

The Short- and Medium-Run Effects of Computerized VAT Invoices on Tax Revenues in China*

(Very Preliminary)

Haichao Fan[†], Yu Liu[‡], Nancy Qian[§] and Jaya Wen[¶]

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Abstract

This paper studies the short and medium-run effects of computerizing VAT invoices on tax revenues and firm behavior in China. We use a balanced panel of manufacturing firms to show that computerization increased VAT revenues. However, the short-run gains are much larger than the longer-run gains. We provide evidence to show that the change over time is consistent with firms adjusting production downwards in response to the tax increase.

Keywords: State Capacity, Technology, Taxation, Short and Long-run Elasticities.

JEL: H25, H26, O12

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[†]Fudan University, fan_haichao@fudan.edu.cn

[‡]Fudan University, dav.yu.liu@gmail.com

[§]Northwestern University, nancy.qian@kellogg.northwestern.edu

[¶]Yale University, jaya.wen@yale.edu

1 Introduction

All governments face the challenge of collecting taxes. Two central questions for policy makers and economists regard enforcement and the economic responses to increased taxes. How can the government enforce payment? How will taxpayers respond? Moreover, will the response differ between the short run, when many factors are inelastic, from the long run, when many more adjustments can be made [Saez et al., 2012].¹ For developing economies, one of the most important contexts within which to ask these questions is that of the Value Added Tax. VAT is thought to be popular with developing economies because it is, in principle, self-enforcing, and thus require lower bureaucratic capacity to collect [Besley and Persson, 2009] and [Besley and Persson, 2010].² While the exact formula varies across countries, VAT is broadly based on sales minus fraction of inputs costs. Thus, upstream firms that sell raw materials to downstream firms are incentivized to understate their sales, but are checked by downstream firms that buy the materials because the latter are incentivized to overstate the value of their input purchases from the upstream firms. For example, VATs account for 18.7% of total government revenues in Mexico, 9.5% in the Philippines, 17% in South Korea and 36.2% in China in 2000 (OECD 2000). In 2002, the revenue from VAT was 814.1 billion RMB, which accounted for 47.61% of the state total tax revenue that year, making it the largest source of tax revenue in China.³

The goal of this paper is to understand how VAT revenues and firm behavior respond to increased enforcement in the short and medium/longer run. We focus on China, where VAT is the most important source of state revenue, and which underwent major improvements in enforcement. Before 2001, the Chinese government's ability to enforce VAT was limited. Firms kept government-issued carbon copy receipts for each transaction. These receipts were meant to allow tax collectors to cross-check sales against reported input values. However, it was very costly for bureaucrats to manually link purchases to sales across firms. With so many firms and so many transactions in the economy, one would expect significant scope for evasion (as well as human error). Between 2001 and 2002, the government computerized the system so that almost

¹Saez et al. [2012] reviews the empirical literature on tax elasticities.

²For example, Besley and Persson [2009] and Besley and Persson [2010] make a point of using the ratio of income tax revenues to GDP as a measure of bureaucratic capacity. The underlying idea is that other tax revenues such as VAT, require much less capacity to administer.

³<http://www.China.org.cn/english/LivinginChina/202770.htm>

all invoices became digitally recorded. The new system was rolled out during 2001 and 2002. This was a significant improvement since mismatched values in upstream sales and downstream purchases show up automatically in the new system.

The empirical analysis faces three serious challenges. First, there has been very little research on taxation in China and the context (e.g., laws, regulations, typical firm behavior) is more or less a black box when we began this study. Second, the tax authorities do not release disaggregated data to researchers. Third, there is the standard difficulty of establishing causal effects. For example, finding that VAT revenues in China increase after 2001 cannot distinguish between the hypotheses that the improved enforcement increased tax revenues from the alternative that VAT revenues increased with GDP growth.

The principal contribution of our paper is to address these difficulties. To understand the Chinese tax system, we conduct extensive archival research into government documents, policy reports, and conduct a large number of interviews with tax officials and managers of firms in the private and state sectors. To overcome the lack of disaggregated administrative tax data, we use reported VAT payments from the census of manufacturing firms, 1998-2008.

For causal identification, we exploit two sources of variation. First, we exploit time variation in the introduction of the computerization in 2001. Second, we exploit cross-sector variation in the intensity of the treatment effect. Tax officials that we interviewed claimed that prior to computerization, the limited manual audits focused on firms in sectors with larger average shares of VAT deductions. For example, consider two sectors that have the same level of average gross VAT obligations (which in China, is 17% of sales). However, final VAT payments are gross VAT minus deductions. Assume that firms in the first sector are on average eligible to deduct 10% while those in the second are on average able to can deduct 90%. Since tax collectors who are manually cross-checking and capacity-constrained choose to focus more attention on the latter sector, then the technological improvement should reduce evasion more for the first sector. Using data on tax personnel, we are able to provide some empirical support for this assumption. See the Section on Data. Our measure of reform intensity is therefore the net VAT as a share of gross VAT paid by firms within a sector. Henceforth, we will just refer to this as VAT share for simplicity.⁴

⁴Note that our strategy is constructed to capture how much the new technology reduced evasion. It will not

The natural experiment is akin to a differences-in-differences estimate. We compare VAT in sectors that had a high VAT share prior to 2001 to sectors with a lower share, before and after 2001. One concern is that the pre-computerization measure of VAT share is confounded by evasion. For example, this is a concern if tax auditors have a separate source of true VAT share measures based on past audit information that the econometrician cannot observe and true VAT share is inversely correlated with reported VAT share prior to computerization. Then, the finding that VAT increases more in sectors with high pre-VAT share will have the opposite interpretation as our preferred one. In practice, this is unlikely to be an issue, since to the best of our knowledge, tax auditors use data that is highly correlated with ours. However, we cannot be sure. Thus, to address this possibility, we instrument for pre-2001 deductible share of each sector with pre-VAT shares of the analogous U.S. sector. The baseline estimate regresses VAT payments from each firm on the interaction of pre-VAT share of the sector in which the firm belongs, and its interaction with a dummy variable for each year in our sample, while controlling for firm fixed effects and year fixed effects. Each interaction is instrumented by the interaction of U.S. VAT share in the analogous sector and the relevant year dummy variable.

For clarity and identification, the main exercise uses a panel of firms that exist throughout the sample period. This allows us to control for firm fixed effects and not worry about the entry or exit of firms. Later, we show that results using all firms are similar, and we find no effect on net entry/exit.

We find that after computerization, VAT revenues (payments) first increased (for approximately three years) and then declined to levels that are similar or only slightly above pre-computerization levels. The same pattern exists when we examine VAT as a share of sales as the dependent variable. Thus, the result is not an artifact of spurious higher growth in sectors that are more affected by computerization.

An important caveat for interpreting the baseline estimates as causal is joint determination – i.e., sectors with higher pre-treatment VAT share differ from those with lower pre-treatment VAT share along other dimensions that would affect the outcome of interest (despite the instrumental variables strategy and controls). We conduct several exercises to investigate and mitigate these

be able to capture increases in VAT that arise from a reduction in human error unless if the error was for some reason positively correlated with our intensity measure. See section 3 for a more detailed discussion.

concerns. First, the dynamic estimates show that there are no pre-trends. However, this does not address our main concern that our estimates are confounded by China’s entry into the WTO in 2001. If export/import tariffs changed differentially according to pre-VAT share, then our results will be confounded. We address this with a second exercise where we control for rebates and tariffs measured at the sector and year level. Our estimates are very robust.

To shed light on why the short and longer run gains in VAT revenues differ, we consider two obvious explanations as motivated by the literature. First, it is possible that firms learned new methods of evasion. However, this is inconsistent with anecdotal evidence from both the tax officials and firm managers that we interviewed. While evasion is certainly possible after computerization, it remained very difficult since all invoices were digitized and cross-referenced from sellers to buyers. To evade, all firms in the production chain would have to opt out of official invoices.⁵

A second candidate explanation is that the relative reduction of long-run gains reflect real change. Specifically, firms are able to make more adjustments over time in response to the tax increases. To investigate this possibility, we develop a simple three-period model of perfect competition and with Cobb Douglas production technology, where we assume that only one factor can adjust in the first period, but all factors can adjust in the longer run. The model produces several interesting and non-trivial results: i) the pre-tax price will increase each period; ii) sales will decline each period; iii) tax revenues will increase from period zero to period one, but then decline in period two to be between the levels of period zero and one; and iv) inputs will decline.

Thus, the model illustrates how the tax increase can generate larger gains in the short run relative to the longer-run. To investigate the plausibility of this model as an explanation of our main finding, we investigate the additional empirical implications with our data. Specifically, we use the same empirical strategy and data to examine the effect of computerization on sales, TFPR (which is equivalent to the pre-tax price in our model), labor and intermediate inputs.⁶ Consistent with the model, we find that computerization leads to a gradual and continued decline in sales and inputs in the six years after computerization, while it leads to a gradual

⁵The exceptions to these are firms at the beginning or the end of a chain. We are currently exploring the possibility of identifying these firms.

⁶Unfortunately, we do not observe deductible material inputs, which are a subset of intermediate inputs.

and continued increase in TFPR.

In addition to the baseline results that use a balanced panel of firms, we also repeat our analysis with all firms to allow entry and exit into/from the sample.⁷ The results are very similar to our baseline results, which suggests that our main results that rely on sector-level variation, is unlikely to miss out of important general equilibrium effects and that results from using surviving firms are likely to have external validity for Chinese manufacturing as a whole.

Taken together, the results show that technology can greatly improve state capacity. However, the tax revenue gains decline over time. We acknowledge that some evasion is present throughout the period that we study. However, the empirical results on sales, TFPR and inputs together show that part the decline is very likely due to real effects – i.e., firms scaling down production in response to the tax increase.

Our study adds to several existing literatures. First, we add to studies in public economics that empirically estimate responses to tax changes. Existing studies have mostly focused on short-run effects, and the contexts of income tax and corporate tax. There is little direct evidence on longer-run effects, even though they are widely believed to be quite different from short-run responses. For a more detailed discussion of the existing literature, see the review article by Saez et al. [2012].⁸ In examining VAT, this paper complements recent studies on the determinants of compliance to VAT in developing countries. Naritomi [2015] uses a natural experiment in Brazil to show that monetary rewards for consumers to collect receipts significantly increases reported firm revenues. Pomeranz [2015] shows that third-party information improves VAT enforcement in Chile. We add to these studies by examining a new context – China, and showing that an improvement of the VAT information chain can affect tax revenues in the absence of third-party enforcement, and by providing new evidence that in the longer-run firms scale down output in response to the tax increases.

Second, we add to studies of state capacity and development [Besley and Persson, 2009] and [Besley and Persson, 2010], and in particular, the effect of technology on bureaucratic capacity. In evaluating a fully scaled (i.e., nationally implemented) technology, our study is most similar

⁷This analysis controls for sector instead of firm fixed effects.

⁸For recent studies that provide important indirect or descriptive evidence on longer run elasticities, see for example, Kleven and Waseem [2013] and Piketty et al. [2014] which studies income tax in Pakistan and the United States, respectively.

to Muralidharan et al. [2016], which shows that biometric technology improves the delivery of state subsidies in rural India. In highlighting the benefits of new technology for governance, we are also related to Banerjee et al. [2008] and Duflo et al. [2012], which provide experimental evidence that time-stamped photographs improve public goods provision (teacher and nurse performance) in India.

Finally, we add to a growing number of studies that investigate firm production in China. Most notably, Hsieh and Klenow [2009] and Hsieh and Song [2015], which use the same data as this study; as well as studies on VAT in China, which have thus far focused on export industries [Garred, 2014, Chandra and Long, 2013, Gourdon et al., 2015]. We add to these by showing the relationships between state capacity, tax revenues and firm output.

This paper is organized as follows. Section 2 discusses the background. Section 3 presents the empirical framework. Section 4 describes the data. Section 5 presents the main results on VAT revenues/payment. Section 6 presents a simple model to interpret the results. Section 7 presents additional results, including robustness checks. Section 8 concludes.

2 Background

The Chinese government introduced VAT in its modern form in 1994. As in many countries with VAT, it takes the place of sales tax and is an important source of state revenue. By 2002, it had become the largest source of tax revenue in China.⁹ To determine how much each firm owed, the government uses a system of invoices for transactions involving deductible goods, with which firms would report the value of their sales and the value of their deductible inputs. This system, which required firms to self-report, was largely manually administered and understandably prone to errors.

In interviews with the authors of this paper, tax collectors state that they focus their limited manpower on firms in sectors which have a higher share of deductibles – i.e., firms which pay less VAT as a share of sales. This is the basis of the cross-sectional variation that we will later exploit in our empirical strategy.

To combat human error and intentional evasion, the Chinese government instituted a multi-

⁹<http://www.China.org.cn/english/LivinginChina/202770.htm>

stage VAT reform, called the Golden Tax Project, characterized by two major reform phases. During Phase I, which took place from 1994 to 1998, the government implemented a VAT invoice cross-check system across China. The crux of this reform was to check whether the sales invoices of firms that produced intermediate goods matched with the input invoices of firms that used the same intermediate goods. However, the system was implemented manually, and suffered from painfully slow implementation and high error rates. Phase II of the Golden Tax Project, which took place from 1998-2003, aimed to strengthen the information chain with modern technology. This was done by computerizing the information needed for cross-checks. The latter was introduced in 2001 and rolled out over two years, 2001 and 2002. Since digitally issued invoices are not useful until the data on them are transferred to tax authorities, we interpret 2001 as the beginning of improved enforcement.

