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THE DYNAMIC EFFECTS OF COMPUTERIZED VAT INVOICES ON CHINESE  
MANUFACTURING FIRMS

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**ABSTRACT**

This paper uses a balanced panel of large manufacturing firms to provide novel evidence on the dynamic effects of computerizing VAT invoices on tax revenues and firm behavior in China, 1998-2007. We find that computerization explains 14.38% of cumulative VAT revenues and increases the effective average tax rate by approximately 4.7-14% in the seven subsequent years. The evidence suggests that the effects of computerization change over time: tax revenue gains are likely to be smaller in the long run. Meanwhile, firms reduce output and input, and increase productivity monotonically over time.

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# 1 Introduction

All governments face the challenge of collecting taxes. Two central considerations for policymakers and economists are how the government can enforce payment, and how taxpayers will respond. Moreover, will the response differ between the short run, when many factors are held constant, and the long run, when adjustments can be made along more dimensions of behavior? A large and growing number of studies provide rigorous empirical evidence on short-run elasticities. Meanwhile, the evidence on longer-run elasticities is relatively scarce.<sup>1</sup>

Our goal is to address this gap in the literature by investigating the short- and longer-run effects of an increase in Value Added Tax (VAT) enforcement on Chinese manufacturing firms during 1998-2007. VAT accounts for around twenty percent of the world's tax revenue and affects four billion people (Keen and Lockwood, 2010). One reason for the popularity of the VAT is its self-enforcing property, which is believed to be particularly advantageous in contexts with lower bureaucratic capacity or higher levels of corruption, such as low- and medium-income countries (Gordon and Li, 2009; Kleven, Kreiner, and Saez, 2016).<sup>2</sup> For example, as a share of total state revenues, VAT accounts for 18.7% in Mexico, 9.5% in the Philippines and 17% in South Korea (OECD, 2016). In China, VAT is the most important source of state revenues. For example, in 2002, Chinese revenue from VAT was 814.1 billion RMB, which accounted for 47.61% of total tax revenues that year.<sup>3</sup>

While the exact formula varies across countries, VAT is generally levied as a fraction of firm sales minus input costs. In principle, this framework creates incentives for firms to understate sales and overstate inputs. For transactions along a production chain, the

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<sup>1</sup>Saez, Slemrod, and Giertz (2012) review the empirical literature on tax elasticities.

<sup>2</sup>Kopczuk and Slemrod (2006) argue that VAT is easier to enforce than sales tax, to which it is otherwise equivalent. Besley and Persson (2009, 2010) make a point of using the ratio of income tax revenues to GDP as a measure of bureaucratic capacity, with the underlying idea that VAT requires much less capacity to administer than other types of taxes.

<sup>3</sup>Source: China Tax Policy Department, Ministry of Finance 2007.

sales of one firm become the inputs of another. As long as the tax authority has the ability to link transactions, upstream and downstream firms provide internal checks of each other. Unfortunately, many developing countries lack the administrative capacity to link transactions. Such weaknesses in the information chain can severely undermine the self-enforcing nature of VAT (Naritomi, 2015; Pomeranz, 2015).

The context of China offers a unique opportunity to study the dynamic effects of an increase in VAT enforcement because of a natural experiment provided by the computerization of invoices in 2001. Prior to 2001, the Chinese government's ability to enforce VAT was very limited, because it lacked the administrative capacity to systematically link firm transactions recorded on carbon paper invoices. This system left significant scope for evasion (and human error). In 2001, the government introduced a computerized tax system that digitally recorded and linked all invoices. The new system automatically highlights inconsistencies between upstream sales and downstream purchases and dramatically improved the enforcement of VAT. This paper studies the effect of this reform in the seven subsequent years for which data are available.

Our empirical analysis faces three main challenges. First, we know much less about the details of VAT in China than other contexts. Second, to the best of our knowledge, disaggregated administrative VAT data from this period are not available to researchers.<sup>4</sup> Finally, we face the usual difficulty of establishing causality. For example, one key difficulty is disentangling enforcement-generated increases in VAT revenue from increases that arise naturally from economic growth.

The principal contribution of our paper is to address these difficulties. To understand the Chinese tax system, we read government documents and policy reports extensively and conducted a large number of interviews with tax officials and firm managers. To overcome the lack of disaggregated administrative tax data, we use reported VAT payments from the *Annual Survey of Industrial Production*, 1998-2007. Our main analysis

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<sup>4</sup>Liu and Mao (2017) obtain firm-level data for a later period.

uses a balanced panel of firms that exist throughout the period which we study.

For causal identification, we exploit two sources of variation. First, we exploit time variation from the 2001 introduction of the computerization. Second, we exploit cross-sector variation in the intensity of the treatment effect. Our reading of government white papers and interviews with tax officials suggest that prior to computerization, the limited manual audits focused on firms in sectors with lower VAT shares (VAT payments as a share of sales) – i.e., higher VAT deductions as a share of sales. Thus, the technological improvement should increase enforcement more in high VAT share sectors – i.e., the treatment intensity is higher in high VAT share sectors. Our cross-sectional measure of reform intensity is therefore sector-level VAT share. We will provide indirect evidence to support this assumption.

Our empirical strategy is similar in spirit to a differences-in-differences estimate: we compare outcomes in high VAT share sectors to those in low VAT share sectors, before and after 2001. The baseline estimates include firm fixed effects to account for all time-invariant differences across firms (e.g., firm size), and year fixed effects to account for all economy-wide changes over time (e.g., macroeconomic growth). To observe dynamic effects, the main specification divides the post-reform era into three periods. To allow for firms of different sizes to evolve differentially over time, the baseline also controls for the interaction of the average size of a firm prior to the reform and the three post-reform period dummy variables.

