higher price, whereas the less productive firms (domestic-owned ones) charge a lower price. By dividing domestic-owned firms into state-owned and private-owned ones, I further show that the price-decreasing effect is mainly driven by state-owned firms.

Overall, I find that the imposition of restrictive TBTs adversely affect firms' intensive and extensive margins, but not significantly affect firms' price on average. More importantly, firms of different types, in the sense of firm size, number of destination markets and ownership types, are affected differently. Given the same restrictive TBTs, firms with higher

productivity suffer less, while firms with lower productivity are more vulnerable to trade barriers.

This paper contributes to the large literature on firm heterogeneity and the role of NTMs on trade, and also provides important political implications. Policy makers should consider the heterogeneous effects of trade agreements, which shifts gains from trade across firms and potentially distorting competition. By taking the performance and benefits (or costs) of individual firm into account, policy makers can better enhance social welfare in trade negotiations.

2.8 Appendix

Table 2.9: OLS, the Impact of Restrictive TBTs on Firms' Export Participation

	TBT Dummy			**TBT Duration**		
	(1)	(2)	(3)	(4)	(5)	(6)
Export Participation						
TBT	-0.0044**	-0.0058***	-0.0123***	-0.0003*	-0.0005***	-0.0010***
	(0.0020)	(0.0020)	(0.0027)	(0.0002)	(0.0002)	(0.0002)
TBT × Size	0.0006**	0.0005*	0.0013***	0.0001***	0.0001***	0.0001***
	(0.0003)	(0.0003)	(0.0003)	(0.0000)	(0.0000)	(0.0000)
TBT × Visibility	0.0605	0.0488	0.0165	0.0220***	0.0206***	0.0184***
	(0.0580)	(0.0577)	(0.0582)	(0.0058)	(0.0058)	(0.0058)
TBT × Multi		0.0116***			0.0009***	
		(0.0020)			(0.0002)	
TBT × Domestic			0.0133***			0.0010***
			(0.0031)			(0.0002)
ln(tariff+1)	0.0018	0.0019	0.0040	0.0013	0.0013	0.0039
	(0.0101)	(0.0101)	(0.0102)	(0.0101)	(0.0101)	(0.0101)
Observations	5,313,505	5,312,987	4,782,874	5,313,505	5,312,987	4,782,874
Firm FEs	Yes	Yes	Yes	Yes	Yes	Yes
Product FEs	Yes	Yes	Yes	Yes	Yes	Yes
HS2-destination-time FEs	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R square	0.340	0.340	0.340	0.340	0.340	0.340
Clusters	70794	70794	70794	70794	70794	70794

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. OLS regressions with firm, product and sector(HS2)-destination-time fixed effects. Robust standard errors clustered by product(HS4)-destination-time in parenthesis. TBT is measured by TBT dummy in column (1) to (3) and by TBT duration in column (4) to (6). Firm size, firms' visibility, multi-destination dummy and domestic dummy are included but not reported when interacted with TBT.

Table 2.10: OLS, the Impact of Restrictive TBTs on Firms' Exit Probability

	TBT Dummy			**TBT Duration**		
	(1)	(2)	(3)	(4)	(5)	(6)
Exit Probability						
TBT	0.0113***	0.0123***	0.0187***	0.0010***	0.0010***	0.0015***
	(0.0022)	(0.0023)	(0.0027)	(0.0002)	(0.0002)	(0.0002)
TBT × Size	-0.0025***	-0.0024***	-0.0027***	-0.0002***	-0.0002***	-0.0002***
	(0.0003)	(0.0003)	(0.0003)	(0.0000)	(0.0000)	(0.0000)
TBT × Visibility	0.0706*	0.0771*	0.0810*	0.0029	0.0035	0.0039
	(0.0427)	(0.0426)	(0.0428)	(0.0040)	(0.0040)	(0.0040)
TBT × Multi		-0.0087***			-0.0005***	
		(0.0024)			(0.0002)	
TBT × Domestic			-0.0123***			-0.0009***
			(0.0024)			(0.0002)
ln(tariff+1)	0.0019	0.0019	0.0007	0.0013	0.0013	-0.0001
	(0.0116)	(0.0116)	(0.0116)	(0.0116)	(0.0116)	(0.0116)
Observations	2,144,807	2,144,698	2,059,284	2,144,807	2,144,698	2,059,284
Firm FEs	Yes	Yes	Yes	Yes	Yes	Yes
Product FEs	Yes	Yes	Yes	Yes	Yes	Yes
HS2-destination-time FEs	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R square	0.120	0.120	0.120	0.120	0.120	0.120
Clusters	60614	60614	60614	60614	60614	60614

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. OLS regressions with firm, product and sector(HS2)-destination-time fixed effects. Robust standard errors clustered by product(HS4)-destination-time in parenthesis. TBT is measured by TBT dummy in column (1) to (3) and by TBT duration in column (4) to (6). Firm size, firms' visibility, multi-destination dummy and domestic dummy are included but not reported when interacted with TBT.

Table 2.11: OLS, the Impact of Restrictive TBTs on Firms' Intensive Margins

	TBT Dummy			**TBT Duration**		
	(1)	(2)	(3)	(4)	(5)	(6)
Export Value						
TBT	-0.0051	-0.0161	-0.0242	-0.0018	-0.0027**	-0.0045***
	(0.0134)	(0.0135)	(0.0154)	(0.0012)	(0.0012)	(0.0013)
TBT × Size	0.0087***	0.0076***	0.0084***	0.0006***	0.0005***	0.0006***
	(0.0015)	(0.0015)	(0.0015)	(0.0001)	(0.0001)	(0.0001)
TBT × Visibility	2.2363***	2.1525***	2.0894***	0.3398***	0.3306***	0.3261***
	(0.5002)	(0.4993)	(0.4993)	(0.0515)	(0.0514)	(0.0514)
TBT × Multi		0.0987***			0.0074***	
		(0.0168)			(0.0014)	
TBT × Domestic			0.0416***			0.0062***
			(0.0159)			(0.0013)
ln(tariff+1)	-0.1484**	-0.1475**	-0.1420*	-0.1500**	-0.1493**	-0.1399*
	(0.0737)	(0.0737)	(0.0735)	(0.0738)	(0.0737)	(0.0734)
Observations	1,732,339	1,732,277	1,659,681	1,732,339	1,732,277	1,659,681
Firm FEs	Yes	Yes	Yes	Yes	Yes	Yes
Product FEs	Yes	Yes	Yes	Yes	Yes	Yes
HS2-destination-time FEs	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R square	0.295	0.295	0.295	0.295	0.295	0.295
Clusters	57304	57304	57304	57304	57304	57304

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. OLS regressions with firm, product and sector(HS2)-destination-time fixed effects. Robust standard errors clustered by product(HS4)-destination-time in parenthesis. TBT is measured by TBT dummy in column (1) to (3) and by TBT duration in column (4) to (6). Firm size, firms' visibility, multi-destination dummy and domestic dummy are included but not reported when interacted with TBT.

Table 2.12: OLS, the Impact of Restrictive TBTs on Firms' Pricing Strategy

	TBT Dummy			**TBT Duration**		
	(1)	(2)	(3)	(4)	(5)	(6)
Pricing Strategy						
TBT	-0.0005	-0.0074	0.0017	-0.0003	-0.0009	-0.0010
	(0.0090)	(0.0091)	(0.0093)	(0.0008)	(0.0008)	(0.0008)
TBT × Size	0.0062***	0.0055***	0.0054***	0.0005***	0.0004***	0.0004***
	(0.0009)	(0.0009)	(0.0009)	(0.0001)	(0.0001)	(0.0001)
TBT × Visibility	0.2395	0.1873	0.2363	0.0355**	0.0295*	0.0345**
	(0.1546)	(0.1552)	(0.1546)	(0.0172)	(0.0173)	(0.0172)
TBT × Multi		0.0621***			0.0048***	
		(0.0077)			(0.0006)	
TBT × Domestic			-0.0053			0.0015**
			(0.0091)			(0.0008)
ln(tariff+1)	0.0169	0.0175	0.0278	0.0164	0.0169	0.0293
	(0.0411)	(0.0411)	(0.0392)	(0.0411)	(0.0411)	(0.0392)
Observations	1,729,199	1,729,137	1,656,702	1,729,199	1,729,137	1,656,702
Firm FEs	Yes	Yes	Yes	Yes	Yes	Yes
Product FEs	Yes	Yes	Yes	Yes	Yes	Yes
HS2-destination-time FEs	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R square	0.754	0.754	0.754	0.754	0.754	0.754
Clusters	57273	57273	57273	57273	57273	57273

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. OLS regressions with firm, product and sector(HS2)-destination-time fixed effects. Robust standard errors clustered by product(HS4)-destination-time in parenthesis. TBT is measured by TBT dummy in column (1) to (3) and by TBT duration in column (4) to (6). Firm size, firms' visibility, multi-destination dummy and domestic dummy are included but not reported when interacted with TBT.

Table 2.13: Exclusion of Big Firms, the Impact of TBTs on Firms' Export Participation (Second-stage IV)

	TBT Dummy			**TBT Duration**		
	(1)	(2)	(3)	(4)	(5)	(6)
Export Participation						
IV TBT	-0.0041**	-0.0060***	-0.0172***	-0.0002	-0.0003*	-0.0012***
	(0.0021)	(0.0021)	(0.0029)	(0.0002)	(0.0002)	(0.0002)
IV TBTSize	0.0011***	0.0011***	0.0020***	0.0001***	0.0001***	0.0001***
	(0.0003)	(0.0003)	(0.0003)	(0.0000)	(0.0000)	(0.0000)
IV TBTMulti		0.0140***			0.0010***	
		(0.0021)			(0.0002)	
IV TBTDomestic			0.0178***			0.0015***
			(0.0033)			(0.0002)
ln(tariff+1)	0.0038	0.0038	0.0036	0.0039	0.0040	0.0042
	(0.0101)	(0.0101)	(0.0098)	(0.0101)	(0.0101)	(0.0097)
Observations	5,239,770	5,239,252	4,713,593	5,239,770	5,239,252	4,713,593
Firm FEs	Yes	Yes		Yes	Yes	
Product FEs	Yes	Yes	Yes	Yes	Yes	Yes
HS2-destination-time FEs	Yes	Yes	Yes	Yes	Yes	Yes
Clusters	71303	71303	71303	71303	71303	71303
First-stage F-stat	188005	188005	188005	188005	188005	188005

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. IV regressions with firm, product and sector(HS2)-destination-time fixed effects. Robust standard errors clustered by product(HS4)-destination-time in parenthesis. TBT is measured by TBT dummy in column (1) to (3) and by TBT duration in column (4) to (6). Firm size, multi-destination dummy and domestic dummy are included but not reported when interacted with TBT.

Table 2.14: Exclusion of Big Firms, the Impact of TBTs on Firms' Exit Probability (Second-stage IV)

	TBT Dummy			**TBT Duration**		
	(1)	(2)	(3)	(4)	(5)	(6)
Exit Probability						
IV TBT	0.0142***	0.0153***	0.0254***	0.0010***	0.0010***	0.0018***
	(0.0026)	(0.0026)	(0.0030)	(0.0002)	(0.0002)	(0.0002)
IV TBTSize	-0.0026***	-0.0025***	-0.0019***	-0.0002***	-0.0002***	-0.0001***
	(0.0003)	(0.0003)	(0.0003)	(0.0000)	(0.0000)	(0.0000)
IV TBTMulti		-0.0097***			-0.0006***	
		(0.0025)			(0.0002)	
IV TBTDomestic			-0.0225***			-0.0018***
			(0.0028)			(0.0002)
ln(tariff+1)	-0.0003	-0.0004	-0.0052	-0.0009	-0.0009	-0.0058
	(0.0120)	(0.0120)	(0.0103)	(0.0120)	(0.0120)	(0.0103)
Observations	2,076,262	2,076,153	1,997,264	2,076,262	2,076,153	1,997,264
Firm FEs	Yes	Yes		Yes	Yes	
Product FEs	Yes	Yes	Yes	Yes	Yes	Yes
HS2-destination-time FEs	Yes	Yes	Yes	Yes	Yes	Yes
Clusters	60472	60472	60472	60472	60472	60472
First-stage F-stat	102456	102456	102456	102456	102456	102456

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. IV regressions with firm, product and sector(HS2)-destination-time fixed effects. Robust standard errors clustered by product(HS4)-destination-time in parenthesis. TBT is measured by TBT dummy in column (1) to (3) and by TBT duration in column (4) to (6). Firm size, multi-destination dummy and domestic dummy are included but not reported when interacted with TBT.

Table 2.15: Exclusion of Big Firms, the Impact of TBTs on Firms' Export Value (Second-stage IV)

	TBT Dummy			**TBT Duration**		
	(1)	(2)	(3)	(4)	(5)	(6)
Export Value						
IV TBT	0.0088	-0.0056	0.0085	0.0001	-0.0010	0.0008
	(0.0128)	(0.0131)	(0.0151)	(0.0011)	(0.0011)	(0.0012)
IV TBTSize	0.0139***	0.0127***	0.0108***	0.0011***	0.0010***	0.0008***
	(0.0014)	(0.0014)	(0.0015)	(0.0001)	(0.0001)	(0.0001)
IV TBTMulti		0.1127***			0.0087***	
		(0.0160)			(0.0012)	
IV TBTDomestic			0.0785***			0.0063***
			(0.0128)			(0.0010)
ln(tariff+1)	-0.0580	-0.0567	-0.1173*	-0.0582	-0.0571	-0.1177*
	(0.0696)	(0.0696)	(0.0686)	(0.0696)	(0.0696)	(0.0686)
Observations	1,663,691	1,663,629	1,601,035	1,663,691	1,663,629	1,601,035
Firm FEs	Yes	Yes		Yes	Yes	
Product FEs	Yes	Yes	Yes	Yes	Yes	Yes
HS2-destination-time FEs	Yes	Yes	Yes	Yes	Yes	Yes
Clusters	57117	57117	57117	57117	57117	57117
First-stage F-stat	102887	102887	102887	102887	102887	102887

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. IV regressions with firm, product and sector(HS2)-destination-time fixed effects. Robust standard errors clustered by product(HS4)-destination-time in parenthesis. TBT is measured by TBT dummy in column (1) to (3) and by TBT duration in column (4) to (6). Firm size, multi-destination dummy and domestic dummy are included but not reported when interacted with TBT.

Table 2.16: Exclusion of Big Firms, the Impact of TBTs on Firms' Pricing Strategy (Second-stage IV)

	TBT Dummy			**TBT Duration**		
	(1)	(2)	(3)	(4)	(5)	(6)
Pricing Strategy						
IV TBT	0.0123	0.0036	0.0140	0.0002	-0.0004	0.0007
	(0.0104)	(0.0105)	(0.0136)	(0.0008)	(0.0008)	(0.0011)
IV TBTSize	0.0062***	0.0055***	0.0083***	0.0005***	0.0005***	0.0006***
	(0.0009)	(0.0009)	(0.0012)	(0.0001)	(0.0001)	(0.0001)
IV TBTMulti		0.0679***			0.0050***	
		(0.0082)			(0.0006)	
IV TBTDomestic			-0.0237**			-0.0020**
			(0.0102)			(0.0008)
ln(tariff+1)	0.0155	0.0163	0.0553	0.0151	0.0157	0.0551
	(0.0409)	(0.0409)	(0.0495)	(0.0410)	(0.0410)	(0.0495)
Observations	1,660,575	1,660,513	1,598,107	1,660,575	1,660,513	1,598,107
Firm FEs	Yes	Yes		Yes	Yes	
Product FEs	Yes	Yes	Yes	Yes	Yes	Yes
HS2-destination-time FEs	Yes	Yes	Yes	Yes	Yes	Yes
Clusters	57085	57085	57085	57085	57085	57085
First-stage F-stat	103169	103169	103169	103169	103169	103169

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. IV regressions with firm, product and sector(HS2)-destination-time fixed effects. Robust standard errors clustered by product(HS4)-destination-time in parenthesis. TBT is measured by TBT dummy in column (1) to (3) and by TBT duration in column (4) to (6). Firm size, multi-destination dummy and domestic dummy are included but not reported when interacted with TBT.