Specifically, after 2001, the state did the following. The State Administration of Taxation issues each firm an IC card with a unique ID that is physically installed into the firm's computer, an IC card reader, invoices, an invoice-issuing computer software, and a special printer for the invoices. Each transaction is physically recorded on the paper invoice (and its carbon copy) as well as on the encrypted IC card. Each month, firms file for VAT deductions by bringing all of the paper invoices and the IC card to the State Administration of Taxation. A firm's input purchases are recorded on paper invoices, while its sales are recorded in its IC card. To verify inputs, the invoices are scanned and the information checked against sales data taken from other firms' IC cards in the national database. To verify sales, data are taken from the IC card and cross checked against input data taken from the input invoices from other firms in the national database. The refund is issued when the data are verified.

Our data include 1998-2008. To the best of our knowledge, there were no other important changes in VAT during this period. For example, the formula for calculating VAT was the same throughout the period.

$$VAT\ paid = VAT\ gross - VAT\ deductions = 0.17 * (Sales - Deductible\ Inputs) \quad (1)$$

VAT is 17% of the difference between sales and deductible inputs. Deductible costs include

the cost of materials, overhead (like rent), and depreciation of physical capital. The most important non-deductible costs include employee wages and benefits, real estate costs, fixed asset or capital purchases, depreciation and interest payments. See the Appendix for a detailed list.

The most common ways for evasion are to overstate deductions or to understate sales. With the invoices perfectly cross-linked in the new computerized system, evasion becomes much costlier in that firms would need to opt out of using state-issued invoices altogether, which can only be done by coordinating with upstream or downstream trading partners. Two exceptions to this are for the firms at the very top and very bottom of the production chain (e.g., raw materials producers and retailers), which can, as always, unilaterally overstate input costs or understate sales, respectively.

Very few sectors/firms are exempt from VAT. An important exception to the standard rule are imports and exports. China has import tariffs throughout the period that we study. Tariffs on inputs are deductible in the same way as the original value of the input is deductible. Similarly, China has given rebates to exporters throughout the period of our study. Unlike many other countries with VAT, Chinese export rebates are typically less than the VAT – i.e., exports have to pay some VAT. Both import tariffs and export rebates vary across sectors (products) and over time. One concern for our study is that China’s entry into the WTO systematically changed the effective VAT for firms in a way that would confound our study. We discuss this in more detail after we present our empirical strategy and main results and will address this concern by controlling for import tariffs and export rebates.

3 Empirical Framework

For identification, we exploit two sources of variation. First, we exploit time variation in the introduction of the computerization in 2001. Second, we exploit cross-sector variation in the intensity of the treatment effect. The latter is motivated by interviews with Chinese tax collectors, which state that manual audits by tax collectors focus on firms in sectors which, on average, have a larger share of VAT deductibles, or in other words, sectors which pay less VAT as a share of sales on average.

Thus, our cross-sectional measure of intensity is \widetilde{VAT}_s , which we refer to as the VAT share. It is calculated with the following formula:

$$\widetilde{VAT}_s = 1 - \left(\frac{\widetilde{Deductions_s}}{Gross_s} \right). \quad (2)$$

The second term, $\left(\frac{\widetilde{Deductions_s}}{Gross_s} \right)$, is the median of the ratio of deductions to gross VAT obligations (based only on sales) in sector s . In other words, we calculate this measure at the firm level and then take the median estimate for each sector.¹⁰ It is easy to see that VAT share is increasing with gross VAT and decreasing with deductions. T

To avoid reverse causality, we use data from a base period that was before the treatment to calculate the intensity variable. Since the computerization took place in 2001, we use the average VAT share during 1998-2000.

Our analysis focuses on the dynamic effects. The baseline second stage equation can be written as the following.

$$y_{ist} = \gamma_0 + \sum_{t=1999}^{2007} \beta year_t * \widetilde{VAT}_s + \tau_t + \phi_i + \epsilon_{st}. \quad (3)$$

Outcomes in firm i sector s and year t , y_{ist} , are functions of: the interaction of a dummy which takes the value of one if it is year t , $year_t$, and an estimated measure of intensity at the sector level, \widetilde{VAT}_s ; firm fixed effects, ϕ_i ; and year fixed effects, τ_t . Since VAT share varies at the sector level, the standard errors are clustered at the sector level. Note that sector fixed effects are absorbed by firm fixed effects. In other words, the identifying variation is at the sector and year level. But we can control for firm fixed effects because our data are a panel of firms.

We are interested in the estimate of β . For example, when the outcome is VAT payment, we hypothesize that the interaction coefficient will be positive, which captures the effect of computerization on increasing VAT payment.

Since evasion was rampant prior to 2001, one may be concerned that pre-VAT shares are mis-measured. For our analysis, this is a concern if we believe that tax officials used different

¹⁰Our results are similar if we use the sector average instead of the median. We prefer the latter because it avoids being affected by outlier firms. Results using sector averages are available upon request.

data sources for VAT share in determining who to audit. In this case, our pre-VAT share from the Manufacturing Censuses could introduce classical or non-classical measurement.

To address this difficulty, we instrument for pre-VAT share in China with average VAT share from the United States. Specifically, equation (3) estimates nine interaction coefficients. We will have nine instruments, which are the interaction of the average U.S. VAT share and each of the nine year dummy variables. For the instruments to address measurement error, no exclusion restriction need to be satisfied.

Note that the main purpose of our instrumental variables strategy is to address the presence of measurement error rather than endogeneity. That said, the main caveat for the 2SLS estimates is that it may be correlated to the error term. An example of endogeneity that is not addressed by the instrument comes from China’s entry to the WTO in 2001. We are concerned that sectors with higher pre-VAT shares may also be sectors which were less likely to switch to exports (that are VAT exempt) after China entered the WTO in 2001 and thus increase relative VAT payments for other reasons. If these are the same sectors in China and the United States, then our instrument will not address it. Thus, after the main results, we will present a large number of robustness checks where we control for additional factors such as sector-specific tariffs.

We note that a natural alternative empirical strategy would be to examine the interaction effect of computerization with a proxy for the cost of manual monitoring. To do this, we collected data on the locations of all tax offices in China and mapped the distances between each firm to the nearest tax office. However, we found that this was not a good strategy in practice because the large manufacturing firms in our sample are almost all in cities, where the tax office is very close. Therefore, there is little variation in distance.

4 Data

The main sample is a balanced panel of firms for the years 1998-2007 based on data reported by China’s *Annual Survey of Industrial Production*. These data are collected by the National Bureau of Statistics and are sometimes referred to as the “Census of Manufacturing Firms”. The unit of observation is the firm; subsidiaries are coded as separate entities as long as they

are unique legal units. The dataset includes all state-owned manufacturing firms and the set of non-state manufacturing firms with sales which are greater than five million RMB. These data have been used by several recent studies. The most well-known is probably by Hsieh and Klenow [2009], which used all of the years available when their paper was written, 1998-2005. We follow the standard procedure for cleaning these data. See the Data Appendix for more details.

The inclusion and exclusion criteria for non-state owned firms are not symmetric. The census includes all state-owned firms and private firms that have revenues above five million RMB. Moreover, the latter threshold does not seem to be systematically imposed. We observe many private firms below this threshold (with no apparent pattern in firm age or other attributes). To avoid interpretational difficulties due to selective sampling, we will impose a uniform cutoff and omit all firms with less five million in revenues in our sector-level analysis.

These surveys report a rich set of variables. The key variables for our study are gross VAT, VAT deductibles and VAT payment. The data often noisy such that VAT payment does not equal what it should be by law, seventeen percent of gross VAT minus deductibles. To ensure data quality, we restrict our sample to observations where VAT payment is within 90-110% of what it should be.¹¹ We will discuss and motivate other variables as they become relevant.

We define sectors to be 4-digit sectors. There are 425 sectors in our sample. All of the values in the paper are reported in real terms.¹² The main sample is a balanced panel of over 15,000 firms.¹³

We use the 2007 United States Input-Output Accounts Data from the Bureau of Economic Analysis to construct U.S. VAT shares. These tables report the share of inputs required by industry s from all other industries in production. Hence, the elements of the table report $Input\ fraction_{sr}$, for $r, s \in S$, where S represents the universe of all sectors. For each sector s , we have $\sum_{r=1}^S Input\ fraction_{sr}=1$.

To construct our measure of U.S. VAT share, we map each sector in the input-output tables into two groups: deductible or non-deductible, according to the rules of the Chinese VAT deductions. In practice, we consider inputs from manufacturing industries to be materials,

¹¹Our main results are similar if we do not impose this restriction. They are available upon request.

¹²We use deflators provided by the Penn World Tables.

¹³Note that the panel is not perfectly balanced because some variables are missing for some years.

and thus deductible under Chinese VAT rules. We treat inputs from service industries to be non-deductible. To obtain the final measure, we sum the fractions of inputs from deductible industries to obtain a single fraction for each industry, representing the share of inputs in that industry that is deductible under Chinese VAT rules. This can be characterized with the following equation, in which D represents the set of deductible industries

$$\widetilde{VAT}_s^{US} = 1 - \sum_{d \in D} Input\ fraction_{sd}. \quad (4)$$

4.1 Descriptive Statistics

4.1.1 Pre-Computerization Enforcement

Despite our best efforts, we were unable to find auditing data to verify the claims by tax officials that firms in sectors with higher deductible shares were more likely to be audited prior to computerization. However, we were to obtain data for the number of tax personnel in each province and year from the *Tax Yearbook of China*, 1998-2000. There are a few missing observations. We use all of the data that are reported and combine them with other variables that would affect the probability a firm would be audited, namely, ruggedness, the size of the province, and the number of firms in a province.¹⁴ The data are at the province and year level. Table 1 presents the results from a cross sectional regression that controls for year fixed effects. VAT share is the average VAT share across firms within a province. The more firms that belong to sectors with higher VAT shares before 2001, the higher this measure will be. Column (1) examines the number of officials per province as the dependent variable. Column (2) examines the log number of officials as the dependent variable. The results are similar. The coefficient for VAT share is negative, which means that provinces with firms in higher VAT share sectors had fewer tax personnels whom could conduct manual audits, controlling for the difficulty of the terrain which can affect how accessible firms are to auditors that mostly reside in large cities (ruggedness), the size of the province which can also affect travel costs, and the number of firms in the province. Only the coefficients for VAT share and the number of firms

¹⁴Ruggedness is computed from ArcGIS by the authors. The size of the province is reported by the *China Statistical Yearbook*, 2000. We calculate the number of firms per province and year using our main dataset, the *Annual Survey of Industrial Production*, 1998-2000.

are statistically significant. When we examine the normalized coefficients, which show the effect of a one standard deviation change in the explanatory variable on the dependent variable in terms of standard deviations, we find that the effect of VAT share is very large. For example, column (2) shows that a one standard deviation increase in average VAT share in the province reduces the log number of tax officials by over half of one standard deviation. These results are consistent with the anecdotal evidence.

Means

The mean value of pre-2001 VAT share is 0.275 in the balanced panel of firms. Table 2 presents the means and standard deviations for all of our main dependent variables (without logging). These are large firms. Average sales/revenues are 97 million RMB. On average, the firms have around 442 workers.

5 Results

5.1 First Stage Estimates

In the first stage regression, we have nine endogenous interaction terms and nine instruments. We present the first stage for each variable in Table 3. The estimates in column (1) show that the only significant instrument for the interaction of pre-VAT share and the dummy variable for1999 is the interaction of U.S. Share and the dummy variable for 1999. Column (2) shows that the only significant instrument for the interaction of pre-VAT share and the dummy variable for 2000 is the interaction of U.S. Share and the dummy variable for 2000, and so forth. This means that the first stage is loading correctly, which is not surprising given our strategy. The estimates also show that the coefficient of the significant instrument is similar across columns. This simply reflects the fact that we have the same pre-VAT share and U.S. VAT share on the left and right-hand sides of each equation. The only thing that differs is which year the pre-VAT share on the left hand side is interacted with. When we estimate the first stage together in one step, we find that the F-statistic is 9.57.

5.2 2SLS Estimates

5.2.1 VAT Payments (per firm Revenues)

For brevity, we focus our discussion on the 2SLS estimates, which are very similar to the OLS and reduced form estimates shown in the Appendix. The figures below plot the coefficients of the instrumented second stage, $\hat{\beta}_t^{2SLS}$ from equation (3), and their 95% confidence intervals.

Figure 1 presents the effect on log VAT paid by the firm (per firm VAT revenues). It shows that there is little change prior to 2001. The coefficients are statistically indistinguishable from zero. After 2001, VAT (measured in constant RMB) gradually begins to increase, until 2004, after which it declines until it reaches to a level that is similar or slightly above pre-computerization levels.

Next, we look at the two components of VAT, gross VAT and VAT deductibles, which are separately reported in the data. Figures 2 and 3 show that computerization led to a decrease in both gross VAT and deductibles. Recall from Section 4 that we restricted our sample to observation with reliable VAT data, where these three variables roughly add up. Thus, Figures 1-3 imply that during the first three years after computerization, deductibles declined more than sales, such that VAT payment increased. However, during the later years, the decline in sales caught up to the decline in deductibles such that VAT payments declined.

To distinguish between the effects of a change in enforcement from a change in firms size (sales), Figure 4 examines VAT payments as a share of firm total sales. We see a broadly similar temporal pattern. This is consistent with our interpretation that the earlier results are due to a change in enforcement.