Another empirical difficulty arises from potential measurement error in sectoral VAT share. If we use data from all years, 1998-2007, to calculate average sectoral VAT share, our measure will include endogenous firm responses to the computerization. If we use Chinese data from the pre-computerization period, 1998-2000, our measure will reflect firm evasion as well as true VAT share. To address problems arising from measurement error, we proxy for VAT share in China with a measure calculated from U.S. input-output tables.

The results show that after computerization, VAT as a share of sales increased for approximately three years and then declined to levels that is slightly above pre-computerization levels. We show that this is driven by computerization increasing VAT revenues, with the gains being larger in the longer run than the shorter run, and by computerization reducing sales with the reduction increasing in magnitude overtime.<sup>5</sup> In terms of magnitudes, the estimates imply that computerization caused the effective tax rate to increase by 4.7% in the short run, 14% in the medium run and 11.7% in the long run, from 4.95 to 5.19-5.65 percentage-points, and explains 14.38% of all VAT revenues during 2001-2007. Thus, the effect on government revenues is sizable.

Since our empirical strategy aims to capture the effect of improved enforcement via a reduction in evasion, and would only capture an increase in VAT from the reduction of human error if human error was positively correlated with VAT share, the estimates should be interpreted as the lower bound of the true increase in VAT payments that result from computerization.

We also find that computerization leads to firm contraction in the long run: it reduced sales and inputs (including deductible inputs that would reduce VAT). At the same time, computerization led to a gradual and continued increase in TFPR. While it is beyond the scope of this paper to be conclusive about the mechanisms, we present a simple model to illustrate one internally coherent interpretation – firms contract in response to an increase in taxes (see Section 3).

There are three important caveats to consider when interpreting our results. The first caveat is the possibility that our estimates are confounded by omitted variable bias – i.e., sectors with higher VAT share differ from those with lower VAT share along other dimensions that would cause these two groups to diverge after 2001. Our prior is that it would be difficult for any one omitted variable to provide a coherent explanation for

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<sup>5</sup>Note that improved enforcement has two offsetting effects on reported sales: a reduction in evasion will increase sales, while the increase in the tax rate could reduce sales (see Section 3 for a detailed explanation). Our estimate for sales captures the net of these two forces.

the large number of outcomes that we examine. Nevertheless, we provide several pieces of support for our identification strategy – the parallel trends assumption which requires that absent computerization, outcomes in high and low VAT share sectors would have evolved in parallel. First, we show that there are no pre-trends in VAT and that the effects begin around the time of computerization. Second, we document the differences between high and low VAT share sectors and control for them directly in our estimates. These additional controls include firm size, export/import share, competitiveness, and crude proxies of demand. To allow the effects of the controls to vary fully flexibly over time, we control for their interactions with year fixed effects. Our results are very robust. Third, we address the concern that our results are spuriously driven by other changes in 2001 that could have differed across high and low VAT share sectors, such as China’s entry into the WTO, as well as changes to VAT policy or enforcement that occurred after computerization (e.g., expansion of the number of deductible inputs, tax revenue sharing). See Section 6.5.

A second caveat is the possibility that our empirical strategy captures an alternative mechanism. While are open to interpretations other than the one we discuss in Section 3, we think it is worthwhile to investigate two of the most obvious alternative explanations that emerge from the literature. First, we investigate the possibility that the reduction in VAT over time is due to firms substituting towards exports, which on average pay lower VAT. We show this is not the case. Second, we show that there is little systematic evidence to support the alternative explanation that the decline in VAT gains in the long-run is due to firms learning new ways to evade. We discuss these in more detail in Section 6.6.

Finally, one may be concerned that using a balanced panel of firms, which has the advantage that it shuts down the possibility of firm entry and exit and is therefore easier to interpret, also has the disadvantage that the results may not be generalizable to the Chinese economy (large manufacturing firms) as a whole. We show that this is not true

and that the results using all firms are very similar to the balanced panel.

In addition to the results above, we examine the effect on corporate taxes to investigate whether the computerization of VAT had positive spillover effects for other types of taxes. We find no evidence of positive spillovers. We also investigate heterogeneous effects. We find suggestive evidence that computerization increased VAT more for firms closer to the end consumer. See Section 6.7.

Our study contributes to several existing literatures. First, we add to studies in public economics that empirically estimate responses to tax changes. Our results support the large body of evidence on the importance of third-party information for compliance (e.g. Gordon and Li, 2009; Kleven, Knudsen, Kreiner, Pedersen, and Saez, 2011; Kumler, Verhoogen, and Frias, 2013; Naritomi, 2015; Pomeranz, 2015). Existing studies have mostly focused on short-run effects. There is little direct evidence on medium- or long-run effects, even though they can, in theory, be quite different from short-run effects. An exception is a recent study by Benzarti, Carloni, Harju, and Kosonen (2017), which finds that VAT has short- and long-run effects on prices in Finland. They do not find evidence of non-monotonic effects on VAT over time.<sup>6</sup> In providing micro empirical evidence about taxation in a developing economy, from which we have much less reliable evidence than for rich economies, we add to the growing number of studies such as Carrillo, Pomeranz, and Singhal (2017); Fisman and Wei (2004); Kleven and Waseem (2013); Kumler, Verhoogen, and Frias (2013); Olken and Singhal (2011).