Chapter 3

Partial VAT Rebates and Firms' Export Performance Across Products*

3.1 Introduction

As a form of consumption tax, VAT has been widely used in more than 135 countries (Yan, 2011). Feldstein and Krugman (1990) point out that VAT, in theory, has a neutral effect on trade given that export VAT is fully rebated; while in the absence of an export rebate, VAT would act like an export tax. Such negative effect of VAT can be compensated by the rebate of VAT on export, which is widely regarded as a form of export subsidy (Feldstein and Krugman, 1990). While export subsidies are supposed to be eliminated under WTO rules, the Chinese setup allows them by implementing the policy of VAT rebates on export.

China introduced VAT to its system in 1994 during the nationwide tax reform and used it extensively thereafter. Unlike other countries that normally fully refund VAT on export, China, by implementing a changing export rebate rate, only *partially* refunds VAT on exports. The VAT rebate rates in China vary across different types of products from zero to full refund of the 17% standard VAT rate. China has adjusted the VAT rebates more than 30 times since the tax reform in 1994 (Braakmann et al., 2020). Such varying VAT

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rebate rates make it possible for the Chinese government to encourage or restrict export of certain products.[1]

There are mainly two purposes for the Chinese government to frequently adjust the VAT rebates. First, the VAT rebate rates are adjusted to promote exports. This motive is highly visible when facing global crisis, during which time the Chinese government increased the VAT rebate rate to mitigate the negative impact on export. Second, the VAT rebate rates are adjusted to modify the structure of the Chinese economy. They are increased for agricultural and high-tech products and decreased for energy-intensive and polluting products. The export VAT rebate system in China appears clearly as a trade instrument nested in the country's overall industrial policy (Julien Gourdon and Poncet, 2014).

Despite the uncommon feature and extensive use of VAT rebates in China, evidence on the trade impact remains scarce. Especially evidence on the impact of partial VAT rebates on multi-product firms is so far largely overlooked. At the macro level, multi-product firms are the key players in international trade, capturing an overwhelming and disproportionately large share of production (Manova and Yu, 2017; Bernard et al., 2012; Tan et al., 2015). At the micro level, products within a firm perform differently. A few core products take the lion's share of a firm's exports and profits in a market (Arkolakis et al., 2010; Bernard et al., 2012). Moreover, within-firm reallocation of resources across products, such as product switching, improve firm productivity in response to shocks such as exchange rate fluctuations or trade reforms (Bernard et al., 2010; Bernard et al., 2011; Manova and Yu, 2017; Gopinath et al., 2011; Chatterjee et al., 2013). It is thus important to investigate China's multi-product exporters and the product variations within a firm.

This paper investigates the impact of partial VAT rebates on multi-product firms and the variation across heterogeneous products within a firm. We model theoretically the effects of VAT rebate changes on the export volume and price of multi-product firms whose products are heterogeneous in the quality, and compile a unique data set to empirically explore the heterogeneous export performance across products within a firm. Consistent with the model's predictions, our empirical analysis shows that multi-product firms skew their export towards core products when facing an increase of VAT rebate rate.

The first contribution of the paper is to provide a theoretical model to guide our empirical analysis. We present a model of VAT rebates in the context of multi-product exporters. In the model, we show that the partial rebate of VAT acts as an export tax. As a result, the

[1] VAT rebate rates and VAT rebates are used interchangeably in this paper.

impact of VAT rebates on exports is heterogeneous across products within a multi-product exporters when the products face different elasticity of demand. In our framework, the products within each firm are heterogeneous in two dimensions: the physical efficiency and quality. We assume that the physical efficiency decreases with the distance to the core competence, implying that physical marginal cost increases with the distance to the core competence (e.g. Eckel and Neary (2010); Bernard et al. (2010); Bernard et al. (2011); Chatterjee et al. (2013); Mayer et al. (2014); Mayer et al. (2016)). Moreover, the quality decreases with the distance to the core competence as well, with the core product being of the highest quality (e.g. Eckel et al. (2015); Manova and Yu (2017)). The higher quality tends to increase marginal cost, which suggests that the marginal cost to produce quality decreases with the distance to the core competence. These two countervailing effects on marginal cost (and thereby price) present flexibility to incorporate both cost-based competence and quality-based competence within a multi-product exporter (e.g. Eckel et al. (2015); Manova and Yu (2017)). We introduce a per-unit cost of exporting, leading to different elasticity of demand and markup across products. As a result, our model suggests that an increase in the VAT rebate rate is associated with an increase in export quantity (a decrease in export price), and the effect increases (decreases) for products that are closer to a firm's core competence.

The second contribution of the paper is to compile a unique data set and test the model empirically. We collect detailed data on VAT rebate rates at 8-digit HS product level in China on a monthly basis, which is the most disaggregated data one can find for the case of China, and link it to export data and firm information for 2003-2006. The export data we use is from Chinese Customs and provides, for each international transaction, information on firm's identification, the product code (HS8), the transaction date, the trading country, the free-on-board (FOB) values in U.S. dollars, and the volume. As we do not observe price directly, we use unit value as a proxy which is calculated by dividing FOB value by quantity. The firm information, such as ownership type, sales, and revenues, is from the Manufacturing Survey, which is the most comprehensive data for China's manufacturing firms. Moreover, we need to differentiate quality across products within a firm, but product quality is mostly unobserved. To cope with this issue, we use product rank as a proxy. It is calculated by ordering the products within a firm based on their destination-specific export values. This approach is similar to Mayer et al. (2014).

Potential endogeneity may arise if the change of VAT rebates is due to export shocks or any other unobserved factors that are related to firms' export behavior. To address this

issue, first, we restrict our sample period to 2003-2006, during which time the shock of VAT rebate is plausibly exogenous. Detailed reasons are listed in section 3.2. In short, during this period, the VAT rebate rates are part of China's reform and development policy and adjusted by the government to modify the economic structure and solve environmental problems. Second, we include a set of fixed effects to largely control for unobserved factors. Finally, a series of robustness checks are conducted.

To the best of our knowledge, our paper is the first using such highly disaggregated firm- and product-level data to explore the impact of partial export VAT rebates on multi-product firms and their product scopes. Overall, we find that products with better quality within a firm have higher resistance to unfavorable changes of VAT rebate rate. More specifically, our baseline analysis shows that, first, a one percentage point increase in the VAT rebate rate is related to 1.1% increase in export quantity, and the quantity increases more if the product has a better quality. Second, a one percentage point increase in the VAT rebate rate is related to 0.75% decrease in export price, and the price decreases less if the product has a better quality.

Our paper relates to three strands of literature. The first strand studies the impact of VAT rebates on trade in general and on Chinese exporters in particular. Theoretical, Feldstein and Krugman (1990) state that VAT has a neutral effect on trade if export VAT is fully rebated. If there is no or only partial export rebate, VAT will act like an export tax. Empirically, Chandra and Long (2013) study the effect of VAT rebates on firms' export volume using firm-level panel data for 2000-2006. Using regional fiscal deficit rate to instrument firms' VAT rebate rate, they find a positive and significant effect. Similar results documenting a positive relationship between partial VAT rebate rate and export quantities are provided by Julien Gourdon and Poncet (2014); Chao et al. (2001). Moreover, Julien Gourdon, Laura Hering and Poncet (2016) confirm that the VAT system is an effective industrial policy and can improve China's international competitiveness. Tan et al. (2015) use the reduction of VAT rebate rate in 2004 as natural experiment to analyze its impact on export behavior of multi-product firms. Braakmann et al. (2020) analyze three major adjustments in VAT rebates and find that, in general, the negative adjustments of VAT rebates reduce export value and quantity by over 15%. Gao et al. (2020) find that the adjustments in VAT rebates significantly and positively affect firms' employment but no significant effect on firms' wage. Compared to these literature, this paper enriches the analysis by constructing a model of VAT rebates in the context of multi-product firms and pay

particular attention to the heterogeneous impacts of VAT rebates on products of different quality within a firm.

Second, this paper is closely related to the growing literature on multi-product firms and heterogeneity in quality and efficiency. Bernard et al. (2011) develop a general equilibrium model with heterogeneous firms and predicts that trade liberalization triggers adjustments along firms' extensive and intensive margins. Nocke and Yeaple (2014) show theoretically how firms' endowment of organizational efficiency determines its product scope. More theoretical model on multi-product firms are developed to show the effect of competition on the distribution of firms' product sales by Eckel and Neary (2010) or on the product range and product mix by Mayer et al. (2014). Using disaggregated Chinese data, Fan et al. (2015) show that trade liberalization induces exporters to upgrade the quality of the products; and Ma et al. (2014) find that firms specialize in their core competence after exporting thus become less capital-intensive but more productive. Our paper enriches the literature by incorporating VAT rebates into the model of multi-product firms.

Third, this paper contributes to the strand of research that studies the reallocation of resources across products within firms. Bernard et al. (2010) find that most product switching happens within existing firms, contributing to resources reallocation toward corresponding firms' most efficient use. Bernard et al. (2011) investigate the effect of trade liberalization on product scope. Using U.S. trade data, they find that tariff reductions cause firms to drop their least-successful products. Manova and Yu (2017) provide evidence on quality sorting of multi-product firms and indicate that quality upgrading is key to exports' success. Firms also respond to shocks, such as exchange rate movements, by adjusting their product mix (Gopinath et al., 2011; Chatterjee et al., 2013). Our paper enriches the existing literature by exploiting the reallocation across products in response to the shock of VAT rebates.

The remainder of the paper is structured as follows. Section 3.2 introduces the features of export VAT rebates in China. Section 3.3 presents the theoretical framework and gives testable predictions. Section 3.4 introduces the data we use. Section 3.5 discusses our specification strategy. Section 3.6 shows the main empirical results. Section 3.7 provides several robustness checks. Section 3.8 concludes the paper.

3.2 China's VAT Rebate Policy

The VAT was first introduced to China's tax regime during the nationwide tax reform in 1994 and gradually became a major source of government revenue, accounting for 45 to 30% of total tax revenue since then (Yan, 2011). Though the VAT system in China closely follows the European VAT system, it also develops its own peculiar feature: VAT on exports is not always fully refunded (Yan, 2011; Ferrantino et al., 2012; Julien Gourdon and Poncet, 2014).

China's VAT rebate rate remains incomplete (less than 17% of standard rate) and is adjusted frequently over the past decades. The rebate rates range from zero to fully refund of 17%, and is implemented mostly at HS8 product level, which is the most disaggregated level in China's product system. Indeed, no other country amends its VAT rebates so often (Julien Gourdon, Laura Hering and Poncet, 2016). Over the 2002-12 period, 87% of the products (HS6) experienced at least one change of the VAT rebate rate (Julien Gourdon and Poncet, 2014).

Moreover, China's VAT rabate rate is highly policy related. The government actively adjusts its export refund rule in line with its economic objectives (Chan, 2008; Ferrantino et al., 2012). Braakmann et al. (2020) point out that the government mainly have two purposes to adjust the VAT rebate rate. The first is to promote exports and the second is to modify the structure of the Chinese economy.

First, the VAT rebate policy is used as an export-promoting tool. For example, China's export was hit heavily during the Asian financial crisis in 1997. So starting from 1998, China gradually increased the VAT rebate rate for several product categories, such as steel and cement, coal industry, and cotton (Chao et al., 2001). The average rebate rate reached 15%. Amid the financial crisis in 2008 and 2009, China increased the VAT rebate rate again to mitigate the negative impact of the global crisis on export (Julien Gourdon, Laura Hering and Poncet, 2016; Julien Gourdon and Poncet, 2014), products like textile, clothing and toys enjoyed a higher rebate rate.

Second, the VAT rebate policy is leveraged to modify the structure of Chinese economy. The adjustments of VAT rebate rate are embedded in China's national development and reform strategy, and become part of a move to promote "higher value" products and curb polluting ones (Julien Gourdon, Laura Hering and Poncet, 2016; Julien Gourdon and Poncet, 2014; Wang et al., 2012). *China's National Climate Change Programme* clearly states that the

use of VAT rebates is to "deepen institutional reform of foreign trade in controlling export of energy-intensive, pollution-intensive and resource-intensive products, so as to formulate an import and export structure favorable to promote a cleaner and optimal energy mix" (NDRC, 2007). To this end, VAT rebate rates are increased for agricultural and high-tech products, and decreased or even cancelled for polluting and energy-intensive products.

Though the VAT rebate rates are under frequent adjustments, the main method of calculating the rebate is rather stable (Ferrantino et al., 2012). According to *Circular No. 7 Cai Shui [2002]*, the most common method for manufacturers exporting self-produced products is implemented as "Exemption, Credit and Refund". These manufacturers are producers doing ordinary trade or processing trade with imported materials. It is now worth distinguishing two types of processing trade here: processing with supplied materials and processing with imported materials. *Processing with imported materials* implies that Chinese firms pay for the raw materials and components. A foreign exchange payment is therefore involved. After processing and assembling, the Chinese firms export the final products to foreign markets. This type of processing trade is eligible for VAT rebate policy as Chinese exporters have paid for the raw materials at beginning. *Processing with supplied materials* means that Chinese firms receive raw materials and components supplied by a foreign company, process them and then export the finished products. This type of processing trade is not eligible for VAT rebate policy as Chinese exporters haven't paid for the raw materials, which remain owned by the foreign customers for the whole period (Ferrantino et al., 2012; Tan et al., 2015; Julien Gourdon, Laura Hering and Poncet, 2016). In brief, firms doing processing with supplied materials are not eligible for export VAT refund and therefore excluded from our analysis.

As defined in *Circular No. 7 Cai Shui [2002]*, the calculation of VAT payable of eligible firms to the government is based on the following formula:

$$VAT\ Payable = domestic\ sales * VAT - input\ VAT + NCNR,$$

where input VAT is the VAT paid on domestically purchased inputs; and NCNR, the non-creditable and non-refundable amount, is given as:

$$NCNR = (Export - BMI) * (VAT - VAT\ \ Rebate\ \ Rate),$$

where export means the value of export; BMI denotes the tax-free imported material. If firms focus on foreign markets and don't engage in domestic sales, the VAT payable is reduced to (NCNR - input VAT). Thus, it is straightforward to draw VAT rebates for eligible firms:

$$VAT\ Rebates\ for\ exporters = input\ VAT - (Export - BMI) * (VAT - VAT\ Rebate\ Rate).$$

If the VAT rebates are positive, the exporters receive VAT refunds from the government; otherwise, the exporters need to pay VAT to the government. The above equation indicates that the VAT rebates are at most equals to input VAT. When VAT rebate rate equals to VAT, firms are fully refunded. However, if VAT rebate rate is less than VAT, firms receive a partial refund. Thus, their VAT rebates from the government will be less than their paid input VAT.