To better examine the magnitude of the results, we estimate a more parsimonious equation that is similar to equation (3), except that we interact the sector VAT share with a dummy variable for if it is 2002-2004, and a dummy variable for if it is 2005-2007. Table4 presents the 2SLS, OLS, reduced form and first stage estimates of this specification. As before, we focus our discussion on the 2SLS estimates in panel A. We find that for a firm with pre-2001 VAT share of one, VAT revenues and VAT as a share of sales increased on average by 2,544 RMB and 3.2 percentage points per firm in the three years after computerization, 2002-2004, relative to pre-computerization. In 2005-2007, these two measures were 2,135 RMB and 2.3 percentage-points

higher than pre-computerization. However, these latter estimates are imprecise. Note that the mean firm in our sample has a pre-VAT share of 0.3. Thus, to estimate the short-run effect of computerization for the mean firm, multiple the coefficient by 0.3. As we observed earlier in the figures, columns (3) and (4) show that gross VAT and VAT deductions continued to decline over time. However, during the first period, the decline was larger for deductibles, while in the second, the declining gross VAT roughly caught up the deductibles. This explains why we first see VAT revenues go up, and then somewhat decline.

6 Interpretation

6.1 Simple Model

This section presents a simple model to guide the empirical analysis and help interpret the results. The main goal is to understand how a an economy-wide increase in VAT enforcement may affect firm behavior. For simplicity, we consider one sector populated by identical, perfectly competitive firms.¹⁵ We assume that all firms in the given sector have the Cobb-Douglas technology $k^\alpha l^{1-\alpha}$ and factor prices of k and l are given by r, w . The pre-tax price of output in a sector is q and the after-tax price is p , with $q = (1 + \tau) p$. Demand for the output of a sector is given by $y = q^{-\sigma}$, where $\sigma > 0$ is the elasticity of demand.

We assume that there are three periods. For simplicity, we assume that prior to computerization, in period 0, there is no tax, $\tau_0 = 0$. The tax is introduced with computerization in period 1 and maintained at a similar rate afterwards in period 2, and $\tau_2 = \tau_1 > \tau_0$. Period 1 represents the "short run" when only one factor, l , can be adjusted. Period 2 represents the "long run" when both factors can be adjusted. We assume that neither k nor l can be deducted from VAT, so VAT is a pure sales tax. In addition, we assume that a sector is "small", so that input r, w are not affected by the change in prices of the given sector. Output prices, q and p , will obviously be affected.

Note that the goal of the model is to present the simplest model that will illustrate the intuition behind the key results. Given that, we point out some important simplifications. (i) It is straightforward to extend our simple model into a full GE model with multiple sectors, so

¹⁵Alternatively, we can assume that firms have constant markups. All of the results carry through.

that tax on sector i affects also economy-wide r, w . The key intuition is similar to our simple model. However, they are less transparent in the more algebraically intensive GE model. (ii) It is similarly straight forward to add intermediate inputs that can be deducted from the VAT, so that the technology can be written as $k^\alpha l^{1-\alpha-\beta} x^\beta$, where x^β is the input. All of the results below will hold, but but the additional algebra would obfuscate the key results and one would need to make assumptions about whether x adjusts in the long or short run. (iii) While we will refer to k as capital in the model, it does not correspond to the “assets” in the data (which we will show change little). Instead, it refers to inputs that you can change over time (e.g. intermediate inputs). Again, it is easy to extend this model to three factors, one of which can be changed in periods 1 and 2, another in period 2 only, and third that never changes. Results with the extensions that are discussed here are available upon request.

6.2 Period 0

Consider the cost function in period 0:

$$\begin{aligned} C_0(y) &= \min_{k,l} rk + wl, \\ \text{s.t. } y &= k^\alpha l^{1-\alpha}. \end{aligned} \tag{5}$$

It obviously gives

$$\begin{aligned} [k] : r &= \eta \alpha k^{\alpha-1} l^{1-\alpha}, \\ [l] : w &= \eta (1 - \alpha) k^\alpha l^{-\alpha}. \end{aligned}$$

This gives optimal capital-labor ratio

$$\frac{k_0}{l_0} = \frac{\alpha}{1 - \alpha} \frac{w}{r}. \tag{6}$$

Marginal costs are

$$C'_0(y) = \eta = \frac{r}{\alpha k^{\alpha-1} l^{1-\alpha}}. \tag{7}$$

In equilibrium, we have

$$C'_0(y_0) = \frac{r}{\alpha \left(\frac{\alpha}{1-\alpha} \frac{w}{r} \right)^{\alpha-1}} \equiv \omega, \tag{8}$$

where ω does not depend on anything under firm's control.

When firms are perfectly competitive, their after-tax price is equal to their marginal cost:

$$p_0 = C'_0(y_0). \quad (9)$$

Consumer demand gives $y_0 = q_0^{-\sigma} = p_0^{-\sigma}$. Substitute into the expression above to get

$$y_0^{-1/\sigma} = C'_0(y_0). \quad (10)$$

The solution to this equation characterizes the output in period 0. In particular, we have

$$y_0 = \omega^{-\sigma}. \quad (11)$$

Since $y_0 = k_0^\alpha l_0^{1-\alpha} = \left(\frac{k_0}{l_0}\right)^\alpha l_0 = \left(\frac{\alpha}{1-\alpha} \frac{w}{r}\right)^\alpha l_0$, it also gives labor

$$l_0 = \omega^{-\sigma} \left(\frac{\alpha}{1-\alpha} \frac{w}{r}\right)^\alpha. \quad (12)$$

We can find k_0, p_0 from the equations above.

6.3 Short-run equilibrium

Suppose VAT tax is introduced. Since we assume that firms cannot deduct anything, it is equivalent to introducing a sales tax. Supposed that in the short run, the firm cannot adjust k , so that $k_1 = k_0$.

Then we have

$$C_1(y) = \min_l rk_0 + wl, \quad (13)$$

$$s.t. \ y = k_0^\alpha l^{1-\alpha}. \quad (14)$$

Which gives

$$[l] : w = \eta(1-\alpha) k_0^\alpha l^{-\alpha}.$$

Therefore, marginal costs are

$$C'_1(y) = \eta = \frac{w}{(1-\alpha)k_0^\alpha l^{-\alpha}}. \quad (15)$$

Competition gives

$$p_1 = C'_1(y). \quad (16)$$

The demand is determined by the pre-tax price $q_1 = (1+\tau)p_1$. Hence, the equilibrium condition is

$$y_1^{-1/\sigma} = q_1 = (1+\tau)C'_1(y_1). \quad (17)$$

We are interested in understanding the effect on inputs, prices, as well as sales, tax revenues and TFPR. Sales that one observes in the data are qy ; tax revenues (payments) are τpy ; TFPR is $\frac{qy}{k^\alpha l^{1-\alpha}} = q$.

Lemma 1. *In the short run, $y_1 < y_0$, $p_1 < p_0$, $l_1 < l_0$, $q_1 > q_0$, $TFPR_1 > TFPR_0$, $taxes_1 > taxes_0 = 0$. If $\sigma > 1$ then $sales_1 < sales_0$.*

Proof. Suppose $y_1 \geq y_0$. Then $l_1 \geq l_0$, and hence $C'_1(y_1) \geq C'_0(y_0)$. This implies that $p_1 \geq p_0$. But $y_1 = [(1+\tau)p_1]^{-\sigma}$, so y_1 and p_1 must go in the opposite directions, a contradiction. Therefore $y_1 < y_0$. $y_1 < y_0$ implies $l_1 < l_0$, $C'_1(y_1) < C'_0(y_0)$, $p_1 < p_0$. From $y_1 = q_1^{-\sigma}$ we get $q_1 > q_0$. Tax revenues are $\tau p_1 y_1 = \tau (1+\tau)^{-\sigma} p_1^{1-\sigma} > 0$. Hence, tax revenues go up. Sales are $q_1 y_1 = q_1^{1-\sigma}$, they decline if $\sigma > 1$. Labor declines $l_1 < l_0$. Capital does not change $k_1 = k_0$. TPFR is equal to q in this model, and thus increases. \square

For the next section, we need to explicitly find l_1 . From the previous equation, we get

$$[k_0^\alpha l_1^{1-\alpha}]^{-1/\sigma} = (1+\tau) \frac{w}{(1-\alpha)k_0^\alpha l_1^{-\alpha}}, \quad (18)$$

$$[k_0^\alpha l_1^{1-\alpha}]^{-1/\sigma} = (1+\tau) \frac{w}{(1-\alpha)k_0^\alpha} l_1^\alpha, \quad (19)$$

$$k_0^{-\alpha/\sigma} l_1^{(\alpha-1)/\sigma} = (1+\tau) \frac{w}{(1-\alpha)k_0^\alpha} l_1^\alpha, \quad (20)$$

$$l_1^{(\alpha-1)/\sigma-\alpha} = (1+\tau) \frac{w k_0^{\alpha/\sigma}}{(1-\alpha)k_0^\alpha}, \quad (21)$$

$$l_1^{(\alpha-1)/\sigma-\alpha} = (1+\tau) \frac{w}{(1-\alpha)} k_0^{\alpha/\sigma-\alpha}. \quad (22)$$

6.4 Long-run equilibrium

Now, consider the long-run equilibrium, when capital can also be adjusted. Therefore, $C_2(y) = C_0(y)$ (the cost function is the same) and in the long run, we have

$$\frac{k_2}{l_2} = \frac{\alpha}{1-\alpha} \frac{w}{r} = \frac{k_0}{l_0}. \quad (23)$$

This gives us

$$C'_2(y_2) = C'_0(y_0) > C'_1(y_1). \quad (24)$$

Therefore

$$p_2 = p_0 > p_1 \quad (25)$$

Since

$$q_2 = (1 + \tau) p_2, \quad (26)$$

$$q_1 = (1 + \tau) p_1 > p_0, \quad (27)$$

$$q_0 = p_0. \quad (28)$$

This implies that TFPR increase over time such that it is higher in period 2 than in period 1, which is higher than in period 0.

$$q_2 > q_1 > q_0, \quad (29)$$

$$TFPR_2 > TFPR_1 > TFPR_0. \quad (30)$$

Remark 1. This is the most interesting result from the model. The intuition is as follows. Tax increases. After tax-prices increase. Demand falls. Firms need to reduce inputs. In the short run, it can only reduce labor. This leads to excess capital. Since the technology has constant returns to scale to both inputs, holding one input fixed, the production function is concave in the other input. Short-run marginal costs are increasing in output. As firms decrease labor, marginal costs must fall. Assuming that firms do not exit, competitive firms charge after-tax price equal to marginal costs. Thus, the after-tax price falls, $p_1 < p_0$. In the longer run, firms can adjust both factors. The constant returns scale technology implies that marginal costs

return to the same as in period 0 (i.e., marginal costs are independent to the scale of the firm), $p_2 = p_0 > p_1$. Since $q_t = (1 + \tau) p_t$ during periods 1 and 2, this means that $q_2 > q_1$.

Figure 5 illustrates the key intuition of the model. Demand is downward sloping. The short-run supply is upward sloping. With no taxes, pre- and after-tax prices are similar in period 0, $q_0 = p_0$. When the tax, τ , is imposed, the supply shifts upwards by the amount of the tax since the marginal cost of production has increased by τ . This increases the pre-tax equilibrium price to $q_1 > q_0$. What the producers receive net of the tax will obviously be the after-tax price minus the tax. The figure shows that the after-tax price will decrease to $p_1 < p_0$. In the long run, we have assumed that the supply curve becomes more elastic. For simplicity, Figure 5 illustrates a perfectly elastic (horizontal) supply curve. Since $q_0 = p_0$ is optimal, we simply rotate the supply curve around the initial point where supply and demand intersect. As with the short-run, the long-run response to the increase in taxes can be illustrated by shifting the supply curve up by the amount of the tax. The long-run after-tax price will be $q_2 > q_1 > q_0$, while the long-run pre-tax price will be $p_2 = q_0 = p_0$.

Demand is

$$y_2 = [(1 + \tau) p_2]^{-\sigma} < [(1 + \tau) p_1]^{-\sigma} < y_1. \quad (31)$$

Therefore,

$$y_2 < y_1 < y_0. \quad (32)$$

Sales are $qy = q^{1-\sigma}$. Thus, if $\sigma > 1$, we have

$$q_2^{1-\sigma} < q_1^{1-\sigma} < q_0^{1-\sigma}, \quad (33)$$

$$\text{sales}_2 < \text{sales}_1 < \text{sales}_0. \quad (34)$$

Tax revenues are $\tau py = \tau \frac{p}{q} qy = \frac{\tau}{1+\tau} \times \text{sales}$. Since $\tau_0 = 0$, $\tau_1 = \tau_2 > 0$, this gives us: if $\sigma > 1$, then we find that tax revenues increase from period 0 to period 1, but then decline from period 1 in period 2, such that period two tax revenues are still higher than in period 0.

$$0 = \text{taxes}_0 < \text{taxes}_2 < \text{taxes}_1. \quad (35)$$

Remark 2. The intuition for these results comes from the previous remark and the assumption that $\sigma > 1$. As q increases in each period, y must fall in each period. If demand is elastic, $\sigma > 1$, y falls faster than q rises, which implies that sales, qy , fall. Since tax revenues are $\frac{\tau_t}{1+\tau_t} \times \text{sales}_t$, it first increases between periods 0 and 1 (since taxes increase from 0 to τ , which offsets the fall in sales) and then falls between periods 1 and 2 (since sales fall again between periods 1 and 2, but the tax rates stay the same).

Finally, we examine labor. Obviously,

$$l_0 > l_1 \text{ and } l_0 > l_2. \quad (36)$$

The comparison of interest is between l_1 and l_2 .