In examining VAT in a developing economy, this paper is most closely related to two important recent studies. Naritomi (2015) uses a natural experiment in Brazil to demonstrate that monetary rewards for consumers to collect receipts significantly increases reported tax revenues. Pomeranz (2015) conducts a large randomized experiment in Chile

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<sup>6</sup>Benzarti, Carloni, Harju, and Kosonen (2017) finds that price responses are larger for VAT increases than for VAT decreases. For recent studies that provide important indirect or descriptive evidence on longer run elasticities, see for example, Kleven and Waseem (2013) and Piketty, Saez, and Stantcheva (2014), which study income tax in Pakistan and the United States, respectively. For a more detailed discussion of the existing literature, see the review article by Saez, Slemrod, and Giertz (2012).



to show that third-party information improves VAT enforcement. In addition, a new working paper by Mittal and Mahajan (2017) compares wholesalers and retailers before and after a policy reform to find that third-party verification increases tax collections of wholesale firms relative to retail firms in Delhi, India. Our results are consistent with these other studies and add to them by examining a new context, China, a wider range of firm behavior and a longer time horizon. The latter allows us to provide strongly suggestive evidence on the non-monotonic pattern of tax revenue gains following an improvement in enforcement, which is consistent with textbook theory, but has not yet been documented in the empirical literature.

In showing that firms downsize in response to VAT, our findings are consistent with a recent study by Harju, Matikka, and Rauhanen (2015), which uses Finnish data to find that VAT causes firms to bunch below a taxation threshold, and that the bunching reflects a real effect: VAT reduces the growth of small firms.<sup>7</sup> Our paper differs in examining dynamic effects and a different context – much larger firms in China. In studying the relationship between VAT and the behavior of large manufacturing firms in China, we are related to a recent working paper by Bai and Liu (2017), which uses a change in the financing of VAT export rebates to identify the presence of internal trade barriers.<sup>8</sup> More generally, we add to recent empirical studies about taxes in China, such as Chen, Liu, Serrato, and Xu (2017) and Fisman and Wei (2004), which document tax evasion in the context of manufacturing firms and imports from Hong Kong to mainland China; and Piketty and Qian (2009) and Piketty, Yang, and Zucman (2017), which describe the

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<sup>7</sup>Also, see Keen and Lockwood (2010) for an overview of the VAT literature. Our findings are also generally consistent with studies documenting evasion: Onji (2009) from Japan, Almunia and Lopez-Rodriguez (2013) from Spain, Liu and Lockwood (2015) from the United Kingdom, Gebresilassey and Sow (2015) from Ethiopia, and Waseem (2015) from Pakistan.

<sup>8</sup>Two other working papers, Cai and Harrison (2017) and Liu and Mao (2017), study an expansion of the number of deductible inputs in three provinces in 2004 on investment. There are also a number of recent studies investigating the relationship between VAT and exports (Fan, Liu, Qiu, and Zhao, 2017; Garred, 2014; Chandra and Long, 2013; Gourdon, Monjon, and Ponset, 2015; Liu and Lu, 2015). Also related is Chen (2017), which argues that the abolition of agricultural taxes increased enforcement of other taxes such as VAT. In Section 6.5, we show that our main findings are not confounded by the aforementioned changes to VAT.

evolution of individual income tax and wealth.

Second, we contribute to a literature on state capacity and development (Besley and Persson, 2009, 2010). In evaluating the impact of a fully-scaled (i.e., nationally-implemented) technology on bureaucratic capacity, our study is most similar to Muralidharan, Niehaus, and Sukhtankar (2016), which shows that biometric technology improves the delivery of state subsidies in rural India, and Barnwal (2016), which finds that the introduction of direct transfers of government subsidies to the bank accounts of intended beneficiaries significantly reduced leakage in India. In exploring the role of new technology for governance, we add to the evidence from Banerjee, Duflo, and Glennerster (2008) and Duflo, Hanna, and Ryan (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 literature on the Chinese economy. In addition to the studies on taxation mentioned earlier, our results on productivity complement the well-known study by Hsieh and Klenow (2009).

This paper is organized as follows. Section 2 discusses the background. Section 3 presents a simple model to guide our interpretation and the empirical analysis. Section 4 presents the empirical strategy. Section 5 describes the data. Section 6 presents the results. Section 7 concludes.

## 2 Background

The Chinese government introduced VAT in its modern form in 1994, which has since become an important source of state revenue. By 2002, VAT had become the largest source of tax revenue in China.<sup>9</sup>

To the best of our knowledge, there were no other major changes in the VAT formula during the period of our study, 1998-2007. During this time, VAT was defined as 17%

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<sup>9</sup>Source: China Tax Policy Department, Ministry of Finance 2007.

of the difference between sales and deductible inputs. Full deductions were given to manufactured inputs, repair inputs, retail inputs, and wholesale inputs, which typically came with VAT special invoices. Partial deductions (13%) were given for agricultural inputs. No deductions were given for labor costs, fixed asset purchases (until 2009), capital depreciation, abnormal losses, rent, fringe benefits, interests from bank loans, and overhead/operating expenses. See the Appendix for a detailed list of items in both categories.

In the Chinese VAT system, transactions between upstream and downstream firms are recorded on official invoices. Firms then self-report the value of their sales and the value of their deductible inputs. To verify the reported values, tax authorities need to link transactions.

## 2.1 Pre-Computerization Enforcement

Prior to 2001, all invoices were linked manually. By all accounts, enforcement was quite low everywhere and susceptible to errors and evasion. The most common forms of evasion were to overstate deductions with fake input invoices or to understate sales by omitting invoices. Tax offices were strained for manpower and mostly unable to link the information chain for the vast number of invoices to effectively enforce VAT.