To sum up, the VAT rebate policy in China is frequently adjusted by the government to pursue different policy goals. It is often the case that VAT rebate rate is lower than the standard VAT rate, making Chinese exporters only receive a partial VAT refund.

3.3 Theoretical Framework

In this section, we build a model of VAT rebates in the context of multi-product exporters. The aim of this model is to show that when VAT rebates are adjusted, the effects on exports are different across products within a multi-product exporter.

3.3.1 Preferences

There is a continuum of differentiated varieties in the market. The preference is symmetric across countries and given as:

$$U = \left(\int_{\Omega} [q(\omega)x(\omega)]^{\frac{\sigma-1}{\sigma}} d\omega \right)^{\frac{\sigma}{\sigma-1}},$$

where Ω is the set of varieties. $q(\omega)$ and $x(\omega)$ are the perceived quality and the consumption of variety ω, respectively. $\sigma > 1$ is the elasticity of substitution between varieties. This preference over product quality has been widely used in the literature (e.g. Baldwin and Harrigan (2011); Crozet et al. (2012); Fan et al. (2015); Chen and Juvenal (2016)). The

demand of variety ω from this preference is given as:

$$x(\omega) = YP^{\sigma-1}\left(\frac{p(\omega)}{q(\omega)}\right)^{-\sigma}, \tag{3.1}$$

where $p(\omega)$ is the price of variety ω. Y is the total expenditure and $P = (\int_\Omega [p(\omega)/q(\omega)]^{1-\sigma} d\omega)^{\frac{1}{1-\sigma}}$ is the price index in the market, respectively.

3.3.2 Multi-product Exporters

Each multi-product exporter has a "core" product with the efficiency φ to produce the physical output, i.e. the physical efficiency. The products within each firm are heterogeneous in two dimensions: the physical efficiency and quality. We assume that the physical efficiency decreases with the distance to the core competence (e.g. Eckel and Neary (2010); Bernard et al. (2010); Bernard et al. (2011); Chatterjee et al. (2013); Mayer et al. (2014); Mayer et al. (2016)). This implies that physical marginal cost increases with the distance to the core competence. Moreover, to accommodate the recent evidence that the core product has a higher price (e.g. Eckel et al. (2015); Manova and Yu (2017)), we assume that quality is positively related to physical efficiency, i.e. firms tend to invest more in the more efficient product and produce higher quality. Therefore, there is also a quality-based competence, with the core product being of the highest quality. As shown later, the higher quality tends to increase marginal cost, which suggests that the marginal cost to produce quality decreases with the distance to the core competence. These two countervailing effects on marginal cost (and thereby price) present flexibility to incorporate both cost-based competence and quality-based competence within a multi-product exporter (e.g. Eckel et al. (2015); Manova and Yu (2017)).

Let $r > 0$ be the rank of product within a multi-product exporter. The product with $r = 0$ is the core product. In the following, we use (φ, r) to denote a variety ω. We assume that the physical efficiency of the variety (φ, q) is:

$$e(\varphi, r) = \varphi\theta^{-r}, \tag{3.2}$$

where $\theta > 1$. As a result, the physical efficiency decreases with the distance to the core competence. We assume that the produced quality of a product with a physical efficiency

$e(\varphi, r)$ is $e(\varphi, r)^{\beta}/\lambda$. Therefore, the quality of the variety (φ, q) is given as:

$$q(\varphi, r) = \varphi^{\beta}\theta^{-\beta r}/\lambda, \tag{3.3}$$

where $\beta > 0$ and $\lambda > 0$. Therefore, the quality decreases with the distance to the core competence.

To incorporate the VAT rebates into the model, we consider a production that requires two factors, labor l and another input m subject to VAT (e.g. materials). More specifically, we assume that the production function to produce $y(\varphi, r)$ units of the variety (φ, q) is given by:

$$y(\varphi, r) = \frac{e(\varphi, r)^{\gamma} \cdot l^{\alpha} \cdot m^{1-\alpha}}{q(\varphi, r)},$$

where $0 < \alpha < 1$. Assume that the wage and the price for the input subject to VAT are endogenously given as w and p_m, respectively. We will consider VAT and VAT rebates in the next section. Here, we ignore them for simplicity. To minimize the total cost of production $(wl + p_m m)$ subject to the output $y(\varphi, r)$, the firm will optimally select the labor l and the input m. As a result, we can find the combined marginal cost of the variety (φ, r) as:

$$c(\varphi, r) = \frac{kq(\varphi, r)}{e(\varphi, r)^{\gamma}},$$

where $k = \frac{w^{\alpha} p_m^{1-\alpha}}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}} > 0$. This combined marginal cost is not related to the output. Note that the marginal cost is affected by both physical efficiency and quality. On the one hand, it decreases with physical efficiency and thereby increases with the distance to the core competence. On the other hand, it increases with quality and thereby decreases with the distance to the core competence. These countervailing factors affect the combined marginal cost in the opposite direction. To substitute equations (3.2) and (3.3) into the above equation, we have the combined marginal cost of the variety (φ, r) is:

$$c(\varphi, r) = \frac{k\theta^{(\gamma-\beta)r}}{\lambda\varphi^{\gamma-\beta}}. \tag{3.4}$$

If $\gamma > (<)\beta$, the combined marginal cost increases (decreases) with the distance to the core competence.

For each export activity, there is an iceberg cost $\tau > 1$, with τ units being exported and only one unit arriving at destination. There is a fixed export cost f_x. Moreover, we

also assume a per-unit distribution cost in the foreign market (e.g. Berman et al. (2012); Chatterjee et al. (2013); Fan et al. (2015); Chen and Juvenal (2016)). More specifically, we assume that the per-unit distribution cost is positively related to the quality of the goods (e.g. Fan et al. (2015); Chen and Juvenal (2016)). Let $p_{fob}(\varphi, r)$and $p_x(\varphi, r)$ be the FOB price and the export price received by the foreign consumers of the variety (φ, r). We have:

$$p_x(\varphi, r) = \tau p_{fob}(\varphi, r) + d \cdot q(\varphi, r), \tag{3.5}$$

where $d \cdot q(\varphi, r)$ is the per-unit distribution cost of the variety (φ, r). We assume $d > 0$ such that $d \cdot q(\varphi, r) > 0$ and the per-unit distribution cost is positively related to the quality of the goods. With demand shown in equation (3.1), the quantity demanded for the variety (φ, r) in the foreign market is then:

$$x(\varphi, r) = Y P^{\sigma-1} \left(\frac{\tau p_{fob}(\varphi, r)}{q(\varphi, r)} + d \right)^{-\sigma}. \tag{3.6}$$

3.3.3 VAT Rebates

According to *Circular No. 7 Cai Shui [2002]*, VAT rebates are calculated as:

$$\text{VAT Rebates} = p_m m \times r_{VAT} - \text{Export value} \times (R_{VAT} - R_{VATR}),$$

where $p_m m$ is the value of the input that the firms have to pay VAT. R_{VAT} and R_{VATR} are the rates of VAT and VAT rebates, respectively. Export value is the value of exports.[2] The VAT rebates are equal to the value of input VAT if the rate of VAT is equal to the rate of VAT rebates ($R_{VAT} = R_{VATR}$). In this case, the input VAT is fully rebated. When the rate of VAT rebates is less than the rate of VAT ($R_{VATR} < R_{VAT}$), VAT rebates are less than input VAT and input VAT is partially rebated.

[2]More accurately, VAT rebates are:

$$\text{VAT Rebates} = p_m m \times R_{VAT} - \text{Domestic sale} \times R_{VAT} - (\text{Export value} - BM) \times (R_{VAT} - R_{VATR}).$$

Domestic sale is the value of domestic sales. BM denotes the value of bonded materials, entering China without payments of duty and VAT, to be reshipped out of China after being stored, processed or assembled. For simplicity, we consider the production of domestic sales and exports are independent and ignore the use of bonded materials.

The profit of exporting $y(\varphi, r)$ units of the variety (φ, r) (with $x(\varphi, r) = y(\varphi, r)/\tau$ units arriving at the foreign market) is:

$$\begin{aligned}\pi(\varphi, r) &= p_x(\varphi, r)y(\varphi, r)/\tau - dq(\varphi, r)y(\varphi, r)/\tau - (wl + p_m m) - p_m m R_{VAT} - f_x \\ &+ \underbrace{(p_m m R_{VAT} - p_{fob} y(\varphi, r)(R_{VAT} - R_{VATR}))}_{\text{VAT Rebates}}.\end{aligned}$$

After substituting equation (3.5) into above equation, we have:

$$\pi(\varphi, r) = p_{fob}(1 - R_{VAT} + R_{VATR})y(\varphi, r) - (wl + p_m m) - f_x.$$

This shows that a partial rebate on VAT makes the non-refunded VAT, i.e. $R_{VAT} - R_{VATR}$, act as an export tax as in Feldstein and Krugman (1990). The lower the rate of VAT rebates is, the higher is the export tax and the lower is the profitability.

The firm's problem can be solved in two stages. In the first stage, the firm minimizes the cost $wl + p_l I_l$ by choosing labor l and the input m given the wage w and the price of input p_m subject to the output $y(\varphi, r)$. This has been addressed in the previous equation and the solution indicates a constant combined marginal cost defined in equation (3.4). Note that the demand in the foreign market is $x(\varphi, r) = y(\varphi, r)/\tau$. As a result, the above profit equation can be rearranged as:

$$\pi(\varphi, r) = \left(p_{fob}(\varphi, r)(1 - R_{VAT} + R_{VATR}) - c(\varphi, r)\right)\tau x(\varphi, r) - f_x.$$

In the second stage, the firm maximizes the profit defined in the above equation by choosing the price p_{fob} given the demand $x(\varphi, r)$ described in the equation (3.6). After solving the maximization, we have the f.o.b price of the variety (φ, r):

$$p_{fob}(\varphi, r) = \underbrace{\frac{\sigma}{\sigma - 1}\left(\frac{1}{1 - R_{VAT} + R_{VATR}} + \frac{d\varphi^{\gamma}\theta^{-r\gamma}}{\sigma\tau k}\right)}_{\text{Markup: } \quad m(\varphi, r)} c(\varphi, r). \tag{3.7}$$

Substituting the price into equation (3.6), we can solve the export quantity.

3.3.4 The Impact of VAT Rebates

In this section, we provide testable propositions of the model on the impact of VAT rebates. In particular, we focus on the impact of VAT rebates on export quantity and export price, i.e. the pass-through of VAT rebates.

Proposition 1. *When VAT rebate rate of a product is higher, the export quantity of the product is higher. The effect decreases with the distance to the core competence.*

Proof. $\frac{\partial \ln x(\varphi, r)}{\partial VATRs} > 0$ and $\frac{\partial^2 \ln x(\varphi, r)}{\partial VATRs \partial r} < 0$

Proposition 2. *When VAT rebate rate of a product is higher, the export price of the product is lower. The effect increases with the distance to the core competence.*

Proof. $\frac{\partial \ln p_{fob}(\varphi, r)}{\partial VATRs} < 0$ and $\frac{\partial^2 \ln p_{fob}(\varphi, r)}{\partial VATRs \partial r} < 0$

The two propositions will be tested empirically in the following sections.

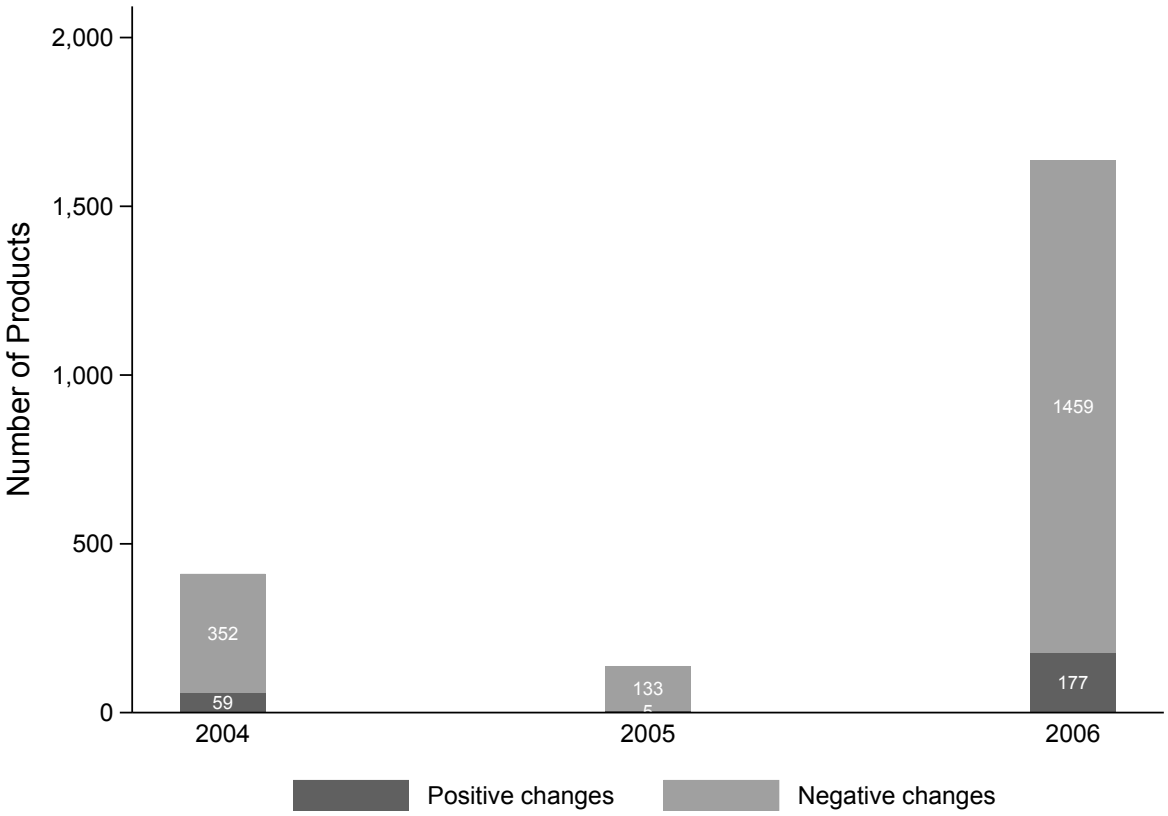
3.4 Data on VAT Rebate Rate and Chinese Firms

We proceed to test the above theoretical predictions empirically. To this end, we build up a unique data set that combines the monthly VAT rebate rate with the monthly Customs Data and annual Manufacturing Survey for China.

Data on VAT rebate rate is self-collected. There is no public database documenting the product-level export VAT rebate rates in China. So we need to refer to different sources and compile the data manually. Data on export VAT rebate is collected from the SAT Taxation Law Database for the period of January 2003 to August 2006, and from the website of Minister of Commerce for the period of September 2006 to December 2006. The data set provides information on VAT rebate rate for over 7000 products (HS8) over the year 2003-2006 at monthly frequency. It is, to our best knowledge, the most detailed data on VAT rebate rate for the case of China. A potential concern arises if firms adjust their export behavior in anticipation of future VAT rebate changes. However, it is a remote possibility as the time between announcement date and implementation date is very close.