In both cases we have $y^{-1/\sigma} = (1 + \tau) C'(y)$. Thus,

$$l_1^{(\alpha-1)/\sigma-\alpha} = (1 + \tau) \frac{w}{(1 - \alpha)} k_0^{\alpha/\sigma-\alpha},$$

$$l_2^{(\alpha-1)/\sigma-\alpha} = (1 + \tau) \frac{w}{(1 - \alpha)} k_2^{\alpha/\sigma-\alpha}.$$

We must have $k_2 < k_0$ (since $k_2/l_2 = k_0/l_0$ and $k_2 (k_2/l_2)^{\alpha-1} = y_2 < y_0 = k_0 (k_0/l_0)^{\alpha-1}$). Therefore, if $\sigma > 1$, then $k_2^{\alpha/\sigma-\alpha} > k_0^{\alpha/\sigma-\alpha}$ and $l_2^{(\alpha-1)/\sigma-\alpha} > l_1^{(\alpha-1)/\sigma-\alpha}$. Since $\alpha < 1$, this implies that $l_2 < l_1$. It follows that labor inputs will decline over time such that it will be lower in period 2 than in period 1, which is lower than in period 0.

$$l_0 > l_1 > l_2. \quad (37)$$

Remark 3. The intuition for this result comes from the observation that the short-run elasticity of labor is smaller than the long-run elasticity of labor (because capital can also be adjusted in the long run) *holding pre-tax prices fixed*. This effect implies that labor should react even more in the long run to the tax change than in the short run. In our settings, there is an offsetting effect, since the pre-tax prices increase which, all things being equal, call for larger inputs. If demand is elastic, prices react little to changes in output, so that the first effect dominates.

6.5 Additional Empirical Implications

The simple model above shows how increased enforcement via computerization increases VAT revenues more in the shorter run than the longer run. In addition, it has several other testable implications.

First, equation (30) states that computerization will lead to a gradual and continued increase in pre-tax prices, q , which we show to be equal to TFPR. To examine this, we re-estimate equation (3) with TFPR as the dependent variable. Figure 6 shows that computerization has little effect on productivity for the first few years. However, in 2004, it begins to rise, and continues to rise afterwards.

Second, equation (34) states that computerization will lead to a continued decline in the sales. Figure 7 shows that computerization led to a gradual but continued decline in log total sales.¹⁶

Third, equation (37) states that that computerization will lead to a continued decline in labor input. Figure 8 show suggestive evidence that labor inputs, measured as the log number of employees, declined in response to the reform. Note that we use the number of employees instead of the total wage bill to side step the difficulty that non-wage compensation comprise a large part of labor compensation in Chinese firms.

An assumption of the model is that non-labor inputs also declined after computerization, but perhaps slightly slower than the decline in labor inputs. Figure 9 shows that computerization led to a decline in log intermediate inputs (material inputs that are deductible from VAT are a subset of intermediate inputs).

As before, we estimate a more parsimonious specification to better assess the magnitudes of the effects. Table 5 presents the 2SLS, OLS and reduced form estimates of the effect of computerization on TFPR, log sales, log employment, and log intermediate inputs. The 2SLS estimates in panel A show that computerization increased TFPR slightly, but imprecisely, in the short run, 2002-2004; and dramatically and statistically significantly in the longer-run, 2005-2007. Columns (2)-(4) show that sales and inputs began to decline immediately after computerization

¹⁶The data reports total sales as a separate variable from gross VAT. The two variables are highly positively correlated and all of our results hold with either variables. To be consistent with other studies, we switch to using the sales variable at this point. The patterns over time look very similar to Figure 2, which examined gross VAT obligations.

in 2002-2004, but the decline was small in magnitude and statistically imprecise. However, in the longer run, 2005-2007, the magnitude of the fall (relative to pre-computerization) had become much larger, and they are statistically significant for sales and intermediate inputs. For the average firm in our sample, which belongs to a sector with pre-2001 VAT share of 0.3, computerization had lowered sales by around 30% by 2005-2007.

6.6 Alternative Interpretation — Learning New Ways to Evade

Here we consider the possibility that after a few years of the newly computerized system, firms learned new methods of evading VAT. This is another possible explanation for why the effect of computerization on increasing VAT began to dissipate starting in 2005, four years after the new system is introduced. The authors of this paper conducted extensive interviews with managers of manufacturing firms and tax officials in China. The interviewees do not believe that there was a systematic increase in evasion over time. Nevertheless, evasion is possible under the new system. The main way is to purchase counterfeit invoices on the black market. However, since the computerized system links all purchases and sales in the country, this way of opting out of using official invoices only works if all firms up and down the chain cooperate by all opting out. This is difficult for obvious reasons and not believed to be widely prevalent. Moreover, to explain our results, we need this practice to increase over time in sectors with higher pre-VAT shares.

More importantly, we need to reconcile evasion with the additional findings that computerization led to a decline in sales, an increase in TFPR, and inputs. We note that a decline in sales is consistent with increased evasion since under-reporting sales would reduce VAT payments. However, the decline in intermediate inputs within which deductible inputs are a subset (see Figure 9) and, more directly, VAT deductibles (see Figure 3) are contrary to increased evasion, since reducing deductible inputs *increase* VAT payments.

In summary, while evasion is likely present throughout the period that we study, it seems unlikely to be a major contributing factor given the difficulty after computerization. We are in the progress of attempting to identify final and primary goods on the production chain. The idea is that if the long-run decline in VAT is partly due to an increase in evasion, we should observe less of a long-run change for the first and last firms on the production chain since it is

always relatively easy for these firms to evade (i.e., the first on the chain is not disciplined by invoices from upstream firms, and the last is not disciplined by downstream firms).¹⁷

7 Additional Results

7.1 Robustness to WTO Entry

The main caveat to the interpretation of our results is that the 2SLS effect captures omitted variables and are driven by other differences between firms in high and low VAT share sectors. Note that our instrument does not resolve this difficulty if the same sectors have relatively high VAT shares in both China and the United States. Omitted factors would only be a concern if they also caused a divergence after computerization.

As we mentioned earlier, our main concern is China’s entry into the World Trade Organization in 2001. Specifically, the concern is that entry into the WTO (or some other policy in 2001) systematically reduced the effective VAT rate for sectors with low U.S. VAT share. This would give us the effect that we observe even if computerization never occurred. To investigate this, we construct measures of import tariffs, export VAT rebate and export duties for each sector and year. Table 6 shows that for all of the main outcomes of interest, the results with different combinations of trade tariff controls are very similar to the baseline. Note that the general effect of entry into the WTO is already controlled for by the year fixed effects.

7.2 Exports

Since exports are exempt from VAT. It is interesting to see if firms increased exports to lower VAT payments. Figures 10 and 11 show that computerization has no effects on log exports or exports as a share of total sales. This is consistent with the belief that there are large fixed costs to exporting.

¹⁷Note that at the time of this study, there is no mechanism for auditing from third parties such as retail customers.

7.3 Ownership and Heterogeneous Effects

Figures 12-14 show that our results are mainly driven by state-owned firms (we use official ownership as reported in the data).¹⁸ The pattern over time look similar for non-state owned domestic firms, but the estimates are very imprecise, probably due to the smaller sample size. There is no effect on foreign-owned firms. This is not surprising since these firms are under much more scrutiny and unlikely to evade in the first place. Moreover, many foreign owned firms are exporters, which are always exempt from VAT.

We also investigated other dimensions for heterogeneous treatment effects, such as the pre-computerization measures of sales, sales growth, TFPR, TFPR growth, exports and export share. We found no evidence of heterogeneous treatment effects.

7.4 The Effect on All Firms

The main analysis uses a balanced panel of firms that do not allow for entry or exit. This is approximately 13% of all firms in the sample, which raises two questions. First, are our findings externally valid to other firms? Second, did computerization change the composition of firms, – i.e., do we miss important general equilibrium effects by restricting entry and exit?

To address this, we re-estimate our baseline with all firms. Since the right-hand side variation in equation (3) is at the sector level, the only change to the estimation when we enlarge the sample this way is that we control for sector instead of firm fixed effects. We use the same instrumental variables strategy. Our results are very similar. Figures 15 and 16 show the 2SLS estimates for log VAT payments and TFPR.

The effects on the other outcomes are also similar. We do not show the figures for brevity. In addition, we examine the number of firms in each sector-year, and the number of entries and exits. We find that computerization has no effect on these outcomes. The results are available upon request.

¹⁸Alternatively, we can divide the sample to whether it is state “controlled” – i.e., the state owns 51%+ of the equity. The effect of computerization does not vary along this distinction.

8 Conclusion

This paper provides novel and rigorous empirical evidence on the dynamic effects of improved state capacity, due to the computerization of VAT invoices, in China. We find that computerization increase VAT revenues. However, the longer-run gains are larger than the short-run gains. This could be to multiple mechanisms and it is beyond the scope of this paper to be conclusive about the exact ones driving the results. However, we provide very suggestive evidence that at least part of the decline in VAT revenues in the longer-run is likely due to firms scaling down production as a response to a decline in demand.

This is a work-in-progress. We are in the progress of attempting to identify final and primary goods on the production chain. The idea is that if the decline in VAT is partly due to an increase in evasion, we should observe less of a long-run change for these sectors, for which it is always relatively easy to evade. We are also in the process of extending the model to formally show that the results carry through with full general equilibrium forces, three factors of production, a factor that is deductible from taxes, and a model with monopolistic competition.

References

- Daniel Akerberg, Kevin Caves, and Garth Frazer. Structural identification of production functions. 2006.
- Abhijit V. Banerjee, Esther Duflo, and Rachel Glennerster. Putting a band-aid on a corpse: Incentives for nurses in the indian public health care system. *Journal of the European Economic Association*, 6(2-3):487–500, 2008. ISSN 1542-4774. doi: 10.1162/JEEA.2008.6.2-3.487. URL <http://dx.doi.org/10.1162/JEEA.2008.6.2-3.487>.
- Timothy Besley and Torsten Persson. The origins of state capacity: Property rights, taxation, and politics. *American Economic Review*, 99(4):1218–44, September 2009. doi: 10.1257/aer.99.4.1218. URL <http://www.aeaweb.org/articles?id=10.1257/aer.99.4.1218>.
- Timothy Besley and Torsten Persson. State capacity, conflict, and development. *Econometrica*, 78(1):1–34, 2010. ISSN 1468-0262. doi: 10.3982/ECTA8073. URL <http://dx.doi.org/10.3982/ECTA8073>.
- Loren Brandt, Johannes Van Biesebroeck, and Yifan Zhang. Creative accounting or creative destruction? firm-level productivity growth in chinese manufacturing. *Journal of Development Economics*, 97(2):339–351, 2012.

- Hongbin Cai and Qiao Liu. Competition and corporate tax avoidance: Evidence from chinese industrial firms. *The Economic Journal*, 119(537):764–795, 2009.
- Piyush Chandra and Cheryl Long. Vat rebates and export performance in china: Firm-level evidence. *Journal of Public Economics*, 103:13–22, 2013.
- Jan De Loecker and Frederic Warzynski. Markups and firm-level export status. *The American Economic Review*, 102(6):2437–2471, 2012.
- Esther Duflo, Rema Hanna, and Stephen P. Ryan. Incentives work: Getting teachers to come to school. *American Economic Review*, 102(4):1241–78, June 2012. doi: 10.1257/aer.102.4.1241. URL <http://www.aeaweb.org/articles?id=10.1257/aer.102.4.1241>.
- Jason Garred. Export taxes, industrial policy and the value china in china after wto. *Working Paper*, 2014.
- Julien Gourdon, Stephanie Monjon, and Sandra Ponset. Incomplete vat rebates to exporters: How do they affect china’s export performance. *Working paper CEPII*, 2015.
- Chang-Tai Hsieh and Peter J. Klenow. Misallocation and manufacturing tfp in china and india. *Quarterly Journal of Economics*, 124(4):1403 –1448, 2009.
- Chang-Tai Hsieh and Zheng Michael Song. Grasp the large, let go of the small: the transformation of the state sector in china. Technical report, National Bureau of Economic Research, 2015.
- Henrik J. Kleven and Mazhar Waseem. Using notches to uncover optimization frictions and structural elasticities: Theory and evidence from pakistan *. *The Quarterly Journal of Economics*, 128(2):669, 2013. doi: 10.1093/qje/qjt004. URL + <http://dx.doi.org/10.1093/qje/qjt004>.
- Karthik Muralidharan, Paul Niehaus, and Sandip Sukhtankar. Building state capacity: Evidence from biometric smartcards in india. *The American Economic Review*, 106(10):2895–2929, 2016.
- Joana Naritomi. Consumers as tax auditors. Working paper, London School of Economics, 2015.
- Thomas Piketty, Emmanuel Saez, and Stefanie Stantcheva. Optimal taxation of top labor incomes: A tale of three elasticities. *American Economic Journal: Economic Policy*, 6(1):230–71, February 2014. doi: 10.1257/pol.6.1.230. URL <http://www.aeaweb.org/articles?id=10.1257/pol.6.1.230>.
- Dina Pomeranz. No taxation without information: Deterrence and self-enforcement in the value added tax. *The American Economic Review*, 105(8):2539–2569, 2015.
- Emmanuel Saez, Joel Slemrod, and Seth Giertz. The elasticity of taxable income with respect to marginal tax rate: A critical review. *Journal of Economic Literature*, 50(1):3–50, 2012.