Nevertheless, some audits did take place, and cross-sectional variation in their implementation will inform our identification strategy. To understand this variation, we conducted extensive research into government white papers and interviewed a large number of tax officials and firm managers. We summarize the evidence here.

The internal documents from the Ministry of Tax instructed tax officials to consider total sales and VAT, and to compare these two measures to the average measures of the same sector and “region”, defined vaguely to be “above the prefecture level”, when deciding whether to issue a citation (The State Administration of Taxation, 1998). Taken literally, this system would apply a higher audit rate to firms whose  $VAT / Sales$ , hence-

forth “VAT share”, was too high or too low relative to the sector-region benchmark. However, interviews with tax officials suggest that audits were rarely based on a firm’s deviation from the average VAT share in a region and sector in practice. Instead, most officials implemented a rule-of-thumb shortcut and targeted their limited audits on firms in sectors with low average VAT share (i.e., high deductible share). The shortcut existed partly because local tax officials (operating out of one of over 3,000 counties in China) usually did not have access to province-sector statistics, while almost all officials had access to national sector-level averages. When officials were asked why they did not use a the deviation of a firm’s VAT share from the national sector-level average, the ubiquitous response was that this would be “too complicated”.

Thus, we will use sector-level VAT share to capture cross-sectional variation in the degree to which computerization increased enforcement (see Section 4 for more discussion).<sup>10</sup>

Despite our best efforts, we were unable to obtain audit data to directly verify the claims by tax officials that firms in sectors with low VAT shares were more likely to be audited prior to computerization. We have not encountered mentions of such data from tax officials or other studies on Chinese taxes. We will therefore substantiate the anecdotal evidence indirectly using tax personnel data in the next section.

## 2.2 Computerization

In 2001, the Chinese government digitized invoices and information cross-checking. The computerization formally began in 2001 and was rolled out across the country over the course of 2001 and 2002. The new system took the following form: the State Administration of Taxation issued each firm an integrated circuit (IC) card with a unique ID. An IC card reader, encoded with the firm’s unique ID, was physically installed into the

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<sup>10</sup>Consistent with the anecdotal evidence, we find that computerization has no effect if we measure the cross-sectional treatment intensity as the deviation of a firm’s pre-reform VAT share from the province-sector or national-sector average pre-reform VAT share. These results are available upon request.

firm's computer, along with an invoice-issuing computer software and a special printer for the invoices.

Each transaction is physically recorded on a paper invoice, its carbon copy, and 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 is 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. A refund is issued when the data are verified.

Evasion is still possible after digitization, but has become much costlier. Entire production chains would need to opt out of the formal economy in order for firms to evade. An interesting question is whether the reform differentially affected firms closer to the end consumer. We examine this in Section 6.7.3.

It is widely believed that digitization increased enforcement for all firms. In addition, because audit probabilities were lower for firms in high VAT share sectors prior to computerization, such sectors experienced a higher increase in enforcement – i.e., higher treatment intensity. We discuss this more in the section on Empirical Strategy.

The VAT rule that we have described thus far applies to almost all goods in China. Two notable exceptions are imports and exports. Import tariffs existed in China throughout this period, and those tariffs were deductible in the same manner as the original input value. Similarly, exports were awarded VAT rebates throughout the period of our study. Unlike many other countries with VAT, Chinese export rebates are typically less than the total sum owed – i.e., firms pay some VAT on exports. Both import tariffs and export rebates vary across sectors (products) and over time. We will pay special attention to this issue in the robustness exercises.

## 2.3 Other Policy Changes

To the best of our knowledge, the only major policy change around 2001 that could have affected the VAT payment of large manufacturing firms was China's entry to the WTO. Thus, an important concern for our identification strategy is that tariffs and rebates systematically changed across high and low VAT share sector after China entered the World Trade Organization in 2001. We will address this later in the paper by controlling for rebates and tariffs for each sector and year.

There were several potentially relevant policy changes that may affect our context in the years after computerization. As we discussed earlier, VAT policy was further fine-tuned after our sample period in 2009 (Cai and Harrison, 2017; Liu and Mao, 2017; Liu and Lu, 2015). Some of the changes were piloted in three provinces (Liaoning, Jilin and Heilongjiang) starting in 2004. Also in 2004, the central government changed how it split the burden of VAT export rebates with local governments (Chandra and Long, 2013; Bai and Liu, 2017). Another potentially relevant policy change was the abolition of agricultural taxes in 2005, which Chen (2017) argues to have increased the enforcement of other taxes as a way to make up for lost revenues. We will investigate the robustness of our results to these policy changes after the main results.

## 3 Conceptual Framework

The main goal of this section is to provide one internally coherent explanation for the empirical results and also to have some framework to guide the empirical analysis. To this end, we develop a simple model for understanding the dynamic effects of increased VAT enforcement on the firm. The formal model is presented in Appendix Section D. The intuition is summarized here.

Figure 1 illustrates the key intuition. Demand is downward sloping and short-run supply is upward sloping. With no taxes, pre-tax and tax-inclusive prices are similar in

period 0,  $q_0 = p_0$ . When the tax,  $\tau$ , is imposed, the supply shifts upwards by the amount of the tax, since the marginal cost of production has increased by  $\tau$ . This shift increases the pre-tax equilibrium price to  $q_1 > q_0$ . Producers receive the pre-tax price minus the tax,  $p_1 = q_1 - \tau$ . The figure shows that the tax-inclusive price will decrease to  $p_1 < p_0$ .