The time gap is around seventy days in 2003 and one to ten days in 2004-2006, which is almost impossible for firms to adjust exports within such short period of time.[3] We are convinced that the anticipation effect is not a major concern. Nevertheless, as a robustness check, we run our regression over the period of 2004-2006, when the time gap between announcement date and implementation date is very short, hence the anticipation effect is unlikely.

Figure 3.1: The Number of Products under Adjustments of VAT Rebate Rates



Note: The graph shows the number of products (HS8) under adjustments of VAT rebate rates.
Source: author's calculation.

The VAT rebate rates were adjusted several times during our sample period. Figure 3.1 shows that the adjustments of VAT rebate rates involve 411, 138 and 1636 products (HS8) in 2004, 2005 and 2006 respectively.[4] A negative (positive) change refers to a reduction

[3]Braakmann et al. (2020) test the possible anticipation effects of these adjustments explicitly and find no evidence.

[4]The VAT rebate rates were implemented but not adjusted in 2003.

(increase) of the VAT rebate rates. We find that the negative adjustments take the lion's share: among products facing adjustments, more than 85% are under reductions of the VAT rebate rates each year. A more detailed breakdown of the adjustments of VAT rebates is provided by Figure 3.2 in the Appendix. Among products facing adjustments of VAT rebates each year, most products (213, 51%) are under reductions by 13 percentage points in 2004. In 2005, 33% (46) products are under reductions by 5 percentage points, what follows are 24% (33) by 13 percentage points and 18% (25) by 2 percentage points. In 2006, most products (881, 54%) are under reductions by 2 percentage points, what follows are 14% (237) by 5 percentage points and 12% (204) by 13 percentage points.

The China Customs Data is collected by the General Administration of Customs of China at monthly frequency. It provides, for each international transaction, information on firms' registration code, product code at the 8-digit HS level, indicator for export and import, the transaction date, trading countries, the types of firm by ownership and the categories of trading goods. It reports the free-on-board value of all import and export transactions in U.S. dollars and the trade quantities for each transaction. Unit values are calculated by dividing value by quantity for each HS-8 digit product category.

The Manufacturing Survey is compiled by the National Bureau of Statistics in China at annual basis. It is the most comprehensive data set for China's manufacturing firms. Above-scale firms, which are all state-owned (SOEs) and non-SOEs with more than 5 million Chinese Renminbi Yuan (around 0.7 million US-dollar) sales per year, are included in the survey. The data set includes firm name, contact information and key financial variables. The most relevant variables are total revenue, capital and material inputs, which will be used to construct proxies for firm-level productivity.

We link the Customs Data and Manufacturing Survey at firm level using firm identification and year.[5] Then we merge the VAT rebate rate to them at the same product level using 8-digit product code and year-month combination.

Several steps of data cleaning are included. Firstly, it is unreasonable to have negative output, sales, export values, capital and intermediate inputs, those negative observations are therefore excluded. Secondly, VAT rebates only apply to exporters, all information about importers are not considered here. Thirdly, as we are interested in the impact of VAT rebates on the variations across heterogeneous products, we mainly focus on exporters that export self-produced goods. Those exporters are also producers and can adjust their

[5]Similar exercise have been conducted by e.g. Wang and Yu (2012); Girma et al. (2009).

product portfolio accordingly. While trade intermediaries that do not engage in manufacturing but only conduct purely export-import business are not included (Manova and Yu, 2017). Fourthly, as the VAT rebates only apply to ordinary trade and processing with imported materials, other trade regimes that are not entitled for VAT rebate policy are not considered. Moreover, this paper focuses on the multi-product firms, which are defined as exporting more than one product at 8-digit product level during the whole time period. 98% of the firms export more than one good and the rest of the firms are excluded from the analysis. We further aggregate export for each firm by year, HS8 products, destination countries and time.

Table 3.1 reports the descriptive statistics of the sample. The final data set covers the period of January 2003 to December 2006. It includes more than 60,000 multi-product firms and 6,952 products at HS 8-digit level, among which 92% of the products receive only a partial VAT rebates. The VAT rebate rates range from 0% to 17%, with a median value of 13%. The product qualities vary within firms, which is approximated by product rank. The detailed methodology is discussed in next section. A higher rank refers to a lower quality. The maximum value of 461 for product rank should not be surprising, as some Chinese firms indeed export a large range of products (HS8). Such feature is well documented by Manova and Zhang (2008).

Table 3.1: Summary Statistics

Variable	Observations	Mean	Std. Dev.	Min	p50	Max
ln(*quantity*)	10,861,759	7.77	2.83	0.00	8.02	21.14
ln(*price*)	10,861,759	1.57	2.08	-10.33	1.27	18.37
VAT Rebate Rate (%)	10,438,301	12.85	2.04	0	13	17
Product Rank	10,896,843	3.20	5.99	1	1	461
# Firms			60,289			
# Products			6,952			
# Products get full rebate			533 (7.7%)			
# Products get no rebate			596 (8.6%)			
# Products get partial rebate			6404 (92.1%)			
# Product-firm pairs			671,589			
# Product-firm-destination pairs			2,162,587			

Note: Summary statistics for the final data set.

3.5 Empirical Implementation

As described in predictions 1 and 2, our theoretical model suggests that an increase in the VAT rebate rate is associated with a lower export price and a higher export quantity. Moreover, within one firm, the effects differ across products of different qualities, measured by product ranks. To provide empirical evidence for these two predictions of our model, we regress the dependent variables (export quantity or export price) on the VAT rebate rate, on the product rank and on the interaction term between the two. The following specification is considered:

$$Y_{cpft} = \beta_1 VATR_{pt} + \beta_2 Rank_{cpft} + \beta_3 Inter_{cpft} + \nu_{fp} + \nu_{kct} + \epsilon_{cpft}. \tag{3.8}$$

Our dependent variables Y_{cpft} are the natural logarithm of quantity (price) for firm f exporting good p to country c at time t, where we use trade unit values as proxy for the price of exported goods.

Our explanatory variables are: (1) $VATR_{pt}$, the export VAT rebate rate at time t for product p at the 8-digit HS level; (2) $rank_{pfct}$, the rank of product p within firm f exported to country c at time t; (3)$inter_{cpft}$, the interaction term between product-level VAT rebate rate and firm-level product ranks. Crucially, it enables us to investigate the variation across quality-differentiated products within a firm when facing the change of VAT rebate rate at the product level. Based on our model, we expect that $\beta_1 > 0$ and $\beta_3 < 0$ in the regression of export quantity and $\beta_1 < 0$ and $\beta_3 < 0$ in the regression of export price.

Following the method from Mayer et al. (2014), we use the product ranks to differentiate product quality within a firm. Mayer et al. (2014) raise up two types of product rank. The first one is firm's *global* product rank, which ranks all the products based on their export values to the world under the assumption that firm's product quality remains constant across destination countries. If we assume that firm's product quality varies across foreign markets, the second measure is a firm's *local* product rank, which ranks the products within a firm based on their destination-specific export values.

Note that the local product rank and global product rank are equivalent if the firm only exports one product to one destination country. But our setting focuses on multi-product firms, making the condition that firms export only one product invalid. In addition, com-

pared with the assumption of a globally steady quality, the assumption that firms' product quality varies across markets is more rational and better supported by recent empirical findings. For example, using Chinese customs data (Manova and Zhang, 2012) or Mexican manufacturing data (Verhoogen, 2008), researchers find that product quality is related to the income level of destination countries. We further compare both types of product rank using our data set. The correlation between firms' local rank and global rank is 0.74, revealing a substantial difference between the two. Therefore, local product rank is preferred for our empirical implementation. It is calculated by aggregating the export value of a HS8 product by firm, year and destination country. A smaller value refers to a higher ranking and also implies that this product is closer to the firm's core competence than other products.

A series of fixed effects are included in the specification. First, a set of firm-product fixed effect is used (ν_{fp}) to control for time-invariant and firm-product-specific unobserved characteristics that might affect exporters' performance. As discussed in section 3.2, the changes of VAT rebates in our sample are mainly based on the product characteristics, e.g. whether the product is polluting, resource-intensive or energy-consuming. These product characteristics can be largely controlled for by the fixed effect ν_{fp}. Second, we include sector(HS4)-destination-time fixed effect (ν_{kct}) to control for sector-destination-time level unobserved characteristics, such as exchange rate fluctuation, sector policies, business cycle, multilateral trade resistance and shocks in the foreign markets. ϵ_{cpft} is an error term.

Finally, we cope with potential endogeneity. As this paper investigates the effect of partial VAT rebate rate on the behavior of multi-product firms exporting quality-differentiated products, it is crucial to exclude any change of VAT rebate rate that is due to the export shocks or any other unobserved factors that could potentially affect export performance. To cope with potential endogeneity concerns, we first restrict our sample to the period of January 2003 to December 2006, during which the VAT rebate rates are mainly adjusted by the government to achieve its second political purpose: upgrade the structure of the economy and curb the environmental problems (Braakmann et al., 2020; Gao et al., 2020; Julien Gourdon, Laura Hering and Poncet, 2016; Julien Gourdon and Poncet, 2014). This sample period is also the time that the adjustments of VAT rebate rate are part of China's nationwide development plan. The Chinese government adjusts the export VAT rebate rate aiming to limit the export of energy-intensive, pollution-intensive and resource-consuming products (Fa Gai Jing Mao [2005] No.1482 and No.2595) (Wang et al., 2012; Gao et al., 2020; Braakmann et al., 2020). Over the sample period, the VAT rebate rate is increased for

products in agricultural and high-tech sectors but decreased for "Liang Gao Yi Zi" products.[6] Therefore, we are convinced that the adjustments of VAT rebate rate are plausibly exogenous to firm-level export in our sample period. Furthermore, the inclusion of a wide range of fixed effects controls for most of the unobserved factors that are correlated with export behavior and thus strongly reduces the endogeneity concerns due to any omitted variable bias. One might concern about product-level time-variant shocks, such as tariffs. This is actually a remote possibility, as tariffs are rather stable during the sample period and adjust less frequently than the VAT rebate rates. In the next section, several robustness regressions are conducted to further quantitatively reduce the endogeneity concerns.

3.6 Empirical Results

The empirical analysis includes two steps. We first examine the effect of partial VAT rebates on multi-product firms' export quantity and price in a general perspective. We then explore heterogeneous effects along different dimensions. In later section, a series of robustness checks will be reported.

3.6.1 Baseline Results

Table 3.2 presents the first main results of our empirical analysis. We regress export quantity on VAT rebate rate, product rank and a interaction term between the two. Firm-product and sector-destination-time fixed effects are included in each regression. Column(1) shows that a one percentage increase in the VAT rebate rate is associated with a 1.1% increase in the trade quantity. The result is in line with our expectation that a higher VAT rebate rate is trade-promoting and encourages producers to export more. It also confirms the theory raised by Feldstein and Krugman (1990): incomplete VAT rebates act like an export tax and therefore reduce export volume. Column(2) reveals that a one percentage increase in the product rank (i.e. one percentage decrease in the product quality within a firm) is related to a 9.24% decrease in export quantity. The negative coefficient on the interaction term in column(3) indicates that the positive effect of VAT rebates on export

[6] "Liang Gao Yi Zi" refers to the products that are high energy-consuming and polluting (e.g. steel products, pesticide, chlorine and other chemical products), resource-based (e.g. rare earth metals, silicon, wooden products) and inducing trade frictions (e.g. textile, clothing, toys) (Gao et al., 2020; Braakmann et al., 2020).

quantity declines as the value of product rank rises. Recall that a higher product rank implies a lower product quality. Thus the negative coefficient suggests that export quantity increases with a higher VAT rebate rate, and this effect is enhanced if the product has a better quality, put differently, the product is closer to the firm's core competence. These empirical findings are in support of our model's prediction 1. The findings also speak to the literature studying intra-firm resources reallocation across products (e.g. Eckel and Neary (2010); Bernard et al. (2010); Bernard et al. (2011)).

Table 3.2: The Impact of VAT Rebates on Export Quantity

	(1)	(2)	(3)
Dependent Variable: Export Quantity			
VAT Rebates	0.0110***	0.0116***	0.0129***
	(0.0040)	(0.0039)	(0.0039)
Product Rank		-0.0924***	-0.0847***
		(0.0016)	(0.0037)
Interaction			-0.0006**
			(0.0003)
Observations	9,633,540	9,633,540	9,633,540
Firm-product FEs	Yes	Yes	Yes
HS4-destination-time FEs	Yes	Yes	Yes
Adj. R square	0.709	0.709	0.709
Clusters	395315	395315	395315

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. OLS regressions with firm-product and sector-destination-time fixed effects. Robust standard errors clustered by firm-product in parenthesis.

Table 3.3 reports the main results for export price. In column(1), a one percentage point increase in VAT rebate rate is related to a 0.75% decrease of the export price. Column(2) shows that the export price is negatively correlated with product rank (i.e. positively correlated with product quality). More specifically, a one percentage increase in the product rank is associated with a 0.7% decrease in the export price. In column(3), the coefficient on the interaction term between the VAT rebate rate and product rank is negative and

statistically significant, indicating that the negative effect of VAT rebates on export price declines with the fall of the product rank (i.e. a rise of product quality). In short, we find that the export price of a product decreases with the rise of the VAT rebate rate, and the price decreases less if the product is closer to the firm's core competence. Namely, export price decreases less if firms reallocate towards their core products in response to the shock of VAT rebates. The findings confirm prediction 2 of our model and indicate an intra-firm reallocation.

Table 3.3: The Impact of VAT Rebates on Export Price

	(1)	(2)	(3)
Dependent Variable: Export Price			
VAT Rebates	-0.0075***	-0.0075***	-0.0070***
	(0.0019)	(0.0019)	(0.0019)
Product Rank		-0.0070***	-0.0043***
		(0.0002)	(0.0013)
Interaction			-0.0002**
			(0.0001)
Observations	9,633,540	9,633,540	9,633,540
Firm-product FEs	Yes	Yes	Yes
HS4-destination-time FEs	Yes	Yes	Yes
Adj. R square	0.928	0.928	0.928
Clusters	395315	395315	395315

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. OLS regressions with firm-product and sector-destination-time fixed effects. Robust standard errors clustered by firm-product in parenthesis.

3.6.2 Heterogeneous Results

We proceed to explore the baseline results in more detail by dividing firms into different groups. Firms are categorized either based on their trade regimes or productivity levels. Equation 3.8 is estimated for each subgroup separately.

First, firms are categorized into ordinary trade and processing trade based on their trade regimes. As already discussed in Section 3.2, processing trade in this paper refers exclusively to processing with imported materials. It is worthwhile to exploit the impact of VAT rebates on trade regimes separately, as the two trade regimes are organized and operated differently. For instance, Manova and Yu (2017) point out that processing firms import inputs for further processing, assembly and re-exporting, while ordinary exporters may or may not use imported materials. Moreover, ordinary trade are entitled to obtain rebates of their domestic and imported inputs, while processing trade only receive refund for their domestic inputs (Liu et al., 2016). In addition, Manova and Yu (2016) indicate that value added and profitability as well as required working capital and up-front cost rise from processing to ordinary trade. As a result, financial constraints may induce firms to choose processing trade.