Figure 1: The Effect of Computerization on VAT Payments (Revenues)

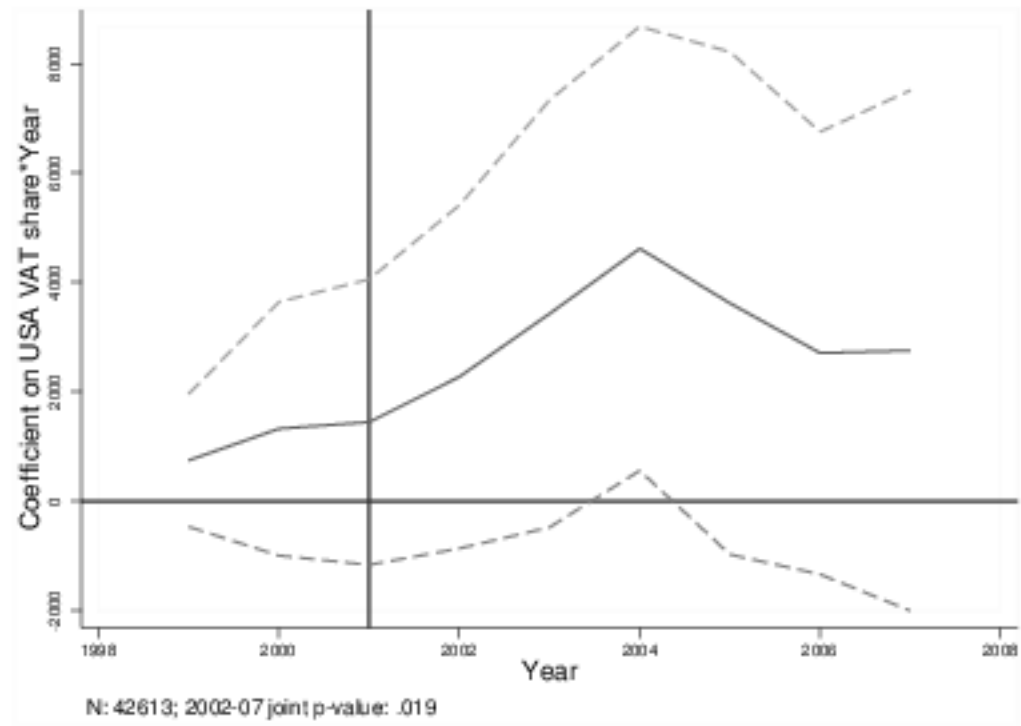


Figure 2: The Effect of Computerization on Ln Gross VAT

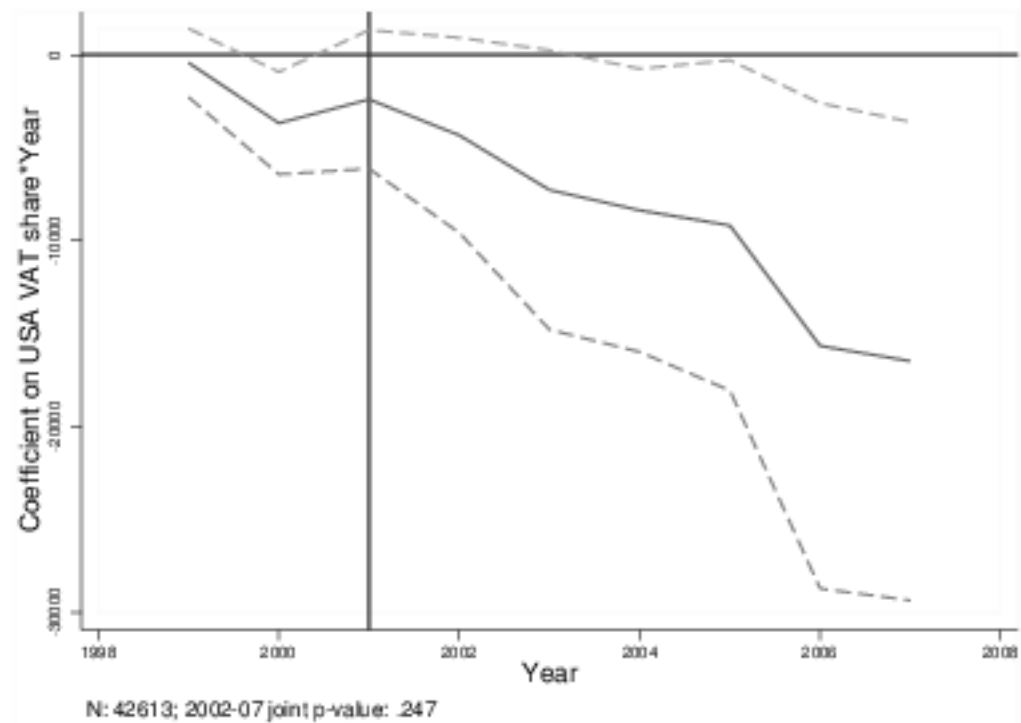


Figure 3: The Effect of Computerization on Ln VAT Deductibles

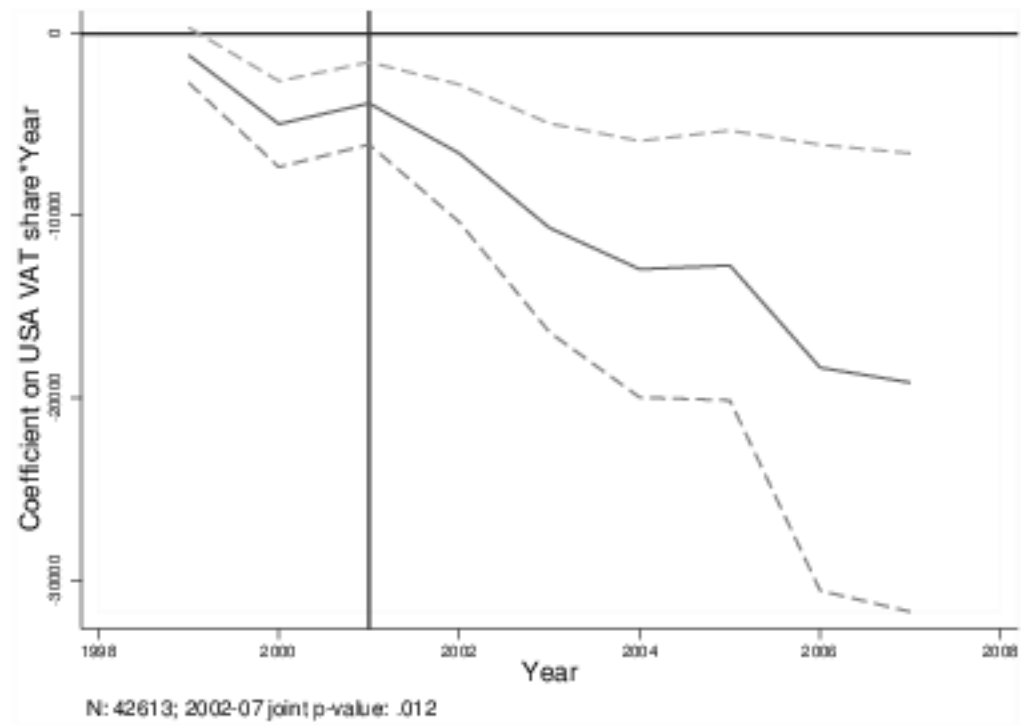


Figure 4: The Effect of Computerization on VAT Payments (Revenues) as a Share of Sales