In the long run, the supply curve becomes more elastic, because we assume that capital (i.e., intermediate inputs) can only be adjusted in the long run. For simplicity, Figure 1 illustrates a perfectly elastic long-run 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 pre-tax price will be  $q_2 > q_1 > q_0$ , while the long-run tax-inclusive price will be  $p_2 = p_0$ .

The model also predicts that labor input will decline over time. 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 setting, there is also an offsetting effect, since the increase in pre-tax prices call for larger inputs, all things being equal. If demand is elastic, prices react little to changes in output, so that the first effect dominates. It follows with a little algebra that other inputs also decline over time.

Several empirically testable implications emerge from the model. First, tax revenues will increase from period zero to period one, and then decline in period 2 to a level between the levels of period 0 and one, such that  $0 = \text{taxes}_0 < \text{taxes}_2 < \text{taxes}_1$ .<sup>11</sup> Second, the pre-tax price, which is algebraically equivalent to *TFPR* as formulated in Hsieh and Klenow (2009), increases every period,  $q_2 > q_1 > q_0$ . Third, if the elasticity of demand,  $\sigma$ , is greater than 1, sales decline each period,  $q_2 y_2 < q_1 y_1 < q_0 y_0$ . Fourth, labor and intermediate inputs decline each period,  $l_0 > l_1 > l_2$  and  $k_0 \geq k_1 > k_2$ .

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<sup>11</sup> $\text{Taxes}_t = \tau q_t y_t$

The baseline model assumes a Cobb-Douglas production function with two factors, labor and intermediate inputs, and perfect competition. We provide several extensions to show that all of the main insights carry through with imperfect competition, endogenous input prices, or with three factors of production (labor, capital, and deductible inputs).<sup>12</sup> See Appendix Section D.

We acknowledge that it will be beyond the scope of this paper to be conclusive about the mechanisms and are open to alternative explanations. After we present the main results, we will consider some of the most obvious ones.

## 4 Empirical Strategy

Our specification uses two sources of variation. First, we exploit time variation in the introduction of computerization in 2001. Second, we exploit cross-sector variation in the intensity of the treatment effect. As we discussed earlier in Section 2, pre-computerization enforcement was low and targeted towards sectors with low VAT shares (higher deductible shares) and low VAT obligations. Thus, firms with high VAT shares (lower deductible shares) and high VAT obligations will be more affected by computerization.

The cross-sectional measure of intensity, VAT share, is denoted as  $\widetilde{VAT}_s$ :

$$\widetilde{VAT}_s = 1 - \left( \frac{\widetilde{Deductions}_s}{\widetilde{Gross}_s} \right). \quad (1)$$

The second term,  $\left( \frac{\widetilde{Deductions}_s}{\widetilde{Gross}_s} \right)$ , is the median of the ratio of deductions to gross VAT obligations in sector  $s$ . We calculate this measure at the firm level and then take the median for each sector.<sup>13</sup> VAT share is increasing with gross VAT and decreasing with

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<sup>12</sup>Note that because our empirical strategy (see the next section) relies on cross-sector as well as time variation, the results, taken literally, will also reflect the ability of factors to reallocate across sectors. For simplicity, our baseline model does not take this additional mechanism into account. The extension is straightforward and available upon request. All of the insights carry through.

<sup>13</sup>Our 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.



deductions.

Since we are able to observe outcomes seven years after computerization, we can capture the dynamic effects of computerization by dividing the post-computerization period into three sub-periods with two to three years in each sub-period:  $\delta = 1$  if it is 2001-2002 (when the reform was being rolled out),  $\delta = 2$  if it is 2003-2005,  $\delta = 3$  if it is 2006-2007. The reference period is the pre-computerization period:  $\delta = 0$  if it is 1998-2000. Later, we will also present yearly estimates.

Our analysis focuses on the dynamic effects of the reform. The baseline equation can be written as the following:

$$y_{ist} = \gamma_0 + \sum_{\delta=1}^3 \beta_{\delta} \widetilde{VAT}_s \times I_{\delta} + \sum_{\delta=1}^3 \theta_{\delta} Sales_s \times I_{\delta} + \tau_t + \phi_i + \epsilon_{ist}. \quad (2)$$

Outcomes  $y_{ist}$  for firm  $i$ , sector  $s$ , and year  $t$  are functions of: the interaction of a dummy which takes the value of one if it is period  $\delta$  and an estimated measure of intensity at the sector level,  $\widetilde{VAT}_s$ ; firm fixed effects,  $\phi_i$ ; and year fixed effects,  $\tau_t$ . 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.

In addition to the fixed effects, we also control for the interaction of year fixed effects,  $I_{\delta}$ , and average annual sales during 1998-2000 across firms in each sector,  $Sales_s$ . This is motivated by recent findings that compliance to tax policy varies by firm size (Bachas and Jensen, 2017; Kleven, Kreiner, and Saez, 2016). For example, one may be concerned that firms in sectors with higher VAT shares are smaller than those in sectors with lower VAT shares.<sup>14</sup>

We are interested in the estimates of the three  $\beta_{\delta}$ 's. For example, when the outcome

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<sup>14</sup>Later, we will carefully document all of the main observable differences across high and low VAT share sectors (see Table 2).

is VAT, we hypothesize that the interaction coefficients will be positive, but perhaps small and/or imprecisely estimated when the reform is being rolled out during the first post period,  $\beta_1 \geq \beta_0 = 0$ ; positive and relatively larger in magnitude when it is fully rolled out during the second post period,  $\beta_2 > \beta_1$ ; and positive but smaller in the third post period,  $\beta_2 \geq \beta_3 \geq \beta_0$ .