Table 3.4 reports the results for estimating equation 3.8 when the shock of VAT rebates hits firms located in different trade regimes-ordinary trade in panel A and processing trade in panel B. The dependent variable in Columns (1)-(3) is the natural logarithm of export quantity, denoted as $Y = ln(Quantity)$, and in Columns (4)-(6) is the natural logarithm of export price, denoted as $Y = ln(Price)$. The same format applies to the rest of the tables in the paper.

Columns (1)-(3) in Table 3.4 present the impact of VAT rebates on export quantity by trade regime. Columns (1)-(2) reveal that the export quantity is positively correlated with the VAT rebate rate and negatively correlated with product rank in both trade regimes, which is consistent with the main results. More specifically, a one percentage point increase in the VAT rebate rate is related to a 0.85% increase in the trade quantity for ordinary trade, and 1.66% for processing trade. It indicates that processing trade is more sensitive to the change of VAT rebate rate than ordinary trade. The coefficients on the interaction terms in Column (3) display some variations-positive and significant for ordinary trade, and negative and significant for processing trade. They suggest that the export quantity increases with a higher VAT rebate rate, and increases less (more) if the product is closer to the firm's core competence in ordinary (processing) trade. A possible explanation is that compared to processing trade, ordinary trade requires higher working capital to conduct up-front technology and improve product quality (Manova and Yu, 2016), it is more costly for them to shift to their core products. It thus dampens the positive impact of a rise of VAT rebates. In short, Columns (1)-(3) show that the export quantity increases with a rise

of the VAT rebate rate, and increases less (more) if the product is closer to the firm's core competence in ordinary (processing) trade.

Columns (4)-(6) in Table 3.4 present the impact of VAT rebates on export price by each trade regime. The VAT rebate rate is negatively correlated with the export price in both trade regimes. A one percentage point increase in the VAT rebate rate is associated with a 0.38% decrease in the price in ordinary trade, and a 1.4% decrease in processing trade. The coefficients on the interaction term are presented in Column(6). As for ordinary trade, the coefficient on the interaction term is negative and significant, implying that the negative effect of the VAT rebate rate on price drops with the fall of the product rank (i.e. a rise of product quality). As for processing trade, despite the lack of significance, the general pattern of the results is in line with our baseline estimation. In short, Columns (4)-(6) suggest that the export price decreases with a rise of the VAT rebate rate, and decreases less if the product has a better quality. The effect is statistically significant for the case of ordinary trade.

Table 3.4: The Impact of VAT Rebates on Export Quantity and Price by Trading Regimes

	Y = ln(Quantity)			**Y = ln(Price)**		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Ordinary Trade						
VAT Rebates	0.0085**	0.0084**	0.0069*	-0.0038*	-0.0039*	-0.0032
	(0.0039)	(0.0039)	(0.0039)	(0.0020)	(0.0020)	(0.0020)
Product Rank		-0.0751***	-0.0842***		-0.0069***	-0.0030**
		(0.0014)	(0.0037)		(0.0003)	(0.0014)
Interaction			0.0007***			-0.0003***
			(0.0003)			(0.0001)
Observations	5,909,752	5,909,752	5,909,752	5,909,752	5,909,752	5,909,752
Adj. R square	0.689	0.689	0.689	0.951	0.951	0.951
Clusters	94998	94998	94998	94998	94998	94998
Panel B: Processing Trade						
VAT Rebates	0.0166*	0.0182**	0.0248***	-0.0140***	-0.0139***	-0.0138***
	(0.0089)	(0.0085)	(0.0087)	(0.0040)	(0.0041)	(0.0041)
Product Rank		-0.1291***	-0.0945***		-0.0064***	-0.0057**
		(0.0047)	(0.0120)		(0.0005)	(0.0027)
Interaction			-0.0026***			-0.0001
			(0.0009)			(0.0002)
Observations	2,973,515	2,973,515	2,973,515	2,973,515	2,973,515	2,973,515
Adj. R square	0.689	0.689	0.689	0.951	0.951	0.951
Clusters	94998	94998	94998	94998	94998	94998

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. OLS regressions with firm-product and sector-destination-time fixed effects. Robust standard errors clustered by firm-product in parenthesis.

Second, firms are categorized into low-productive and high-productive ones. We leverage the rich nature of our data to measure firm-level productivity using the Levinsohn and Petrin methodology (Levinsohn and Petrin, 2003), and split firms into low-productive and high-productive ones based on the median value of the sample.[7] Table 3.5 provides the results on low-productive firms in panel A and high-productive firms in panel B.

[7]Firm's output is measured as gross revenue and the production function is estimated by each HS2 industry.

Table 3.5: The Impact of VAT Rebates on Export Quantity and Price by Firm Productivity

	Y = ln(Quantity)			**Y = ln(Price)**		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Low-productive Firms						
VAT Rebates	0.0112**	0.0107**	0.0125**	-0.0029	-0.0029	-0.0026
	(0.0051)	(0.0050)	(0.0050)	(0.0023)	(0.0023)	(0.0023)
Product Rank		-0.0963***	-0.0846***		-0.0072***	-0.0050***
		(0.0021)	(0.0038)		(0.0003)	(0.0013)
Interaction			-0.0009***			-0.0002*
			(0.0003)			(0.0001)
Observations	6,050,563	6,050,563	6,050,563	6,050,563	6,050,563	6,050,563
Adj. R square	0.711	0.711	0.711	0.930	0.930	0.930
Clusters	186094	186094	186094	186094	186094	186094
Panel B: High-productive Firms						
VAT Rebates	0.0057	0.0069	0.0140**	-0.0048*	-0.0047*	-0.0029
	(0.0055)	(0.0053)	(0.0058)	(0.0025)	(0.0025)	(0.0026)
Product Rank		-0.0883***	-0.0506***		-0.0063***	0.0032
		(0.0025)	(0.0116)		(0.0003)	(0.0038)
Interaction			-0.0029***			-0.0007**
			(0.0009)			(0.0003)
Observations	3,227,796	3,227,796	3,227,796	3,227,796	3,227,796	3,227,796
Adj. R square	0.711	0.711	0.711	0.930	0.930	0.930
Clusters	186094	186094	186094	186094	186094	186094

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. OLS regressions with firm-product and sector-destination-time fixed effects. Robust standard errors clustered by firm-product in parenthesis.

Columns (1)-(3) in Table 3.5 present the impact of VAT rebates on export quantity by productivity level. Irrespective of firms' productivity level, export quantity is positively correlated with VAT rebates and negatively correlated with product rank. Despite the lack of significance of coefficient on VAT rebates for high-productive firms, the association remains stable. In Column (3), the coefficient on the interaction term between VAT rebates and product rank is negative and significant in both panels, indicating that the positive effect of VAT rebates on export quantity declines with rising product rank for both low-

and high-productive firms. The magnitude of this impact is larger for high-productive firms compared to low-productive firms.

Columns (4)-(6) in Table 3.5 present the impact of VAT rebates on the export price by productivity level. Column (4) shows that the export price is negatively related to the VAT rebates. Although there is a lack of significance for low-productive firms in panel A, the association is stable. Column (5) shows that the export price decreases in product rank, i.e. increases in product quality, in both panels. Lastly, Column (6) indicates that, in line with our baseline results, the negative impact of VAT rebates on the export price is mitigated if the product has a higher quality for both low- and high-productive firms.

Third, a triple interaction term is included in the analysis. In order to investigate whether the difference between subgroups (ordinary vs. processing trade, and high vs. low productivity) is significant or not, we include triple interactions between VAT rebate rate, product rank, and firm characteristics in the model. Firms characteristics are captured by two dummy variables: (1) a dummy of trade regimes (henceforth "regime dummy"), taking the value of 1 if firms conduct processing trade and 0 ordinary trade; (2) a dummy of productivity (henceforth "TFP dummy"), taking the value of 1 if firms are high-productive and 0 low-productive.

Table 3.6 extends benchmark equation 3.8 by including triple interaction between VAT rebate rate, product rank, and the regime dummy into the estimation. The effects on export quantity are reported in Columns (1)-(2) and export price in Columns (3)-(4). The negative and significant coefficient on the triple interaction in Column (2) suggests that the positive effect of VAT rebates on export quantity are greater if firms are in processing trade regime and their products have better quality. Such findings provide direct support to the ones in Table 3.4, which finds a positive and significant coefficient on the interaction between VAT rebates and product rank in ordinary trade, while negative and significant coefficient in processing trade. For the case of export price, Column (4) shows that the triple interaction between VAT rebate rate, product rank, and firms' trade regimes is negative but lack of significance, meaning that the combined impact of VAT rebates and product rank on export price has no statistically significant difference between ordinary and processing trade.

Table 3.6: The Impact of VAT Rebates on Export Quantity and Price with Regime Dummy

	Y = ln(Quantity)		**Y = ln(Price)**	
	(1)	(2)	(3)	(4)
VAT Rebates	0.0062	0.0064	-0.0075***	-0.0068***
	(0.0041)	(0.0040)	(0.0019)	(0.0019)
Product Rank		-0.0838***		-0.0039***
		(0.0036)		(0.0014)
VAT Rebates × Product Rank		0.0004		-0.0003**
		(0.0003)		(0.0001)
Regime Dummy	0.7710***	0.7795***	0.0527***	0.0531***
	(0.0344)	(0.0429)	(0.0150)	(0.0172)
VAT Rebates × Regime Dummy	0.0087***	0.0146***	-0.0019*	-0.0025*
	(0.0026)	(0.0032)	(0.0012)	(0.0013)
Product Rank × Regime Dummy		-0.0010		-0.0002
		(0.0102)		(0.0034)
VAT Rebates × Product Rank × Regime Dummy		-0.0028***		0.0002
		(0.0008)		(0.0003)
Observations	9,147,705	9,147,705	9,147,705	9,147,705
Firm-product FEs	Yes	Yes	Yes	Yes
HS4-destination-time FEs	Yes	Yes	Yes	Yes
Adj. R square	0.713	0.713	0.927	0.927
Clusters	394390	394390	394390	394390

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. OLS regressions with firm-product and sector-destination-time fixed effects. Robust standard errors clustered by firm-product in parenthesis.

Table 3.7 includes the triple interaction between VAT rebate rate, product rank and productivity dummy in the specification. The case of export quantity is reported in Columns (1)-(2), and export price in Columns (3)-(4). Again, the coefficients on VAT rebates, product rank and interaction between VAT rebates and product rank are comparable to the baseline results in both magnitude and significance. Crucially, the insignificant coefficient on triple interaction term reveals that the impact of VAT rebates and product rank on export quantity (or price) is not significantly different between low- and high-productive firms. These findings not only verify the results in Table 3.5, but also show that the performance of high- and low-productive firms does not significantly differ from each other.

Table 3.7: The Impact of VAT Rebates on Export Quantity and Price with TFP Dummy

	Y = ln(Quantity)		**Y = ln(Price)**	
	(1)	(2)	(3)	(4)
VAT Rebates	0.0105***	0.0126***	-0.0074***	-0.0069***
	(0.0040)	(0.0040)	(0.0019)	(0.0019)
Product Rank		-0.0844***		-0.0049***
		(0.0035)		(0.0013)
VAT Rebates × Product Rank		-0.0008***		-0.0002*
		(0.0003)		(0.0001)
TFP Dummy	0.0528***	0.0466*	0.0207**	0.0132
	(0.0189)	(0.0245)	(0.0092)	(0.0109)
VAT Rebates × TFP Dummy	0.0019	0.0016	-0.0002	0.0002
	(0.0015)	(0.0019)	(0.0007)	(0.0008)
Product Rank × TFP Dummy		0.0015		0.0037
		(0.0075)		(0.0030)
VAT Rebates × Product Rank × TFP Dummy		0.0002		-0.0002
		(0.0006)		(0.0002)
Observations	9,622,353	9,622,353	9,622,353	9,622,353
Firm-product FEs	Yes	Yes	Yes	Yes
HS4-destination-time FEs	Yes	Yes	Yes	Yes
Adj. R square	0.710	0.710	0.928	0.928
Clusters	394840	394840	394840	394840

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. OLS regressions with firm-product and sector-destination-time fixed effects. Robust standard errors clustered by firm-product in parenthesis.

3.7 Robustness Checks

In our baseline specification, we regress export quantity or export price on VAT rebate rate, product rank and their interaction to explore the impact of VAT rebates across products within multi-product firms. In this section, alternative specifications are conducted to ensure the robustness of our main results.

3.7.1 Alternative Samples

Table 3.8 shows the results of estimating benchmark equation 3.8 with alternative samples. We change one dimension of the baseline sample at a time.

Panel A changes the sample period. Instead of using 2003-2006, we change the sample period to 2004-2006. Recall that in the main specification, we estimate the effect of the VAT rebates on multi-product exporters over the year 2003 to 2006. However, the VAT rebate rate in China is relatively stable for the year 2003 but undergoes major changes from year 2004 to 2006. Moreover, the announcement date and implementation date is the longest, around 70 days, in 2003. In order to exclude the stable period and reduce potential anticipation effect, we focus mainly on the period of 2004-2006 for the robustness check. The results in panel A show that all the coefficients remain similar to the baseline results in both magnitude and significance.

Panel B drops big firms. Endogeneity concerns may arise if big firms are powerful enough to push government to adjust the export rebate policy in favor of their needs. To address this issue, we drop big firms, whose export value of product-destination combination is above the 99th percentile. The results presented in panel B are consistent with our main regression in both magnitude and significance.

3.7.2 Lagged VAT Rebate Rate

In Section 3.2, we explain in detail that China's VAT rebates are mainly policy-driven and is credibly exogenous in our sample period. As a further way to reduce endogeneity concern, we estimate our regression with lagged VAT rebate rate. First we use the VAT rebate rate lagged by one month. Indeed, the VAT rebate rate at time $t-1$ is likely to be exogenous to individual firms' export behavior at time t. On top of that, we lag the VAT rebate rates by several months to further support our findings. Key findings are presented in Table 3.9. The results using one-month-lagged VAT rebate rate are similar to the benchmark results in both magnitude and significance. Interestingly, when VAT rebate rate are lagged by more months, the coefficients on VAT rebates and product rank become larger in terms of magnitude, while the coefficients on the interaction terms remain at the same level. Detailed results are provided in Table 3.10 - 3.13 in the Appendix 3.9.

Table 3.8: Robustness Check: Alternative Samples

	Y = ln(Quantity)			**Y = ln(Price)**		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: 2004 - 2006						
VAT Rebates	0.0110***	0.0112***	0.0125***	-0.0071***	-0.0071***	-0.0065***
	(0.0037)	(0.0036)	(0.0036)	(0.0017)	(0.0017)	(0.0017)
Product Rank		-0.0956***	-0.0874***		-0.0071***	-0.0040***
		(0.0017)	(0.0038)		(0.0003)	(0.0013)
Interaction			-0.0006**			-0.0002**
			(0.0003)			(0.0001)
Observations	8,082,808	8,082,808	8,082,808	8,082,808	8,082,808	8,082,808
Adj. R square	0.714	0.714	0.714	0.930	0.930	0.930
Clusters	357031	357031	357031	357031	357031	357031
Panel B: Drop Big Firms						
VAT Rebates	0.0145***	0.0134***	0.0166***	-0.0066***	-0.0067***	-0.0062***
	(0.0037)	(0.0036)	(0.0037)	(0.0017)	(0.0017)	(0.0018)
Product Rank		-0.2645***	-0.2378***		-0.0149***	-0.0112***
		(0.0014)	(0.0055)		(0.0005)	(0.0022)
Interaction			-0.0021***			-0.0003*
			(0.0004)			(0.0002)
Observations	8,138,063	8,138,063	8,138,063	8,138,063	8,138,063	8,138,063
Adj. R square	0.719	0.719	0.719	0.931	0.931	0.931
Clusters	321537	321537	321537	321537	321537	321537

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. OLS regressions with firm-product and sector-destination-time fixed effects. Robust standard errors clustered by firm-product in parenthesis.