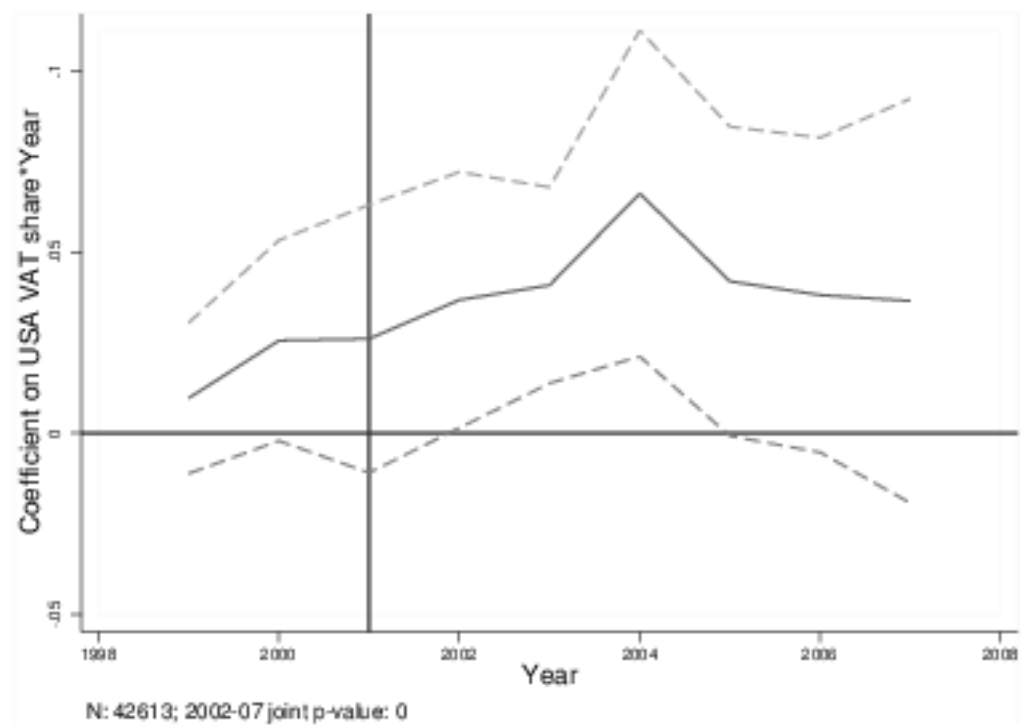


Figure 5: Simple Illustration: Short- and Long-run Responses to VAT

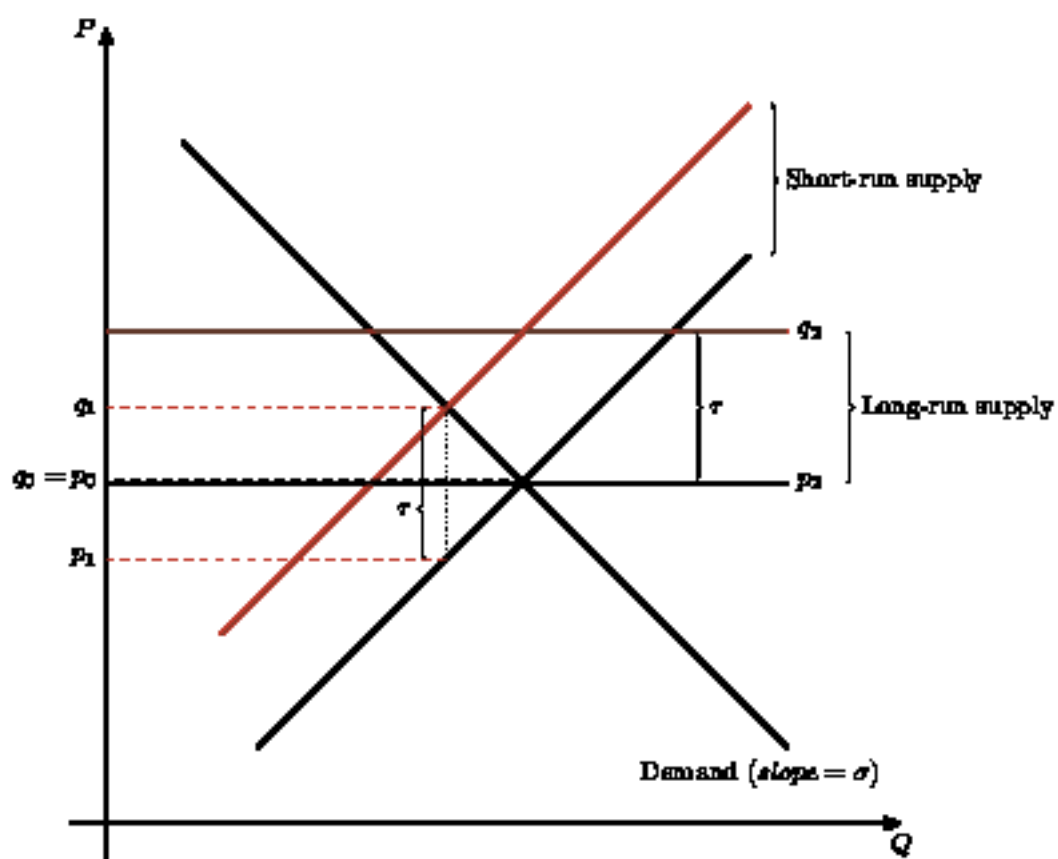


Figure 6: The Effect of Computerization on TFPR

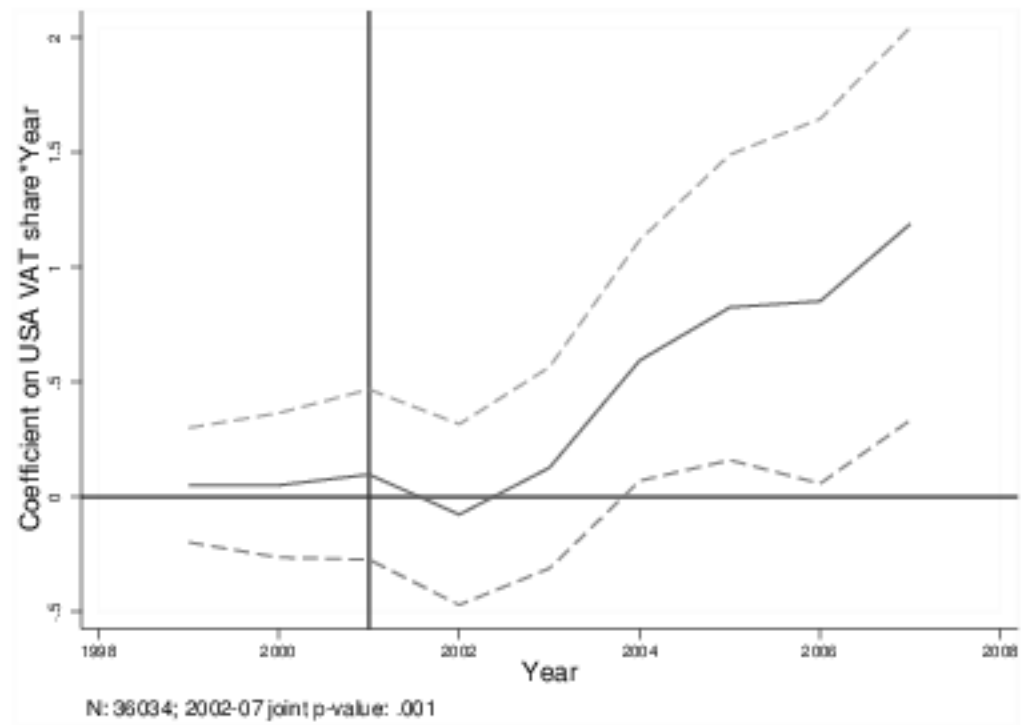


Figure 7: The Effect of Computerization on Ln Sales

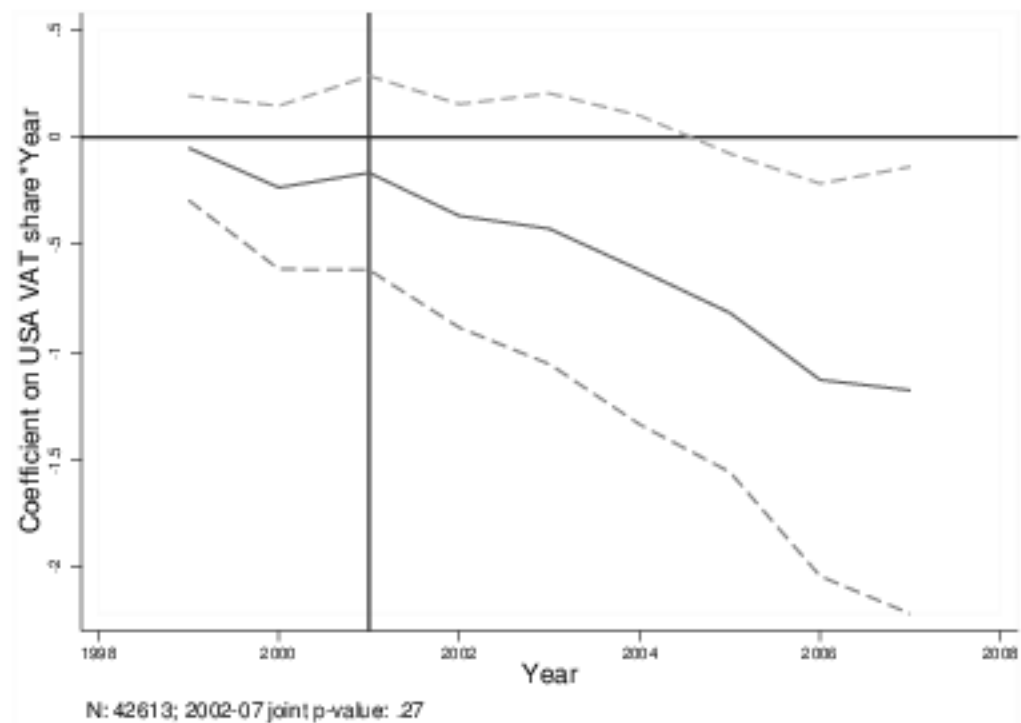


Figure 8: The Effect of Ln Employment (# of Workers)