There are two important issues regarding our empirical strategy. The first is how to measure  $\widetilde{VAT}_s$ . Using the average over all of the years in the Chinese data, 1998-2007, is problematic since it will include the effect of the reform (captured by the data from post-reform years, 2001-2007). An alternative is to use Chinese data from before the reform, 1998-2000. However, the presence of evasion prior to 2001 could render this measure problematic. To address these difficulties, we proxy for pre-treatment VAT shares in China with sector average VAT shares calculated from U.S. input-output tables.<sup>15</sup> This assumes that the rank of sectors by VAT share calculated from U.S. data is similar to the true rank in our context. Given that our study focuses on very large firms, this assumption seems *prima facie* reasonable.

We also present estimates using the U.S. measures as instruments for  $\widetilde{VAT}_s$  calculated from Chinese pre-reform data. The results are qualitatively similar. See Section 6.7.5 and Appendix Section C.

The second issue is one of identification. Our strategy is similar to a *difference-in-differences* (DD) strategy that compares outcomes before and after the reform, between sectors with low VAT share and sectors with high VAT share. The main difference between our strategy and the textbook DD strategy is that we do not use binary treatment variables: the cross-sectional measure of intensity is a continuous variable and we divide the post-reform period into three sub-periods. However, the identification assumptions are similar. Our strategy assumes parallel trends – i.e., absent the reform, the outcomes of interest across sectors with different VAT shares will evolve along parallel trends. We

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<sup>15</sup>We use the *2007 U.S. Input-Output Accounts Data* from the Bureau of Economic Analysis.

will provide support for this assumption by conducting a pre-trend analysis, as well as a number of robustness tests to address potential omitted variable concerns. We discuss these checks in detail after the main results.

## 5 Data

The main sample is a balanced panel of firms for the years 1998-2007 constructed from China's *Annual Survey of Industrial Production*. These data are collected by the National Bureau of Statistics and are often 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.<sup>16</sup> The dataset includes all state-owned manufacturing firms and non-state manufacturing firms with sales greater than five million RMB. These data have been used by several recent studies. The most well-known is probably Hsieh and Klenow (2009), which used all of the years available when their paper was written, 1998-2005.

The inclusion and exclusion criteria for non-state owned firms are not symmetric. The survey includes all state-owned firms, but only 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 attributes). To avoid complications in interpretation due to selective sampling, we impose a uniform cutoff and drop all observations with less than five million RMB in revenues.

The data contain a rich set of variables. The key variables for our study are gross VAT, VAT deductibles and VAT payment. The data are measured with error such that VAT payment does not always 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 according to reported gross

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<sup>16</sup>For regulatory reasons, most subsidiaries are separate legal entities in China.

VAT, VAT deductibles and the official formula.<sup>17</sup> It is important to note that our VAT data accounts for export rebates and reflect actual VAT payments. We will discuss and motivate other variables as they become relevant.

All of the values in the paper are reported in real terms.<sup>18</sup> The main sample is a balanced panel of 8,096 firms that operate from 1998-2007.<sup>19</sup> To avoid outlier-driven results, our sample excludes observations with the top and bottom 1% values of VAT and sales each year.<sup>20</sup> We use 4-digit Chinese Industry Classification sector definitions. There are 299 sectors in our sample.

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 for one unit of production in industry  $s$  from all other industries. 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  $s$ ,  $\sum_{r=1}^S \text{Input fraction}_{sr} = 1$ .

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, 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 that represents the share of inputs deductible under Chinese VAT rules. This object can be characterized by the following equation, where  $D$  represents the set of deductible industries:

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<sup>17</sup>See the Data Appendix for more details.

<sup>18</sup>We use deflators provided by the Penn World Tables. To the extent that one is concerned about region-specific changes in prices, we show that our result are robust to controlling for province-year fixed effects in the robustness section.

<sup>19</sup>Note that the panel is not perfectly balanced because some variables are missing for some years. All firms in the sample have non-missing values for the key variables for at least nine of the ten years that we study.

<sup>20</sup>The results are qualitatively similar without dropping the outliers, but slightly less precise. They are available upon request.

$$\widetilde{VAT}_s^{US} = 1 - \sum_{d \in D} Input\ fraction_{sd}. \quad (3)$$

Figure 2 plots U.S. VAT share measures for each sector against analogous measures calculated from the 1998-2000 Chinese data together with the 45-degree line. The two measures of VAT share are strongly positively correlated.<sup>21</sup>

We acknowledge that U.S. VAT share will measure Chinese VAT share with error, which if classical, will attenuate the results. Appendix Section C presents the results using U.S. VAT measures to instrument for Chinese VAT measures. The main analysis will focus on the reduced form estimates using U.S. VAT measures for simplicity and because the 2SLS estimates are qualitatively similar, and the reduced form results are the most conservative.

## 5.1 Indirect Evidence on Pre-computerization Enforcement

We provide indirect evidence for the claim that audit rates were lower in high VAT share sectors by examining the number of tax officials according to average VAT share in a province. The logic assumes that more tax officials per firm enable higher audit rates. We obtain data for the number of tax personnel in each province and year from the *Tax Yearbook of China*, 1998-2007. There are only a few missing observations. We regress the number of tax officials on our average intensity measure, as well as other variables that would affect the probability a firm would be audited: ruggedness, the geographic size of the province, the total province population, and the number of firms in a province.<sup>22</sup> The data are at the province and year level. To focus on cross-province variation, we control for year fixed effects.