Table 3.9: Robustness Check: Lagged VAT Rebate Rates

	Y = ln(Quantity)			**Y = ln(Price)**		
	(1)	(2)	(3)	(4)	(5)	(6)
One-month Lag						
VAT Rebates	0.0136***	0.0142***	0.0153***	-0.0078***	-0.0077***	-0.0072***
	(0.0043)	(0.0041)	(0.0042)	(0.0020)	(0.0020)	(0.0020)
Product Rank		-0.0924***	-0.0859***		-0.0070***	-0.0040***
		(0.0016)	(0.0038)		(0.0002)	(0.0014)
Interaction			-0.0005*			-0.0002**
			(0.0003)			(0.0001)
Four-month Lag						
VAT Rebates	0.0233**	0.0233**	0.0245**	-0.0134***	-0.0134***	-0.0128**
	(0.0101)	(0.0097)	(0.0098)	(0.0051)	(0.0051)	(0.0052)
Product Rank		-0.0925***	-0.0855***		-0.0070***	-0.0036**
		(0.0016)	(0.0041)		(0.0002)	(0.0015)
Interaction			-0.0005*			-0.0003**
			(0.0003)			(0.0001)
Five-month Lag						
VAT Rebates	0.0255**	0.0252***	0.0265***	-0.0133***	-0.0133***	-0.0127**
	(0.0100)	(0.0096)	(0.0097)	(0.0050)	(0.0051)	(0.0051)
Product Rank		-0.0923***	-0.0846***		-0.0070***	-0.0035**
		(0.0016)	(0.0042)		(0.0002)	(0.0015)
Interaction			-0.0006*			-0.0003**
			(0.0003)			(0.0001)
Six-month Lag						
VAT Rebates	0.0278***	0.0273***	0.0290***	-0.0132**	-0.0133**	-0.0126**
	(0.0099)	(0.0096)	(0.0096)	(0.0052)	(0.0052)	(0.0052)
Product Rank		-0.0923***	-0.0829***		-0.0070***	-0.0032**
		(0.0016)	(0.0044)		(0.0002)	(0.0016)
Interaction			-0.0007**			-0.0003**
			(0.0003)			(0.0001)

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. OLS regressions with firm-product and sector-destination-time fixed effects. Robust standard errors clustered by firm-product in parenthesis. For details see Table 3.10 - 3.13 in the Appendix.

3.8 Conclusion

This paper investigates the impact of partial VAT rebates on multi-product exporters with heterogeneous product quality. China is a suitable setting for this purpose, as on the one hand, it has spectacular export growth since the WTO accession in 2001, and on the other hand, its export VAT rebate remains incomplete and is subject to constant adjustments no other countries have ever experienced.

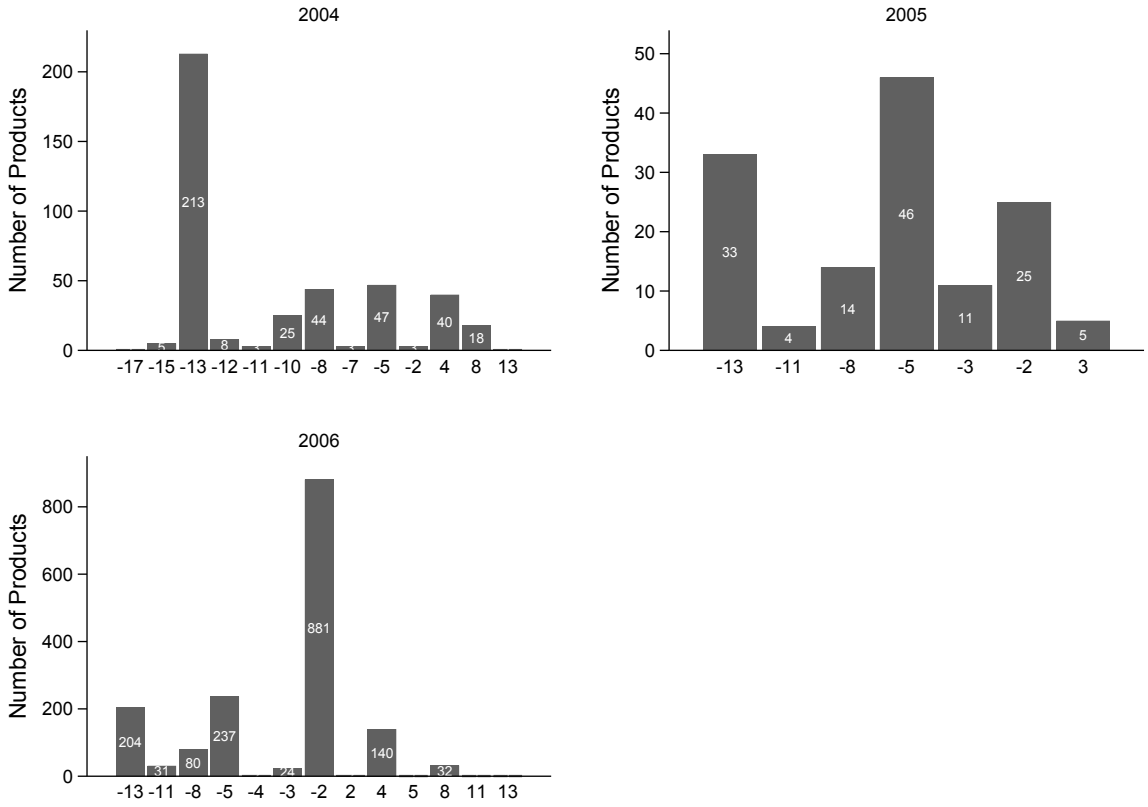
The first contribution of this paper is to present a theoretical model of VAT rebates in the framework of multi-product firms with quality-differentiated products. Two testable predictions regarding the relationship between the VAT rebate rate and export are derived. The second contribution of this paper is to compile a unique data set and test the model empirically. We collect detailed data on VAT rebate rate at 8-digit HS product level and link it to export data and firm characteristics for 2003-2006. Local product rank is calculated to proxy the product quality within firms.

Overall, the empirical results confirm our model's predictions. First, the export quantity increases with VAT rebate rate, and it increases more if the product is closer to the firm's core competence. Second, the export price decreases with VAT rebate rate, and it decreases less if the product is closer to the firm's core competence. In short, multi-product exporters reallocate towards the core products when facing an increase of the VAT rebate rate. Moreover, we find that the effects of VAT rebates differ across trade regimes and firm-level productivity. In particular, first, the positive effect of VAT rebates on export quantity is smaller (larger) if the product is closer to the firm's core competence in ordinary (processing) trade. Second, the export price decreases with a rise of VAT rebate rate, and decreases less if the product has a better quality for the case of ordinary trade. Third, baseline patterns appear in both high-productive and low-productive firms, and the two groups do not behave significantly different from each other. Our results survive different robustness tests.

Our findings inform the impact of export-promoting policies in China, as well as multi-product firms' performance in the context of quality differentiation across products. More general, our results shed light on the impact of trade reforms or economic shocks at the firm level and on the reallocation of resources across products within firms.

3.9 Appendix

Figure 3.2: The Number of Products under Adjustments of VAT Rebate Rates by Year



Note: The graph shows the number of products (HS8) under adjustments of VAT rebate rates per year. The numbers in x-axis denote the adjustments of VAT rebate rates in percentage points. *Source:* author's calculation.

Table 3.10: Robustness Check: VAT Rebate Rates Lagged One Month

	Y=ln(Quantity)			**Y=ln(Price)**		
	(1)	(2)	(3)	(4)	(5)	(6)
VAT Rebates	0.0136***	0.0142***	0.0153***	-0.0078***	-0.0077***	-0.0072***
	(0.0043)	(0.0041)	(0.0042)	(0.0020)	(0.0020)	(0.0020)
Product Rank		-0.0924***	-0.0859***		-0.0070***	-0.0040***
		(0.0016)	(0.0038)		(0.0002)	(0.0014)
Interaction			-0.0005*			-0.0002**
			(0.0003)			(0.0001)
Observations	9,516,231	9,516,231	9,516,231	9,516,231	9,516,231	9,516,231
Firm-product FEs	Yes	Yes	Yes	Yes	Yes	Yes
HS4-destination-time FEs	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R square	0.710	0.710	0.710	0.928	0.928	0.928
Clusters	392667	392667	392667	392667	392667	392667

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. OLS regressions with firm-product and sector-destination-time fixed effects. Robust standard errors clustered by firm-product in parenthesis.

Table 3.11: Robustness Check: VAT Rebate Rates Lagged Four Month

	Y=ln(Quantity)			**Y=ln(Price)**		
	(1)	(2)	(3)	(4)	(5)	(6)
VAT Rebates	0.0233**	0.0233**	0.0245**	-0.0134***	-0.0134***	-0.0128**
	(0.0101)	(0.0097)	(0.0098)	(0.0051)	(0.0051)	(0.0052)
Product Rank		-0.0925***	-0.0855***		-0.0070***	-0.0036**
		(0.0016)	(0.0041)		(0.0002)	(0.0015)
Interaction			-0.0005*			-0.0003**
			(0.0003)			(0.0001)
Observations	9,166,557	9,166,557	9,166,557	9,166,557	9,166,557	9,166,557
Firm-product FEs	Yes	Yes	Yes	Yes	Yes	Yes
HS4-destination-time FEs	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R square	0.711	0.711	0.711	0.929	0.929	0.929
Clusters	384929	384929	384929	384929	384929	384929

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. OLS regressions with firm-product and sector-destination-time fixed effects. Robust standard errors clustered by firm-product in parenthesis.

Table 3.12: Robustness Check: VAT Rebate Rates Lagged Five Month

	Y=ln(Quantity)			**Y=ln(Price)**		
	(1)	(2)	(3)	(4)	(5)	(6)
VAT Rebates	0.0255**	0.0252***	0.0265***	-0.0133***	-0.0133***	-0.0127**
	(0.0100)	(0.0096)	(0.0097)	(0.0050)	(0.0051)	(0.0051)
Product Rank		-0.0923***	-0.0846***		-0.0070***	-0.0035**
		(0.0016)	(0.0042)		(0.0002)	(0.0015)
Interaction			-0.0006*			-0.0003**
			(0.0003)			(0.0001)
Observations	9,039,498	9,039,498	9,039,498	9,039,498	9,039,498	9,039,498
Firm-product FEs	Yes	Yes	Yes	Yes	Yes	Yes
HS4-destination-time FEs	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R square	0.711	0.711	0.711	0.929	0.929	0.929
Clusters	382066	382066	382066	382066	382066	382066

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. OLS regressions with firm-product and sector-destination-time fixed effects. Robust standard errors clustered by firm-product in parenthesis.

Table 3.13: Robustness Check: VAT Rebate Rates Lagged Six Month

	Y=ln(Quantity)			**Y=ln(Price)**		
	(1)	(2)	(3)	(4)	(5)	(6)
VAT Rebates	0.0278***	0.0273***	0.0290***	-0.0132**	-0.0133**	-0.0126**
	(0.0099)	(0.0096)	(0.0096)	(0.0052)	(0.0052)	(0.0052)
Product Rank		-0.0923***	-0.0829***		-0.0070***	-0.0032**
		(0.0016)	(0.0044)		(0.0002)	(0.0016)
Interaction			-0.0007**			-0.0003**
			(0.0003)			(0.0001)
Observations	8,911,425	8,911,425	8,911,425	8,911,425	8,911,425	8,911,425
Firm-product FEs	Yes	Yes	Yes	Yes	Yes	Yes
HS4-destination-time FEs	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R square	0.711	0.711	0.711	0.929	0.929	0.929
Clusters	379199	379199	379199	379199	379199	379199

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. OLS regressions with firm-product and sector-destination-time fixed effects. Robust standard errors clustered by firm-product in parenthesis.

Chapter 4

Where has the Rum gone? Firms' Choice of Transport Mode under the Threat of Maritime Piracy*

4.1 Introduction

With 180 incidents in 2017 which lead to 166 crew members being taken hostage or kidnapped and three killed, maritime piracy remains a real threat to international merchant shipping (ICC IMB, 2018).[1] Beyond the risk faced by the crew, piracy increases the cost carried by shipping companies, including higher wage premia, a rise in insurance payments due to a lower expected value of a shipment (since it may be damaged or sunk with a higher probability), ransom payments, as well as the actual cost of protecting the ship through military escorts, armed guards, electric fencing, razor wire, water cannons, non-lethal laser or acoustic devices (Towergate Insurance, 2018; Gilpin, 2009). Increased fuel

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[1]The reasons for piracy are manifold and include traffic along particular trade routes, economic conditions (Percy and Shortland, 2009; Cariou and Wolff, 2011), inadequate government action against piracy (Hastings, 2009; Chalk, 2008), geographic position, weak judicial systems and political instability (Murphy, 2007). For an overview, definitions and historical context the reader is referred to Mejia et al. (2012).

and time cost of altering routes can also be substantial. For example, routing around the Strait of Malacca - one of the world's busiest sea lanes and frequently prone to pirate attacks - would mean a detour of about 1,000 nautical miles (Berg et al., 2006). Estimates for the direct costs of piracy due to such measures range from 7 billion USD to 12 billion USD in 2010 (Bowden et al., 2010).[2]

This paper combines Chinese firm-level customs data with data on maritime piracy to investigate how exporting firms respond to such piracy induced costs. They cannot be modelled as iceberg transport costs because they are transport mode specific - goods shipped by air are not subject to pirate attacks - and accrue per journey, as one military escort or security staff is required per ship, no matter whether the latter runs at full capacity. The paper shows that pirate activity on a certain trade route induces firms to change transportation mode, shipping some of their goods by plane rather than by ship. The remaining average shipments per firm however become larger and average producer prices fall, indicating that exporters absorb parts of the costs. Despite these compensating activities, overall exports from China decline on routes affected by piracy.

The paper relates to two strands of literature. The first strand concerns the determinants of firms' choice of transportation mode and has already attracted significant research attention. At the macro level, Hummels (2007) discusses how declining transport costs such as the spread of containerization have contributed to an increase in international trade. Correspondingly, this paper shows that an increase in transportation costs on specific ocean routes due to pirate activity reduces bilateral trade flows along the affected routes.

Harrigan (2010) develops a Ricardian model to investigate the interaction between trade, transport cost and the choice of transport mode and tests its predictions using US import data. Beyond the finding that goods with high unit values are more likely to be shipped by air, the author demonstrates that countries more distant from the destination market have a comparative advantage in lightweight goods. Related to that, Hummels and Schaur (2013) model a firm's choice between air and ocean transportation, showing that more time sensitive goods are more likely to be shipped by air. Ge et al. (2014) use Chinese customs data to investigate the choice of transport mode at the firm-level, finding that

[2]Indirect costs of piracy range from threatening the participation of neighboring states in maritime trade, tourism and fishery (Mbekeani and Ncube, 2011) to an increase in corruption and thus weakening of the legitimacy of governments and even potentially environmental disasters as pirates attack oil tankers or ships carrying toxic chemicals (Chalk, 2008).

high productivity firms are more likely to ship goods by air, indicating that they specialize in time sensitive high value products.