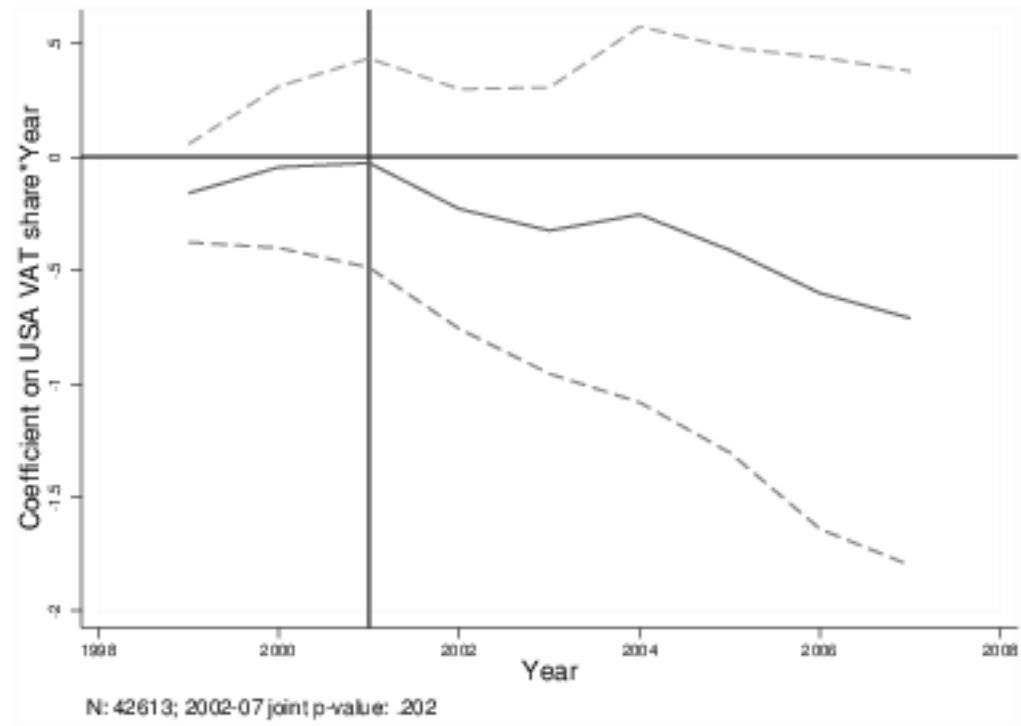


Figure 9: The Effect of Computerization on Ln Intermediate Inputs

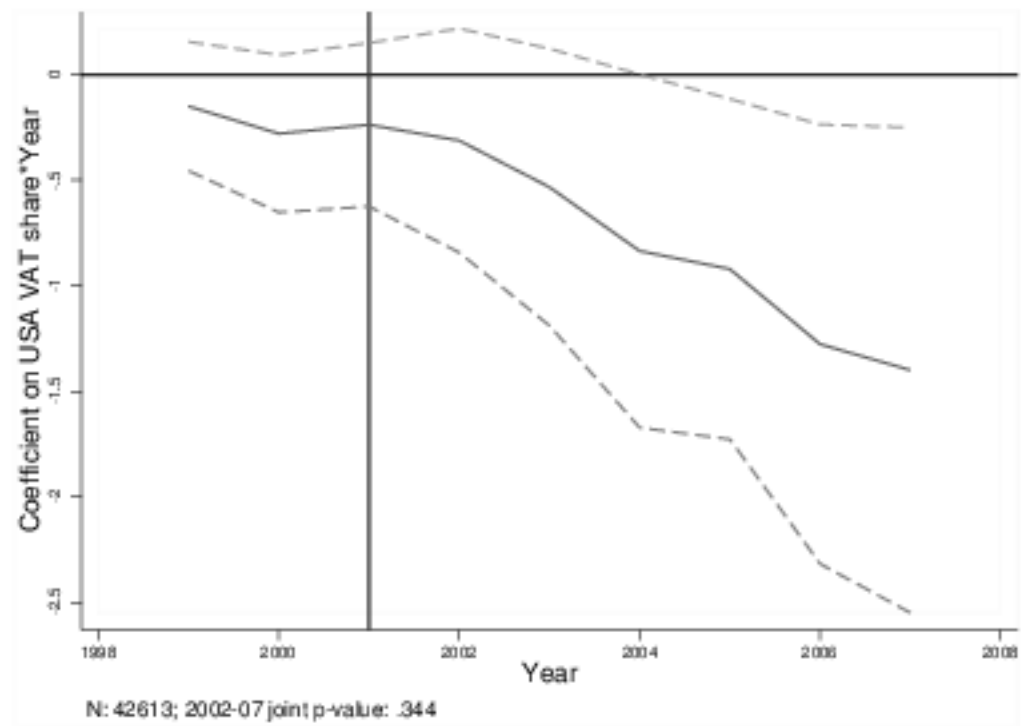


Figure 10: The Effect on Computerization on Ln Exports

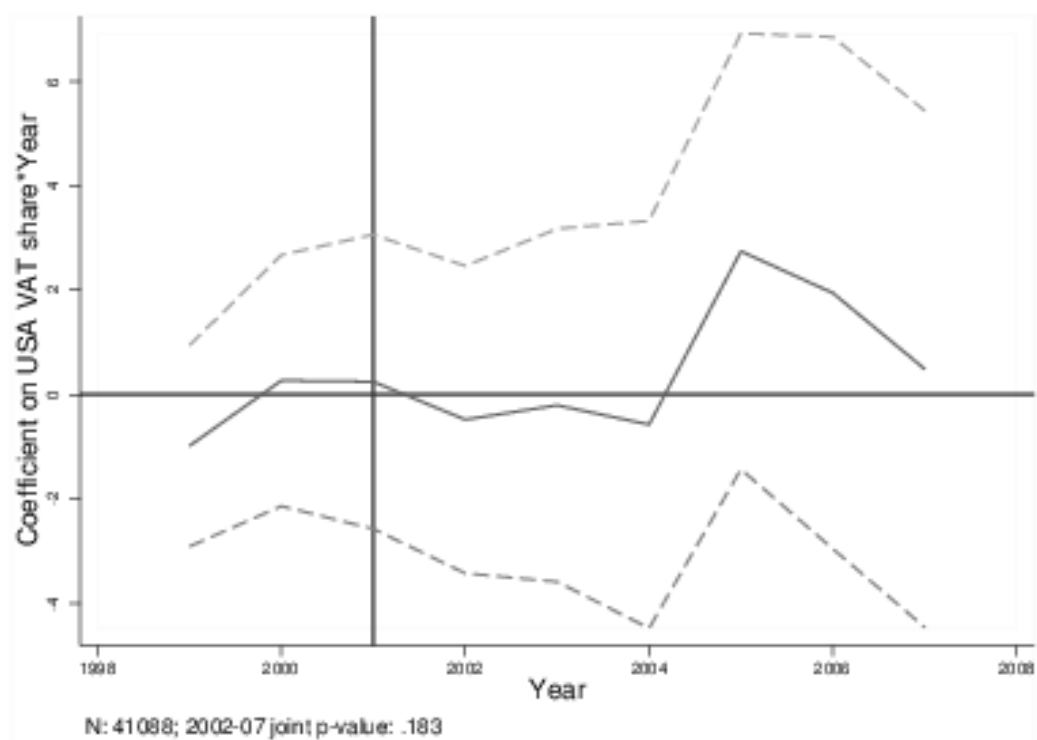


Figure 11: The Effect on Export Share

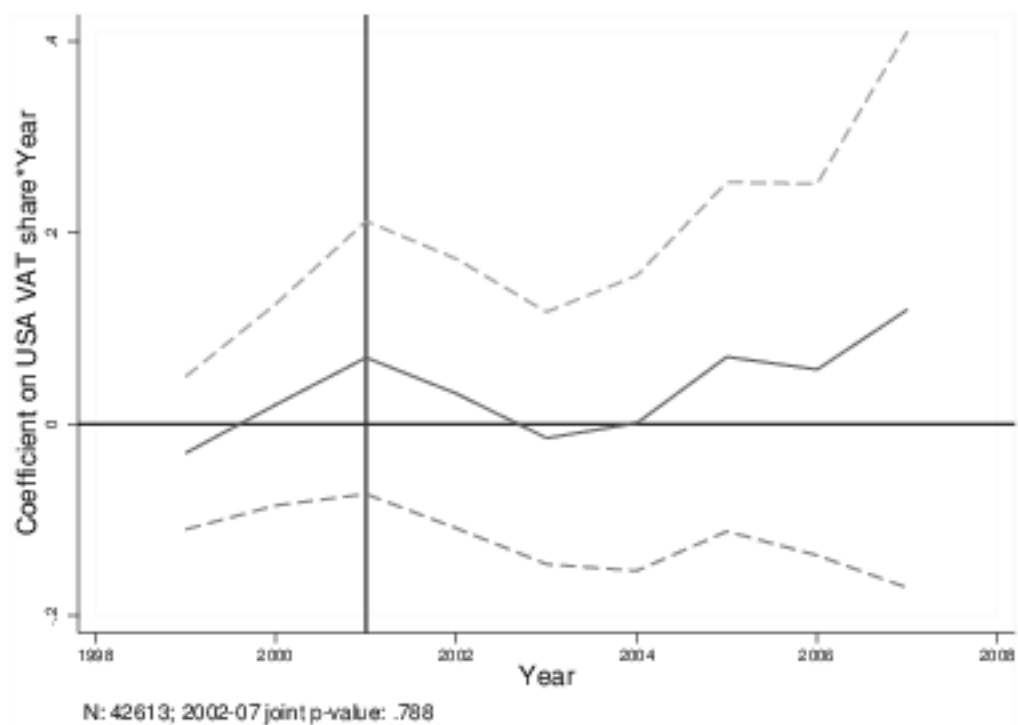


Figure 12: The Effect on VAT for State Owned Firms

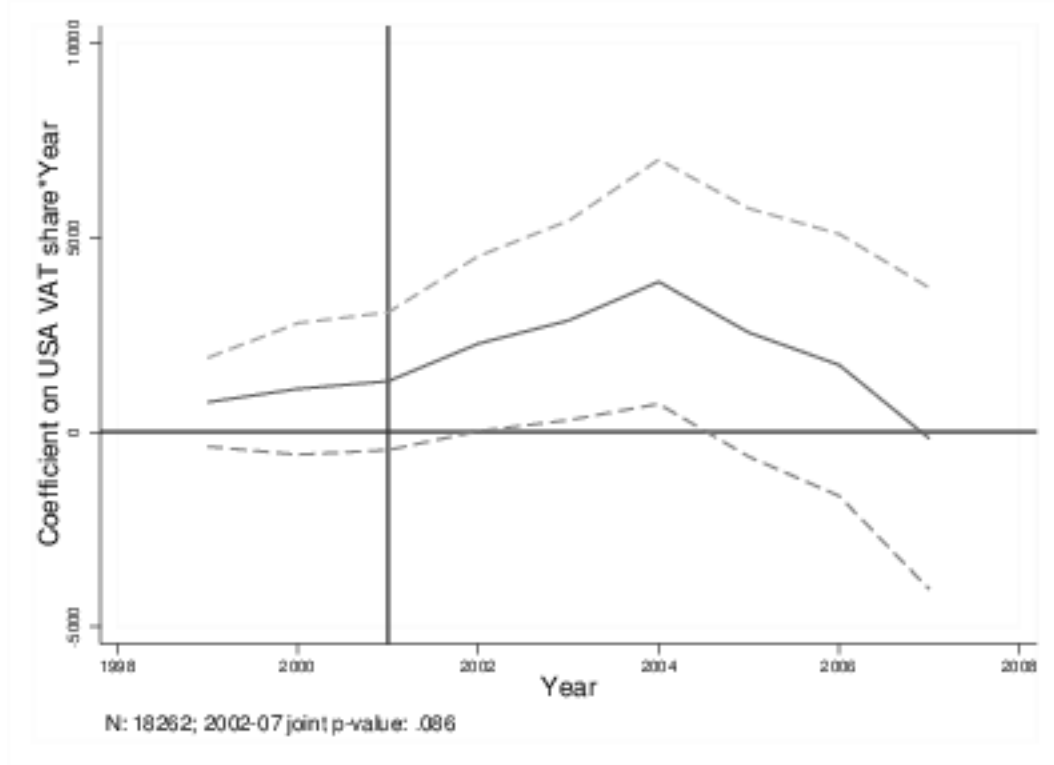


Figure 13: The Effect on VAT for Privately Owned Firms

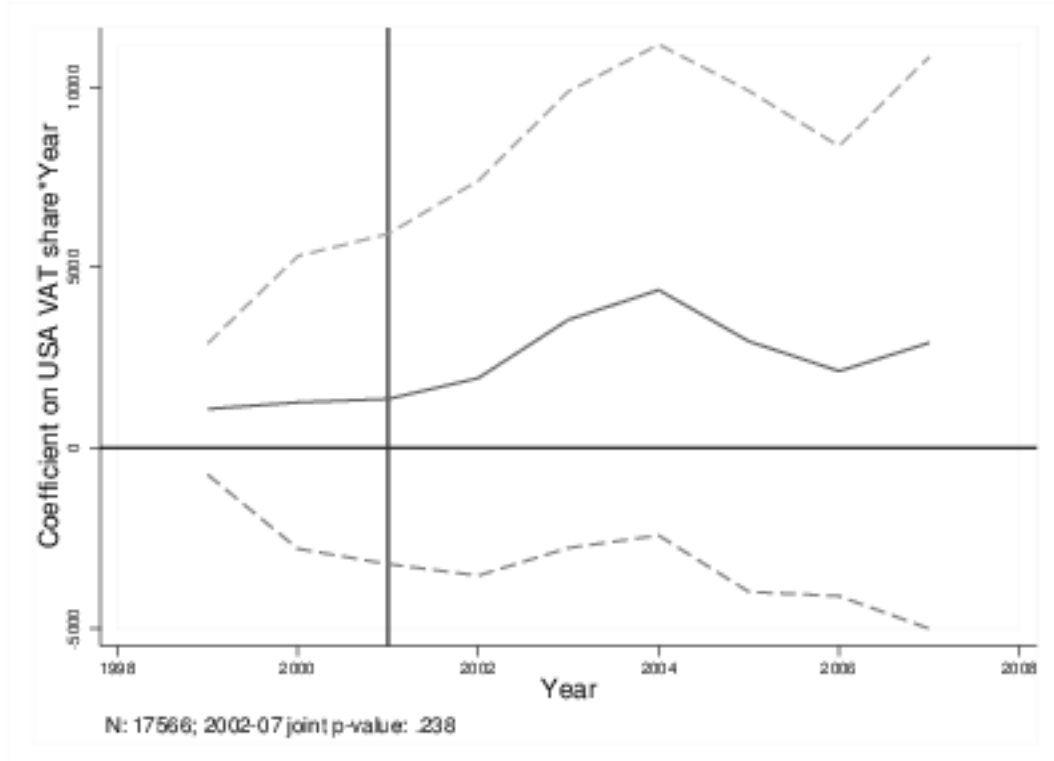


Figure 14: The Effect on VAT for Foreign Owned Firms

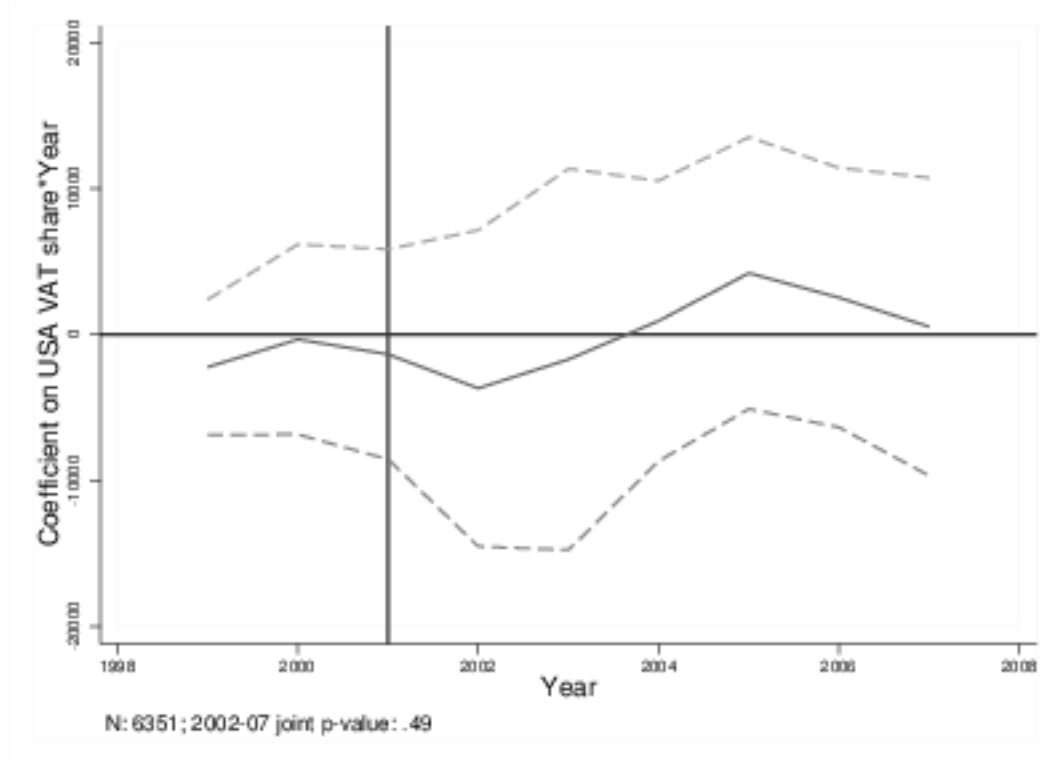


Figure 15: The Effect on VAT for All Firms

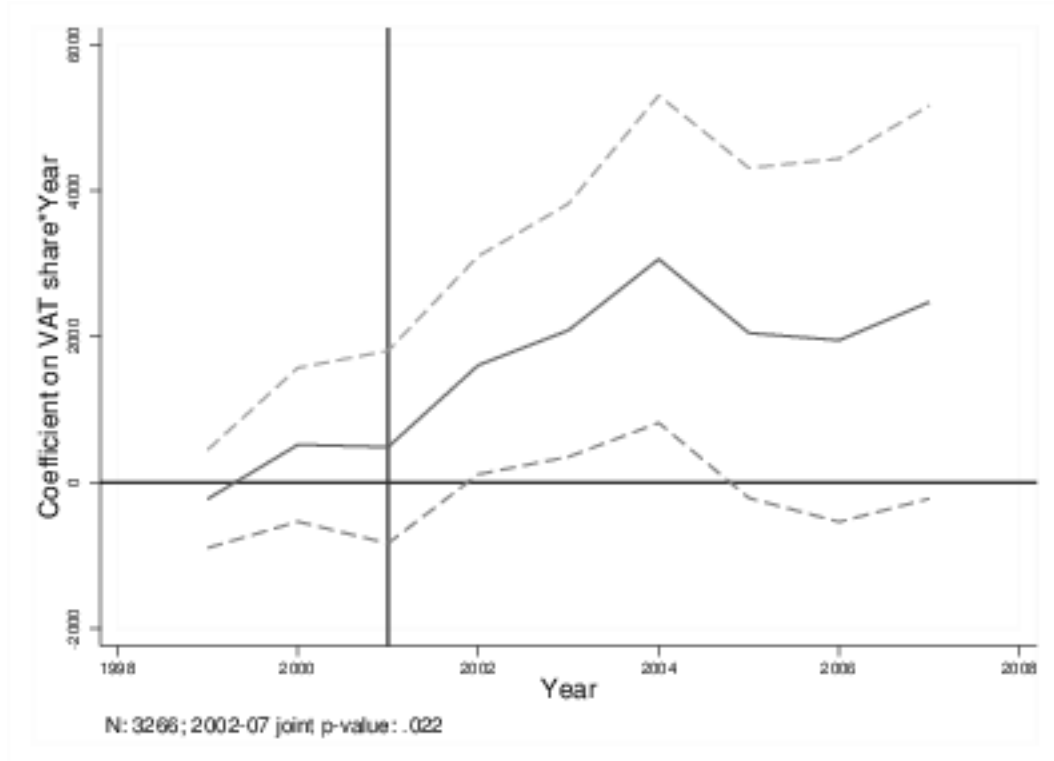


Figure 16: The Effect on TFPR for All Firms

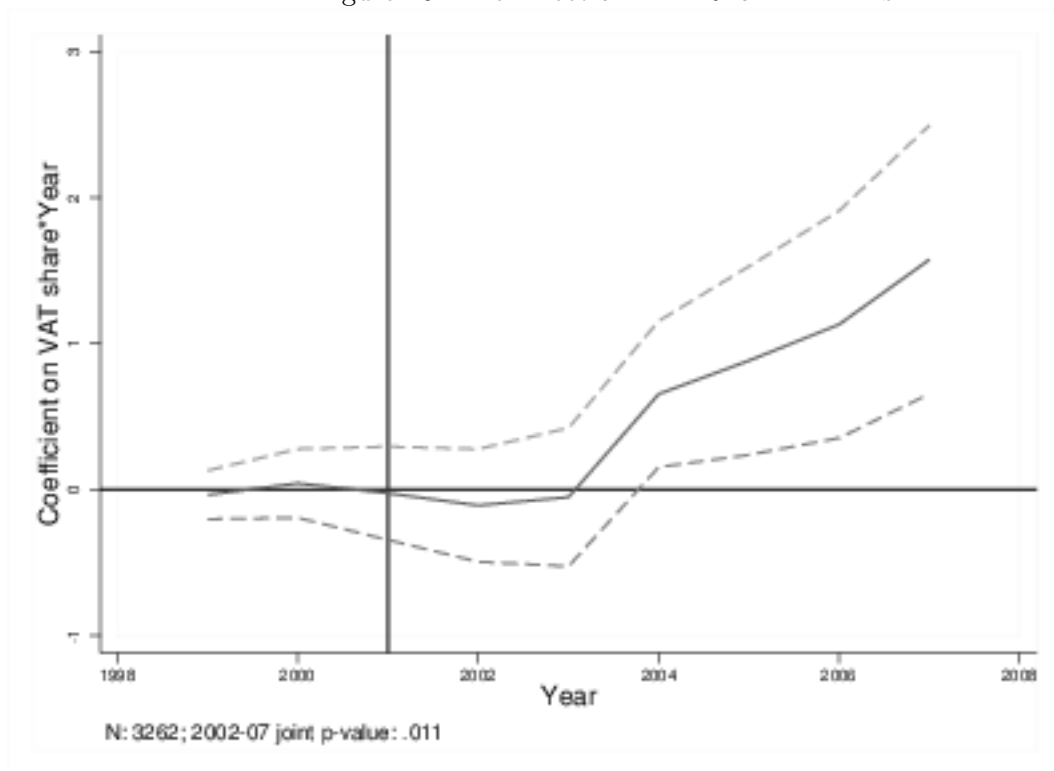


Table 6: The Effect of Computerization on VAT – Robustness to WTO Entry

	(1)	(2)	(3)	(4)
Additional Controls	Baseline	Export Rebates, Import and Export Duties	Import and Export Duties	Export Rebates
A. Dependent Variable: VAT				
Dep Var Mean (not logged)	2169	2169	2169	2169
VAT share x 2002-2004	2,544** (1,188)	2,406* (1,297)	2,363* (1,286)	2,595** (1,197)
Vat share x 2005-2007	2,135 (1,597)	1,851 (1,631)	1,806 (1,600)	2,146 (1,617)
Observations	42,613	42,604	42,604	42,604
R-squared	0.766	0.766	0.766	0.766
B. Dependent Variable: TFPR				
Dep Var Mean (not logged)	0.139	0.139	0.139	0.139
VAT share x 2002-2004	0.149 (0.119)	0.121 (0.120)	0.112 (0.119)	0.156 (0.120)
Vat share x 2005-2007	0.885*** (0.296)	0.853*** (0.283)	0.844*** (0.279)	0.890*** (0.298)
Observations	36,034	36,025	36,025	36,025
R-squared	0.858	0.858	0.858	0.858
C. Dependent Variable: Ln Sales				
Dep Var Mean (not logged)	4658.7	4658.7	4658.7	4658.7
VAT share x 2002-2004	-0.355 (0.246)	-0.425 (0.277)	-0.442 (0.268)	-0.333 (0.253)
Vat share x 2005-2007	-0.923** (0.406)	-1.058*** (0.373)	-1.075*** (0.363)	-0.907** (0.407)
Observations	42,613	42,604	42,604	42,604
R-squared	0.804	0.806	0.805	0.804
D. Dependent Variable: Ln # Employees				
Dep Var Mean (not logged)	290.6	290.6	290.6	290.6
VAT share x 2002-2004	-0.210 (0.245)	-0.161 (0.230)	-0.154 (0.224)	-0.218 (0.251)
Vat share x 2005-2007	-0.513 (0.439)	-0.446 (0.404)	-0.438 (0.400)	-0.521 (0.439)
Observations	42,613	42,604	42,604	42,604
R-squared	0.860	0.860	0.860	0.860
E. Dependent Variable: Ln Intermediate Input				
Dep Var Mean (not logged)	3215.2	3215.2	3215.2	3215.2
VAT share x 2002-2004	-0.391 (0.261)	-0.440 (0.284)	-0.457* (0.274)	-0.369 (0.269)
Vat share x 2005-2007	-1.027** (0.439)	-1.134*** (0.404)	-1.152*** (0.393)	-1.010** (0.441)
Observations	42,613	42,604	42,604	42,604
R-squared	0.781	0.782	0.782	0.781

Notes: The table presents 2SLS estimates. This sample comprises of a balanced panel of firms during 1998-2007. All regressions include year fixed effects and sector fixed effects. The standard errors are clustered at the sector level. *** p<0.01, ** p<0.05, * p<0.1

Table 1: Tax Personnel and VAT Share Prior to Computerization

	Dependent Variable: # of Tax Officials	
	(1) Officials	(2) Ln Officials
VAT Share	-159,543*** (39,824)	-4.644*** (5.835)
<i>Normalized Coef.</i>	-0.162	-0.556
Ruggedness	2,314 (1,684)	0.151 (0.110)
<i>Normalized Coef.</i>	0.125	0.0965
Size of Province (Square km)	0.000685 (0.00231)	2.20e-07 (2.15e-07)
<i>Normalized Coef.</i>	0.0189	0.0717
# Firms	2.146*** (0.272)	0.000125*** (1.85e-05)
<i>Normalized Coef.</i>	0.644	0.442
Observations	91	91
R-squared	0.404	0.502

Notes: This sample comprises of a panel of provinces during 1999-2001. All regressions control for year fixed effects. The observations are at the province-year level. Robust standard errors are presented in the parentheses. *** p<0.01, ** p<0.05, * p<0.1. Data are reported by the *Tax Yearbook of China*.

Table 2: Descriptive Statistics

Variable	Full Sample		
	Obs {1}	Mean {2}	Std. Dev {3}
VAT {1000s RMB}	236487	4644	8241
Sales {1000s RMB}	236487	96858	165826
Asset {1000s RMB}	236487	69358	552556
Employment {workers}	236487	442	563
Inventory {1000s RMB}	236487	25333	142651
TFPR	199410	0.11	0.46

Notes: A unit of observation is a firm in a given year. The sample comprises a balanced panel of firms, 1998-2007.

Table 3: First Stage Estimates

Additional Controls	Dependent Variable								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	VAT share x 1999	VAT share x 2000	VAT share x 2001	VAT share x 2002	VAT share x 2003	VAT share x 2004	VAT share x 2005	VAT share x 2006	VAT share x 2007
VAT share x 1999	0.517*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)
VAT share x 2000	-0.0144*** (0.00423)	0.517*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)
VAT share x 2001	-0.0144*** (0.00423)	-0.0144*** (0.00423)	0.517*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)
VAT share x 2002	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	0.517*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)
VAT share x 2003	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	0.517*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)
VAT share x 2004	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	0.517*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)
VAT share x 2005	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	0.517*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)
VAT share x 2006	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	0.517*** (0.00423)	-0.0144*** (0.00423)
VAT share x 2007	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	-0.0144*** (0.00423)	0.517*** (0.00423)
Observations	2,920	2,920	2,920	2,920	2,920	2,920	2,920	2,920	2,920
R-squared	0.886	0.886	0.886	0.886	0.886	0.886	0.886	0.886	0.886

Notes: This sample comprises of a balanced panel of firms during 1998-2007. All regressions include year fixed effects and sector fixed effects. The standard errors are clustered at the sector level. *** p<0.01, ** p<0.05, * p<0.1

Table 4: The Effect of Computerization on VAT

	(1) VAT	(2) VAT/Sales	(3) VAT Gross	(4) VAT Deductions
A. 2SLS				
Dep Var Mean (not logged)	2169	0.0508	7166	5006
VAT share x 2002-2004	2,544** (1,188)	0.0324*** (0.00959)	-4,997* (2,844)	-7,515*** (2,244)
Vat share x 2005-2007	2,135 (1,597)	0.0234 (0.0155)	-12,072** (5,343)	-14,156*** (4,848)
Observations	42,613	42,613	42,613	42,613
R-squared	0.766	0.645	0.748	0.709
B. OLS				
Dep Var Mean (not logged)	2169	0.0508	7166	5006
VAT share x 2002-2004	1,658*** (395.6)	0.00351 (0.00483)	-1,047 (916.7)	-2,692*** (772.0)
Vat share x 2005-2007	870.7 (619.6)	-0.00634 (0.00536)	-5,369* (2,769)	-6,219** (2,569)
Observations	48,132	48,132	48,132	48,132
R-squared	0.761	0.639	0.743	0.705
C. Reduced Form				
Dep Var Mean (not logged)	2169	0.0508	7166	5006
U.S. VAT share x 2002-2004	1,016** (510.3)	0.0129*** (0.00308)	-1,995* (1,066)	-3,000*** (691.3)
U.S. VAT share x 2005-2007	852.3 (596.0)	0.00932* (0.00529)	-4,819** (2,294)	-5,651*** (1,945)