Table 1 presents the results. VAT share is the average VAT share of firms within a

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<sup>21</sup>Appendix Table A.1 lists the sectors with the highest and lowest VAT share measures computed using the U.S. data.

<sup>22</sup>Ruggedness is computed using ArcGIS by the authors. The size of the province is reported by the *China Statistical Yearbook*, 2000. We calculate VAT Share and the number of firms per province and year using the full sample (not the balanced panel that we use for the regressions) of our main dataset.

province, which we claim to be positively associated with the average treatment intensity in a province. Column (1) shows that the coefficient for VAT share is negative, which means that provinces with firms in higher VAT share sectors had fewer tax personnel who could conduct manual audits. Other factors also correlate with the number of tax personnel in the way that one would expect. Provinces that are larger, that have higher population and firm density have more tax officials.<sup>23</sup>

Note that the R-squared in column (1) is 0.947, implying that our crude controls explain 94.7% of the cross-province variation in tax personnel. Moreover, the standardized coefficient for VAT share, which estimates the effect in terms of standard deviations, show that a one standard deviation increase in VAT share reduces the number of tax officials by 0.24 standard deviations. This is sizable in terms of magnitude.

In column (2), we examine the post-computerization period. The estimates are very similar.

These results are consistent with the anecdotal evidence that the low level of enforcement prior to computerization focused on sectors with high deductible shares, i.e, low VAT share, and that there was little change in the allocation of tax officers after computerization was introduced.

## 5.2 High vs. Low VAT Share, Pre- vs. Post-Computerization

To illustrate the variation behind our empirical strategy, Figure 3 plots average VAT over time for firms with above and below the sample median VAT share. Since average VAT payments are much higher from the high VAT share group (576,000 RMB) than the low VAT share group (385,000 RMB), we subtract the pre-reform mean from average VAT for each group in each year to make it easier to visually compare the trends over time. The figure shows that VAT increased throughout the entire sample period for both groups. The increase was similar between the two groups prior to the reform, and diverge

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<sup>23</sup>Since we also control for province size, we interpret the coefficients on population and firms as the effect of population and firm densities.

after 2001, with the high VAT share group experiencing a larger increase. Our empirical strategy will compare the average difference between the two lines after the reform to the average difference before the reform. The similarity in the pre-reform increase supports the parallel trends assumption of our empirical strategy. The timing of the divergence supports our interpretation that the pre-post second difference captures the effects of computerization rather than other changes that occurred before or afterwards.

### 5.3 Correlates of VAT Share

Since VAT share is not randomly assigned, one of the main concerns for our identification strategy is omitted variables. Table 2 documents the differences between high and low VAT share sectors by estimating the correlation coefficient of VAT Share (calculated from U.S. input output tables) and a number of pre-reform firm characteristics averaged at the sector level. For brevity, we focus on variables which we later examine as outcomes. These cross-sector correlation coefficients show that, on average, sectors with high VAT shares (obviously) pay higher VAT as a share of sales, have lower output, lower intermediate inputs and are less competitive, as measured by the Herfindahl-Hirschman Index that we construct for each sector. Later, after we present the main results, we will show that they are robust to controlling for these cross-sector differences.

## 6 Main Results

### 6.1 VAT

Table 3 examines the effect of computerization on VAT. The pre-computerization means of the dependent variables are stated at the top of the table. Column (1) examines VAT as a share of sales. We examine this variable first because an increase in enforcement should increase taxes as a share of sales. However, it is important to note that in the VAT context, better enforcement could also increase reported sales (since under-

reporting sales is one way to evade VAT), which would reduce VAT / sales. Thus, our estimates will capture the net of the two forces and provide a lower bound estimate for the change in VAT as a share of true sales. The three interaction coefficients are all positive and statistically significant at the 10% and 5% levels. They show that computerization caused a small increase in VAT as a share of sales in the first post-reform period when computerization was being rolled out, a much larger increase in the second post period, and a slightly smaller but quite similar increase in the third post-reform period. The p-values at the bottom of the table show that the interaction coefficients are statistically different between the first and second post periods, and statistically similar between the second and third post periods. These results are important in showing that computerization improved the enforcement of VAT, and goes against the concern that increases in VAT are driven by sectors with higher VAT shares experiencing more output growth for spurious reasons.

Column (2) examines VAT. All three interaction coefficients are positive. The estimate is statistically insignificant at conventional levels during the 2001 and 2002 when the reform was being rolled out. It becomes larger in magnitude and significant at the 5% level in the subsequent three years, 2003-2005. However, the magnitude of the coefficient six and seven years into the reform, 2006-2007, declines relative to 2003-2005. It is still positive, but statistically imprecise. The p-values at the bottom of the table show that the effect of computerization during the first and second periods are statistically different at the 1% level. The difference between the second and third periods is significant at the 15% level. These results are consistent with our model, which predicts that computerization will increase VAT gains, but that the positive gains will be smaller in the long-run.

To assess these magnitudes, consider that mean U.S. VAT share is 0.5033 and cumulative VAT revenues from the average firm during 2001-2007 is 14,423,662 RMB. Also note that VAT is reported as 1,000s of RMB in our data. The coefficients imply



that the increase in VAT payments for the mean firm cumulated during 2001-2007 is 2,073,527 RMB ( $2,073,527 = (234.8 \times 2 + 926.5 \times 3 + 435.4 \times 2) \times 0.5033 \times 1000$ ). Thus, computerization explains approximately 14.38% of total VAT revenues during 2001-2007 ( $0.1438 = 2,073,527/14,423,662$ ). This effect is economically meaningful, especially when we recall that VAT is the main source of government revenue. For example, VAT accounted for 47% of all government revenues in 2002, which means that computerization explains 6.76% of all government revenues in 2002 ( $0.0676 = 0.1438 \times 0.47$ ).