Part of the cost of piracy comes from additional shipping time due to re-routing of vessels to avoid areas with pirate activity. For example, a round voyage of a container ship from Singapore to Rotterdam takes on average 33 days if travelling via the Suez Canal and 42 days if travelling around the Cape of Good Hope (Bendall, 2010). Such an increase in shipping time constitutes one explanation for the decision of exporting firms to switch from ocean to air transport.

This paper also relates to the work of Kropf and Sauré (2014). The authors construct and empirically test a model of the relationship between fixed costs per shipment and a firm's choice regarding the size and frequency of shipments. In line with their results, this paper finds that a piracy induced increase in fixed costs per shipment reduces shipment frequency and increases shipment size.[3] An alternative channel through which pirate activity may affect trade and the choice of shipment mode is through uncertainty. Békés et al. (2017) show that firms tend to send less frequent but larger shipments to more uncertain markets. Piracy increases uncertainty by increasing the probability of losing a ship at sea. In line with Békés et al. (2017), it is hence not surprising to see exporters responding to piracy by reducing the number of shipments while increasing their size.

The second strand of literature this paper relates to concerns the effects of piracy on trade in general and firms' choice of transport mode in particular. A good overview is provided by Endler et al. (2012), who also show that most studies are either descriptive or focus on a particular region. For example, Bendall (2010) specifically calculates the costs of re-routing ships from the Suez Canal to the Cape of Good Hope using a model of shipping costs. Using OECD data on maritime transport costs, Bensassi and Martínez-Zarzoso (2013) estimate the effects of piracy on transport cost. The authors find that the hijacking of one additional ship between Europe and Asia increases transport costs between the two continents by 1.2%. However, the authors do not discuss the implications of such increases in costs on prices and the choice of transport mode. This paper shows how piracy affects producer prices, the choice of shipment mode as well as the size of shipments.

[3]The term "shipment size" in this paper refers to the size of the transaction reported in the customs data. It is not the same as the amount of goods carried by a ship. Costs for military escorts or higher wages for the crew increase the cost of a ship's journey. If these additional costs are divided across containers, the costs of shipping an additional container increases from the perspective of the exporter, thus providing her with an incentive to use its entire capacity.

Fu et al. (2010) construct a model of the container liner shipping market in order to investigate the impact of piracy on trade volumes. The authors find that Somali pirates have reduced traffic between Europe and the Far East through the Suez Canal by about 30%. As only some of this traffic is rerouted via the Cape of Good Hope, the annual loss is estimated to be around 30 billion USD. Bensassi and Martínez-Zarzoso (2012) estimate a gravity model, finding that 10 additional vessels being hijacked reduce exports by 11%. Both studies focus on trade between Europe and Asia. This paper extends the scope by considering the universe of Chinese exports to all destination countries to empirically investigate the effects of piracy on trade. Moreover, it separately investigates effects on ocean and air trade.

The remainder of this paper is structured as follows. Section 4.2 presents the data used, while Section 4.3 discusses the empirical strategy. Section 4.4 presents the results, followed by some robustness checks in Section 4.5. Section 4.6 concludes.

4.2 Data

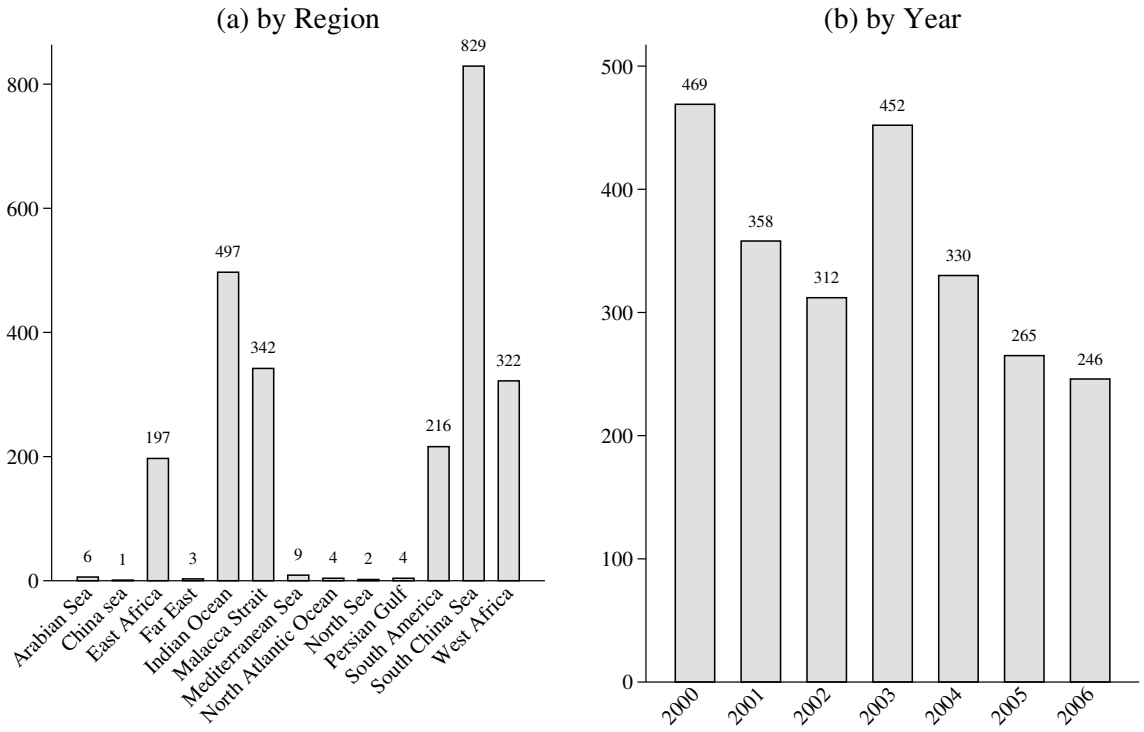
To investigate the impact of piracy on trade and the choice of transport mode, this paper uses Chinese customs data, which provides information on monthly export transactions at the firm-product(8 digit)-destination-country level for the period 2000 to 2006. Crucially, for every transaction it also reports the main transport mode employed. While value in USD and quantity are reported directly, unit values are imputed by dividing value by quantity. Since export values are reported free on board, unit values can be interpreted as producer prices.

Overall, the Chinese customs data differentiates between six different modes of transport of which we use "sea and river" and "air". We abstain from using "rail" and "road" for two reasons. First, transportation by land is restricted primarily to Asia. Second, it may also be subject to armed robberies that may or may not correlate with pirate activity. For the final two modes "mail" and "other", it is not clear how they are transported, which is why they are excluded from the analysis.

Data on piracy is taken from the International Maritime Organization which provides monthly reports on piracy incidents (allegedly committed and attempted attacks) in 13 different geographical areas. Panel (a) of Figure 4.1 shows the total number of pirate

incidents between 2000 and 2006 by region. With only one observed case in the China Sea and 497 in the Indian Ocean, the figure indicates substantial cross sectional variation.

Figure 4.1: The Number of Piracy Incidents by Region and Year



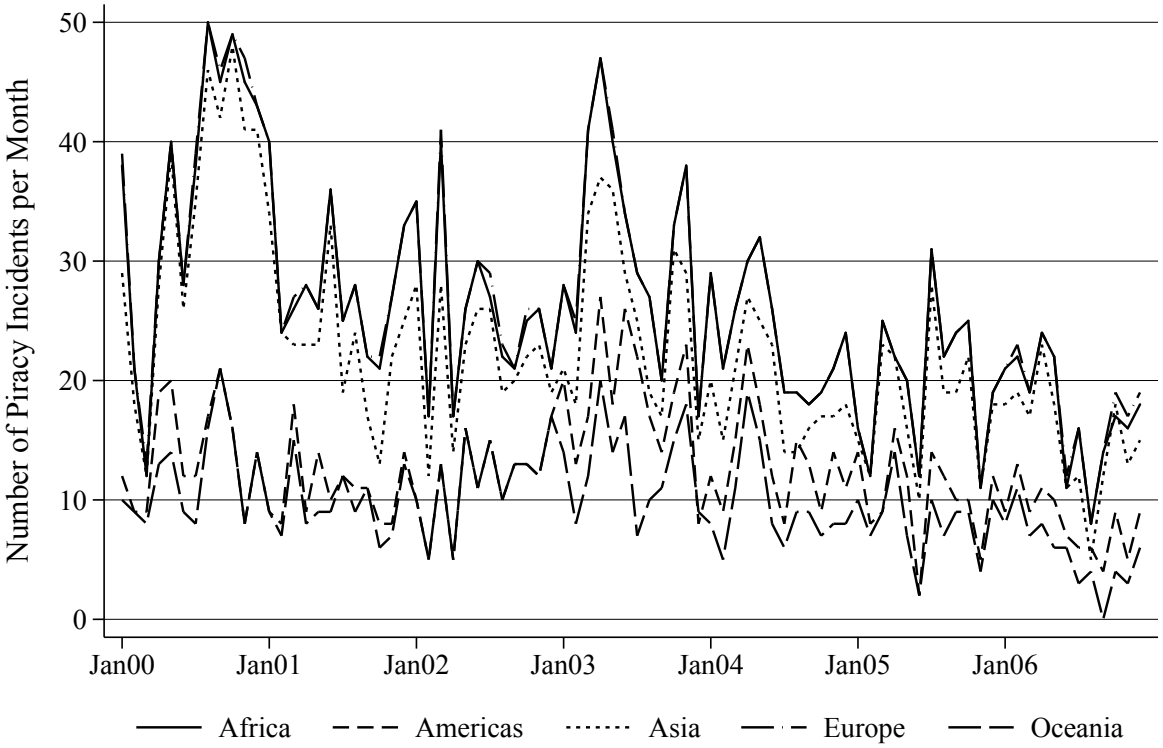
Note: Panel (a) shows the total number of piracy incidents from 2000 - 2006 by region. Panel (b) shows the total number of piracy incidents over all regions by year. *Source:* Data from International Maritime Organization.

The three regions most affected by piracy in the period under investigation are the South China Sea with an average of 118 incidents per year, the Indian Ocean (71 incidents per annum) and the Strait of Malacca (49 incidents per annum). Piracy along the Coast of Somalia (East Africa, 29 incidents per year) is not among the top three affected regions, as pirate activity there only increased dramatically in 2008 and 2009. We choose not to extend our analysis to these years for two reasons. First, export data for the years 2007 to 2009 are available only at the annual level. However, aggregating to the annual level would substantially reduce variation over time. In addition, it is possible that the financial crisis affected different trade routes differently, which could bias our estimated treatment effect.

The number of pirate incidents by year is reported in Panel (b) of Figure 4.1. It indicates a declining trend which is however interrupted by sudden increases. A more detailed breakdown of pirate incidents by region and year is provided by Figure 4.3 in the Appendix. It shows that while piracy declined in some regions such as the South China Sea, it actually increased in others such as East Africa. Since not all piracy incidents are reported (Berg et al., 2006; Murphy, 2007), all numbers constitute a lower bound for piracy activity.

Matching the Chinese customs data with the piracy data is a challenge because the former does only report the destination country, not the exact route taken. For example, goods can be shipped from China to France either through the Suez Canal or by going around Africa along the Cape of Good Hope. The choice of route depends on several factors, including distance, weather conditions, duties, whether or not the ship calls at certain ports for loading and unloading of additional freight and of course the risk of piracy. It is thus not evident which route a ship takes.

Figure 4.2: The Number of Piracy Incidents over Time by Destination Continent



Note: The graph shows the total number of reported piracy incidents per month, covering all possible routes from China to each of the five destination continents. *Source:* Data from International Maritime Organization.

This paper applies a conservative approach, considering all possible ocean routes between China and the continent to which the destination country belongs. The number of piracy cases on the route between China and the destination continent is taken to be the sum of all piracy incidents in all areas covered by the possible ocean routes. Information on the exact matching between areas affected by piracy and destination continent is provided in Table 4.4 in the Appendix. Even though this reduces the cross sectional variation in piracy incidents to five continents, Figure 4.2 nevertheless shows that there remains significant variation both across continents and over time. The average number of piracy incidents per month between 2000 and 2006 was 26 along all routes to Africa, 12 for America, 22 for Asia, 26 for Europe and 10 for Oceania.

There are two obvious drawbacks to this approach. First, it is possible that all or most piracy incidents are observed at a route which is not the preferred route anyway. In this case, the choice of shipment mode should be independent of the piracy incidents, leading to an underestimation of the treatment effect. The results presented in this paper should thus be seen as a lower bound of the effect and a first step towards estimating the impact of piracy on trade and the choice of transport mode.

Second, it is impossible to observe a switch in shipping routes, which also constitutes a plausible response to piracy. A switch from one route to another due to increased pirate activity along the first one would not be picked up by the regressions, as the variation takes place at a more disaggregated level than the one observed in the data. However, a switch from one ocean route to another ocean route would affect neither air travel nor the overall value of goods shipped by ocean. While the effect of piracy on the choice of ocean routes is an interesting research question in itself, the fact that it cannot be observed in the data should not lead to an underestimation of the treatment effect when evaluating the effect of piracy on overall trade as well as the choice of transport mode. However, this is only true as long as diversion to different routes does not increase demand for shipping services and thus transport costs along that alternative route, thus affecting the amount of goods shipped.

4.3 Estimation Strategy

The effect of piracy on the choice of transport mode is estimated as follows:

$$Y_{cpft} = \beta_1 Piracy_{tc} + \beta_2 ln\ p_{cpft} + \nu_{cpf} + \nu_{pft} + \epsilon_{cpft}, \tag{4.1}$$

where Y_{cpft} is a dummy (henceforth "ocean dummy") that equals one if a shipment to country c from firm f of good p at time t is carried out by ship and zero otherwise. In an alternative specification, Y_{cpft} is the natural logarithm of the size of the transaction. Since we are using monthly data, a time-unit equals a particular month in a particular year. $Piracy_{tc}$ is the number of piracy incidents on the route to country c at time t, $\ln p_{cpft}$ is the natural logarithm of the unit value of the transaction, ν_{cpf} and ν_{pft} are destination country-product-firm and product-firm-time fixed effects respectively and ϵ_{cpft} is an error term.

Using the natural logarithm of transaction size as dependent variable and controlling for country-product-firm fixed effects ensures that the piracy coefficient β_1 identifies how the average quantity of product p shipped by firm f to country c changes with every additional piracy incident along a route connecting China to destination country c. Using the ocean dummy as dependent variable, β_1 informs about the effect of piracy on the choice of shipment mode.

Country-product-firm fixed effects also control for all unobserved time invariant variables that may correlate with both the dependent variable and the number of piracy incidents, thus ruling out one possible source of omitted variable bias. In particular, some routes are more likely to experience piracy than others. One reason for this could be geography - natural harbors provide a good basis for piracy operations. Another is the popularity of the route as those with a lot of traffic might either attract piracy (greater likelihood of capturing a ship) or deter it (ships in distress may quickly call for help). However, while popular routes with large trade values may or may not cause increased piracy activity, this relationship is less likely to hold at the firm-transaction-level. Average shipment size and value (per container) should not affect piracy on the route. Nevertheless, any remaining correlation is controlled for by using country-product-firm fixed effects.