Observations	42,613	42,613	42,613	42,613
R-squared	0.766	0.647	0.748	0.710
D. 1st Stage – Dependent Variable: VAT share x Post				
Dep Var Mean (not logged)	0.0945	0.0945		
U.S. VAT share x 2002-2004	0.399*** (0.0897)	3.37e-06 (3.02e-06)		
U.S. VAT share x 2005-2007	1.24e-05 (1.36e-05)	0.399*** (0.0897)		
Observations	42,613	42,613		
R-squared	0.949	0.949		
F-stat	11.80	9.918		

Notes: This sample comprises of a balanced panel of firms during 1998-2007. All regressions include year fixed effects and sector fixed effects. The standard errors are clustered at the sector level. *** p<0.01, ** p<0.05, *

Table 5: The Effect of Computerization on TFPR, Sales, Inputs

	(1) TFPR	(2) LnSales	(3) Ln # Employees	(4) Ln Intermediate Input
A. 2SLS				
Dep Var Mean (not logged)	0.139	46587	290.6	32152
VAT share x 2002-2004	0.149 (0.119)	-0.355 (0.246)	-0.210 (0.245)	-0.391 (0.261)
Vat share x 2005-2007	0.885*** (0.296)	-0.923** (0.406)	-0.513 (0.439)	-1.027** (0.439)
Observations	36,034	42,613	42,613	42,613
R-squared	0.858	0.804	0.860	0.781
B. OLS				
Dep Var Mean (not logged)	0.139	46587	290.6	32152
VAT share x 2002-2004	0.119* (0.0641)	-0.0735 (0.133)	-0.294* (0.160)	-0.00484 (0.143)
Vat share x 2005-2007	0.584*** (0.136)	-0.382 (0.236)	-0.561* (0.292)	-0.277 (0.240)
Observations	40,782	48,132	48,132	48,132
R-squared	0.852	0.804	0.858	0.781
C. Reduced Form				
Dep Var Mean (not logged)	0.139	46587	290.6	32152
U.S. VAT share x 2002-2004	0.0588 (0.0526)	-0.142 (0.101)	-0.0839 (0.115)	-0.156 (0.102)
U.S. VAT share x 2005-2007	0.347*** (0.115)	-0.368** (0.167)	-0.205 (0.214)	-0.410** (0.161)
Observations	36,047	42,613	42,613	42,613
R-squared	0.857	0.805	0.860	0.782

Notes: This sample comprises of a balanced panel of firms during 1998-2007. All regressions include year fixed effects and sector fixed effects. The standard errors are clustered at the sector level. *** p<0.01, ** p<0.05, * p<0.1

APPENDIX

A VAT Deductibles

The regulation that governs VAT remittance rules during the study period is the *Provisional Regulations of the People's Republic of China on Value-Added Tax* (State Council Order 134, published in December 1993). The rules are effective between Jan 1, 1994 and Jan 1, 2009, when these *Regulations* are amended for the first time. The *Regulations* specifies the deductible items for VAT, which are not exactly the same as in other countries. The general principle is that any purchases that come with VAT special invoices, regardless from the domestic seller or from the Customs paid by international seller, can be deducted from the VAT duty. Under this principle, full deductions are allowed for manufactured inputs, repair inputs, retail inputs, and wholesale inputs, which typically come with VAT special invoices. Partial deductions are allowed for agricultural products at a rate of 10%, for old and waste materials at a rate of 10%, and for transportation costs at a rate of 7%. No deductions are allowed for labor costs, fixed asset purchases, capital depreciation, abnormal losses, rent, fringe benefits, interests from bank loans, and overhead/operating expenses. Although three Northeastern provinces, namely Liaoning, Jilin, and Heilongjiang, have experimented VAT reforms in eight sectors in 2004 to allow for deductions of fixed asset purchases, a full-fledged reform did not happen until 2009.

B Data

We follow the standard procedure for cleaning these data, as first used in Cai and Liu [2009]. We drop firms for which any reported sub-component of assets is greater than total assets, as well as firms for which the start month does not fall between 1 and 12. We also drop observations for which the founding year of the firm is greater than the year of the survey.

We make two additional restrictions. First, we remove the influence of extreme outliers, which are likely to represent coding errors in these self-reported data. We replace the top and bottom one percent of observations with missing values, without dropping the firm entirely, for each of the following variables: total VAT, total profit, output, value added, employees, gross

VAT, and VAT deductions. Except for variables that should take negative values, like profit, we take the natural log of firm observables to adjust for their log-normal distributions.

Second, to ensure that we examine firms where the VAT data are reported relatively accurately, we restrict the sample to observations where reported VAT payments are within 10% above or below what they should be based on reported gross VAT and VAT deductibles – i.e., $0.9(0.17(Gross - Deductible)) \leq VATpayments \leq 1.1(0.17(Gross - Deductible))$.

C TFPR Calculation

To estimate productivity, we closely follow the procedure of Akerberg et al. [2006] and De Loecker and Warzynski [2012]. These estimation procedures allow us to remove the bias in estimating productivity due to the response of observed input choices to contemporaneous productivity shocks. We use a translog production function with labor, capital, and materials as input factors, given by $y_{ft} = \beta_l l_{ft} + \beta_m m_{ft} + \beta_k k_{ft} + \beta_{ll} l_{ft}^2 + \beta_{mm} m_{ft}^2 + \beta_{kk} k_{ft}^2 + \beta_{lm} l_{ft} m_{ft} + \beta_{mk} m_{ft} k_{ft} + \beta_{kl} k_{ft} l_{ft} + \varphi_{ft} + \epsilon_{ft}$.

From our data, we use the sales revenue as a measure of y_{ft} , the net value of fixed assets as a measure of k_{ft} , labor employment as a measure of l_{ft} and the total value of intermediate materials as a measure of m_{ft} . We deflate these values with sector-specific price indices provided by Brandt et al. [2012] to back out the physical quantity of y_{ft} , k_{ft} , and m_{ft} .

Just as in Akerberg et al. [2006] and De Loecker and Warzynski [2012], in the first stage of our estimation, we eliminate measurement error from observed output by regressing output on a large third-order polynomial of the three inputs and their interactions using OLS. From this step, we recover an estimate of expected output, based on observables.

In the second stage of estimation, we model the structure of the error term and the relationships between observables and expected output to generate ten moment conditions. We estimate this set of moment conditions using GMM and obtain measures of the nine production function parameters, and the parameter in the innovation process of productivity.

Using the nine production function parameter estimates we obtained in the second stage,

we can then recover our estimate of total factor revenue productivity.

$$\begin{aligned}
TFPR_{ft}(\beta) = & y_{ft} - \hat{\beta}_l l_{ft} - \hat{\beta}_m m_{ft} - \hat{\beta}_k k_{ft} - \hat{\beta}_{ll} l_{ft}^2 - \hat{\beta}_{mm} m_{ft}^2 \\
& - \hat{\beta}_{kk} k_{ft}^2 - \hat{\beta}_{lm} l_{ft} m_{ft} - \hat{\beta}_{mk} m_{ft} k_{ft} - \hat{\beta}_{kl} k_{ft} l_{ft}.
\end{aligned}$$