Global economic conditions might constitute another source of omitted variable bias. In particular, a strong global economy might be associated with an increase in shipping activity as well as a decline in pirate activity under the assumption that the latter is correlated

with economic hardship. Similarly, seasonality might play a role as seasonal weather conditions simultaneously affect shipping and piracy activity. Both factors can be controlled for by using product-firm-time fixed effects, which also account for unobserved product-firm specific time trends.

Since we are also interested in the effect of piracy on total trade, we regress total export quantity at the product-country-time-level (thus aggregating over all firms) on the number of piracy incidents according to the following equation:

$$\ln Y_{cpt} = \beta_1 Piracy_{(t-3)c} + \nu_{cp} + \nu_{cy} + \nu_{cm} + \nu_{pt} + \epsilon_{cpt}, \tag{4.2}$$

where $\ln Y_{cpt}$ is the natural logarithm of total quantity shipped of product p to country c at time t. Since such an estimation may be subject to simultaneity as more popular trade routes are more likely to attract piracy, the number of piracy incidents $Piracy_{tc}$ is lagged by three months. This might only pose a partial solution if trade per route is correlated over time. We therefore also use country-product fixed effects to account for all time invariant factors as well as country-year fixed effects. Seasonality is controlled for using country-month fixed effects and product-time fixed effects control for global as well as product specific time trends.[4] Hence, the estimated coefficient β_1 tells us how total exports of a particular product p to a particular country c change at a point in time t if the number of piracy incidents has changed three months ago.

4.4 Results

4.4.1 Firm-level Regressions

The baseline results of the firm-level regressions are reported in Table 4.1. The first column shows results from regressing the ocean dummy, which identifies whether a transaction has been carried out by ship as opposed to air, on the number of piracy incidents as well as controls. The coefficient of $\ln price$ is negative and significant at the 1% level, indicating that a one percentage point increase in unit values is associated with a reduction in the likelihood of the transaction being carried out by sea by 4.5%. Qualitatively, this result is in line with the finding of Harrigan (2010).

[4] "Month" in this context means January - December, whereas "time" is a year-month combination, e.g. January 2000.

Table 4.1: The Effects of Piracy on the Choice of Transport Mode

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent Variable	Ocean Dummy	ln quantity All	ln quantity Ocean	ln quantity Air	ln price All	ln price Ocean	ln price Air
Piracy cases	-0.0002***	0.0007***	0.0014***	-0.0001	-0.0002*	-0.0002*	-0.0001
	(0.0000)	(0.0003)	(0.0003)	(0.0009)	(0.0001)	(0.0001)	(0.0004)
ln price	-0.0453***	-0.6740***	-0.6851***	-0.5159***			
	(0.0008)	(0.0041)	(0.0039)	(0.0079)			
Observations	10,650,883	10,614,099	8,127,057	1,437,225	10,650,883	8,136,755	1,461,519
R^2	0.5799	0.8025	0.8597	0.8592	0.9585	0.9673	0.9558
Clusters	978225	975291	820381	152990	978225	821182	155136

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. OLS regressions with country-product-firm and product-firm-time fixed effects. Robust standard errors clustered by country-product-firm in parenthesis.

The negative piracy coefficient of -0.0002 is significant at the 1% level and indicates that one additional pirate incident on a particular route reduces the probability that a given firm ships a given product to a particular country by ship by 0.02%. This result provides evidence that increased pirate activity induces firms to reduce the number of transactions carried out by ship relative to those by plane.

Column 2 of Table 4.1 presents the effects of piracy on average shipment size across both ocean and air shipments. The statistically significant coefficient of 0.0007 means that the average quantity shipped increases by 0.07% for each pirate incident on a route. This coefficient is twice as large when only looking at goods shipped by sea (Column 3), while it turns insignificant when only considering air shipments (Column 4). Together with results in Column 1, this implies that piracy induces firms to reduce the number of shipments by sea relative to air and to increase the size of the remaining shipments. As stated in Section 4.1, one explanation for this observation is the fact that the additional costs of piracy accrue per journey and are thus not ad-valorem. In order to minimize costs per ton shipped, ships have an increased incentive to run at full capacity. If they charge more per container, firms have an increased incentive to fill them, thus explaining increased average shipment size.

Column 5 of Table 4.1 shows regression results from regressing $\ln price$ on the number of pirate incidents. The coefficient of -0.0002 is significant at the 10% level and indicates

that average unit values per shipment fall in the presence of piracy on a given route. This observation may also be explained through the costs associated with piracy. Depending on the elasticity of demand, the increase in transport costs will only partially be passed through to consumers, so that exporters reduce producer prices. As shown by Column (6), this effect is driven by goods shipped by sea. There is no evidence for a change in unit values of goods shipped by air (Column 7).

4.4.2 Product-level Regressions

Table 4.2 presents regression results at the product-level. The significantly negative coefficient of -0.0009 reported in Column (1) means that one additional case of piracy along a particular route is associated with a 0.1% fall in exports to all countries on that route. Looking at Column (2), it can be seen that this aggregate trade effect is driven by a reduction in ocean trade. While ocean trade declines by 11%, the respective coefficient for air trade (Column (3)) is, while identical in magnitude, not significantly different from zero. Looking at Figure 4.2, that means that in an average month with 26 piracy cases along the route to Europe, trade is around 2.3% lower than in the absence of piracy.

Table 4.2: The Effects of Piracy on Chinese Exports

	(1)	(2)	(3)
Dependent Variable	ln quantity Aggregate	ln quantity Ocean	ln quantity Air
Piracy cases (lagged)	-0.0009**	-0.0011***	-0.0011
	(0.0004)	(0.0003)	(0.0008)
Observations	4,896,465	3,770,565	1,019,446
R^2	0.6346	0.8071	0.7852
Clusters	211881	194934	70184

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. OLS regressions with piracy cases lagged by 3 months, country-product, country-year, country-month and product-time fixed effects. Robust standard errors clustered by country-product in parenthesis.

4.5 Robustness Checks

In our baseline regression, we use Chinese export data to investigate effects of piracy on firms' choice of transport mode. In a robustness check, we run the same regressions using import data. The results are summarized in Table 4.3 below. The significantly negative coefficient of piracy in Column (1) reveals that Chinese importers also react to piracy by switching to air transportation. The coefficient is twice as large as its equivalent in Table 4.1, suggesting that importers may react more sensitively than exporters. The coefficient of ln *price* is similar to the baseline.

However, Column (2) of Table 4.3 does not provide evidence for increased shipment size following an increase in pirate activity. This is true for both, trade carried out by ocean (Column (3)) and air (Column (4)). Finally, Column (5) indicates no effect of piracy on prices. This result is, however, not directly comparable to the baseline because import values - and thus imputed unit values - are reported at cost insurance freight. They can be interpreted as consumer prices and provide evidence that producers do not pass on the piracy induced increase in transportation cost to consumers. The result is hence in line with falling producer prices indicated by Column (5) of Table 4.1. Interestingly, the price coefficient for ocean shipments (Column 6) is significantly negative while that for air shipments (Column 7) remains insignificant. There is no evidence that piracy negatively affects import quantity at the product-level (Table 4.5 in the Appendix).

Table 4.3: The Effects of Piracy on the Choice of Transport Mode, Imports

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent Variable	Ocean Dummy	ln quantity All	ln quantity Ocean	ln quantity Air	ln price All	ln price Ocean	ln price Air
Piracy cases	-0.0004***	-0.0009	-0.0015	-0.0004	-0.0006	-0.0009**	-0.0006
	(0.0001)	(0.0007)	(0.0010)	(0.0009)	(0.0004)	(0.0005)	(0.0006)
ln price	-0.0455***	-0.6441***	-0.6439***	-0.5265***			
	(0.0007)	(0.0037)	(0.0073)	(0.0048)			
Observations	7,155,017	6,854,297	2,959,643	2,385,407	7,155,017	3,020,738	2,565,631
R^2	0.6206	0.8560	0.9010	0.8618	0.9210	0.9515	0.9190
Clusters	548448	529845	283530	205965	548448	288199	220062

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. OLS regressions with country-product-firm and product-firm-time fixed effects. Robust standard errors clustered by country-product-firm in parenthesis.

Product-firm-time fixed effects are used in the baseline to control - among other things - for seasonal variation. However, when it comes to the choice of transport mode, weather conditions can be very different across different routes at the same point in time. As an additional robustness check, we hence perform the firm-level regression, controlling for country-month fixed effects. The results are reported in Table 4.6 in the Appendix. All coefficients remain similar to the baseline results in both magnitude and significance. The only exception are the estimated effects of piracy on prices presented in Columns (5) and (6) of Table 4.6, which turn insignificant.

4.6 Conclusion

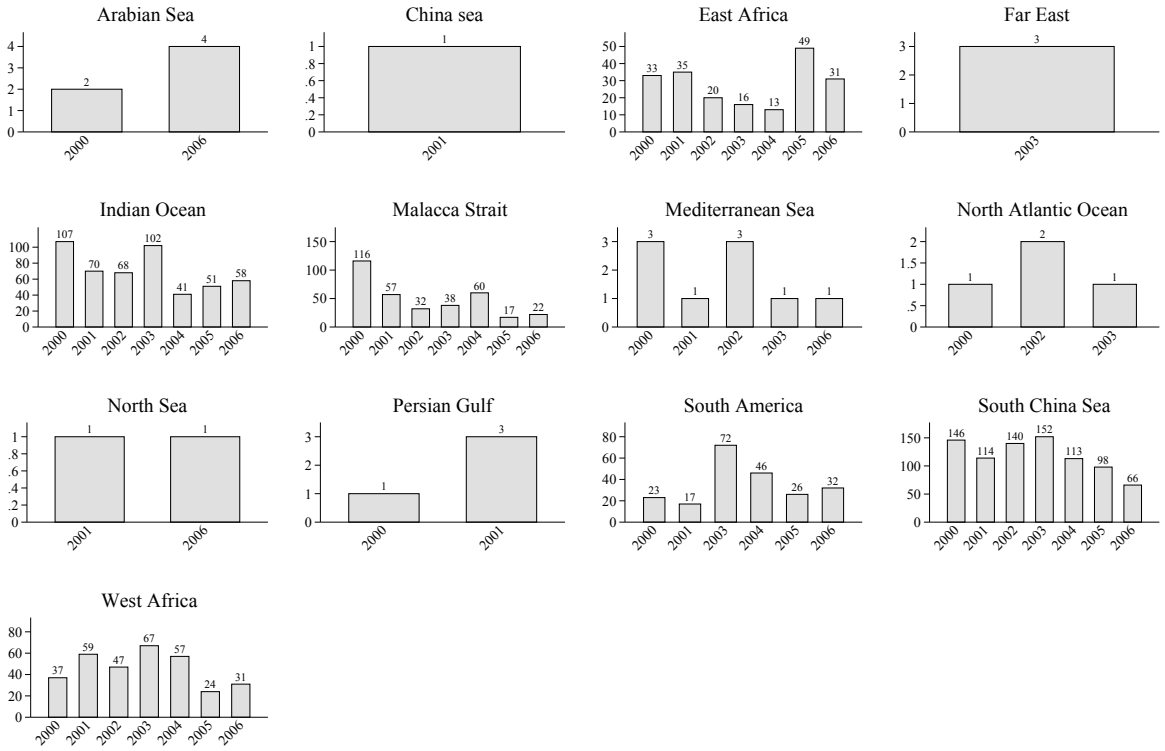
This paper combines Chinese customs data with detailed information on pirate activity to investigate the effects of piracy on firms' choice of transport mode as well as aggregate trade flows. After briefly illustrating that piracy can be modelled as an increase in fixed costs per shipment, it was shown that, in line with the literature, an increase in piracy along a trade route induces exporters to switch from ocean to air transport, while the remaining ocean shipments become larger. This is accompanied by a fall in average producer prices, which can be explained by the fact that a piracy induced increase in transport costs is not fully passed on to consumers.

Aggregating over all firms exporting a particular product to a particular country, it was shown that, despite the aforementioned reactions of exporters, overall trade declines along routes affected by piracy. More specifically, 26 piracy incidents per month on a particular route (the average number for Europe) reduce exports on average by 2.3%. Given the sources of measurement error due to data availability discussed in Section 4.2, this estimate is likely to constitute a lower bound of the true treatment effect.

Overall, the results thus show that piracy does have a small but significant dampening impact on trade. Beyond obvious humanitarian reasons, this constitutes an additional motive for governments to act. Moreover, the switch from ocean to air travel along routes affected by piracy may have second order effects for other industries that have not yet been considered.

4.7 Appendix

Figure 4.3: The Number of Piracy Incidents over Time by Region



Note: The graph reports the total number of piracy incidents from 2000 - 2006 by region. *Source:* Data from International Maritime Organization.

Table 4.4: Matching of Regions to Continents

Continent	**Region**	**Continent**	**Region**	**Continent**	**Region**
Africa	East Africa China Sea South China Sea Malacca Strait Far East Indian Ocean West Africa	Europe	China Sea South China Sea Malacca Strait Far East Indian Ocean Arabian Sea Mediterranean Sea West Africa North Atlantic Ocean North Sea East Africa	Asia	China Sea South China Sea Malacca Strait Far East Indian Ocean Arabian Sea Persian Gulf East Africa
Americas	China Sea South China Sea South America	Oceania	China Sea South China Sea Far East		

Note: Authors' own allocation

Table 4.5: The Effects of Piracy on Chinese Imports

	(1)	(2)	(3)
Dependent Variable	ln quantity Aggregate	ln quantity Ocean	ln quantity Air
Piracy cases (lagged)	0.0004	0.0001	0.0014
	(0.0006)	(0.0008)	(0.0008)
Observations	2,814,960	1,599,758	1,104,302
R^2	0.7210	0.8622	0.7807
Clusters	88113	67523	54258

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. OLS regressions with piracy cases lagged by 3 months, country-product, country-year, country-month and product-time fixed effects. Robust standard errors clustered by country-product in parenthesis.

Table 4.6: The Effects of Piracy on the Choice of Transport Mode, Seasonality

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent Variable	Ocean Dummy	ln quantity All	ln quantity Ocean	ln quantity Air	ln price All	ln price Ocean	ln price Air
Piracy cases	-0.0002***	0.0006**	0.0013***	-0.0001	-0.0002	-0.0001	-0.0001
	(0.0000)	(0.0003)	(0.0003)	(0.0010)	(0.0001)	(0.0001)	(0.0004)
ln price	-0.0453***	-0.6738***	-0.6849***	-0.5159***			
	(0.0008)	(0.0041)	(0.0039)	(0.0079)			
Observations	10,650,819	10,614,035	8,126,992	1,436,978	10,650,819	8,136,690	1,461,273
R^2	0.5800	0.8026	0.8598	0.8594	0.9586	0.9673	0.9559
Clusters	978206	975272	820360	152924	978206	821161	155072

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. OLS regressions with country-product-firm, product-firm-time and country-month fixed effects. Robust standard errors clustered by country-product-firm in parenthesis.

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