From these estimates, we can also calculate the effect of computerization on the effective average tax rate (i.e., VAT / sales). The top of Table 3 shows that the pre-reform mean tax rate is 4.95 percentage-points. The estimates imply that computerization caused VAT / sales to be 5.19 percentage-points in the short run ( $0.0519 = 0.0495 + 0.00466 \times 0.5033$ ), 5.65 percentage-points in the medium run ( $0.0565 = 0.0495 + 0.0139 \times 0.5033$ ) and 5.53 percentage-points in the long run ( $0.05529 = 0.0495 + 0.01150 \times 0.5033$ ). Thus, computerization causes the effective tax rate to increase by 4.7% ( $0.047 = (0.0519 - 0.0495)/0.0495$ ) in the short run, 14% ( $0.1413 = (0.0565 - 0.0495)/0.0495$ ) in the medium run and 11.7% ( $0.1269 = (0.05529 - 0.0495)/0.0495$ ) in the long run. As we discussed earlier, these should be interpreted as lower bound estimates of the increase in the effective tax rate.

## 6.2 Year by Year Estimates

To examine the timing of the effects of computerization at a more granular level, we estimate the following equation where we examine each year separately:

$$y_{ist} = \gamma_0 + \sum_{t=1999}^{2007} \beta year_t * \widetilde{VAT}_s + \sum_{\delta=1}^3 \theta_\delta Sales_s \times I_\delta + \tau_t + \phi_i + \epsilon_{ist}. \quad (4)$$

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 a measure of intensity at

the sector level,  $\widehat{VAT}_s$ ; firm fixed effects,  $\phi_i$ ; and year fixed effects,  $\tau_t$ . 1998 is treated as the reference year. The only difference between this specification and the baseline equation is that we create a dummy variable for each year and separately interact each dummy variable with VAT share.

Figure 4a plots the coefficients and their 95% confidence intervals. The figure 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 a level that is similar to, or slightly above, pre-computerization levels. This pattern over time is consistent with our model. Note that the visual peak in 2004 should not be interpreted as the literal “peak”, since it is statistically indistinguishable from the coefficients in the preceding and following years.

The pattern over time shown in Figure 4a is also important for our identification strategy, which relies on the parallel trends assumption. That there is no pre-trend and that changes gradually begin at the time of the reform are both reassuring facts and consistent with the identification assumptions.

Figure 4b repeats the year by year estimates using VAT / Sales as the outcome variable. The pattern over time looks similar. There is no pre-trend and the increase in VAT / Sales begins in 2001.

The coefficients and their standard errors are presented in Appendix Table A.3. The p-values at the bottom of the table show that the interaction coefficients for the post-reform period are jointly different from zero.

### 6.3 Sales, VAT Gross, VAT Deductibles

In columns (3) - (5) of Table 3, we examine the different components of VAT. VAT is the difference between gross VAT (sales $\times$ 0.17) and VAT deductions. Sales, gross VAT and VAT deduction are reported as separate variables in the data. The pre-reform dependent

means in columns (3) and (4) show that gross VAT in our sample is approximately 17% of sales. To be comprehensive, column (3) examines sales and column (4) examines gross VAT as the dependent variables. For both variables, the interaction coefficients are all negative and grow in magnitude over time. They are statistically insignificant during the first post-reform period when computerization was being rolled out, and statistically significant at the 10% or 5% levels in the second and third post-reform periods. The p-values at the bottom of the table show that the interaction coefficient in the second post-period are statistically different from those in the first period at approximately the 10% level. The second and third post-period coefficients differ statistically only at the 20% level. These results are consistent with the model which predicts that sales decline each period.<sup>24</sup>

Column (5) examines VAT deductions. The interaction coefficients are negative and statistically significant for all periods and grow in magnitude over time. Comparing the estimates in columns (4) and (5), we see that at first, gross VAT declines less than deductibles, which generates the initial increase in VAT payments. But the fall in gross VAT catches up over time, which explains the decline in VAT payments over time.

## 6.4 TFPR, Inputs and Export Share

Table 4 presents the estimated effect of computerization on the other outcomes of interest. Column (1) examines TFPR as measured in Hsieh and Klenow (2009). It shows that computerization increases TFPR. To address the possibility that inputs are endogenous to unobserved productivity shocks, column (2) measures TFPR using the De Loecker and Warzynski (2012) method. The pattern of increasing TFPR over time is similar across the two different measures. We note that the interaction coefficients in column (2) are only statistically significant for the third post-reform period. However, the p-

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<sup>24</sup>Note that our results do not have direct implications on the elasticity of output with respect to the tax rate or VAT. This is because the difference-in-difference strategy exploits cross-sector variation and taken literally, captures both the reallocation of production across sectors as well as a general contraction of output.

values at the bottom of the table show that the increase in magnitude in each period is statistically significant at the 5% and 1% levels.

Next, we examine labor inputs. In the Chinese data, the high share of non-wage benefits (e.g., subsidized housing) makes the wage bill a very noisy measure of labor costs. Thus, we examine the number of employees in column (3). The interaction coefficients are negative and declining (increasing in magnitude) over time. All of the estimates are, unsurprisingly, imprecise.

Column (4) examines intermediate inputs, which include “direct materials”, “intermediate inputs in manufacturing”, “intermediate inputs in management”, “intermediate inputs in operations” and “financial costs”. Deductible inputs are a subset of intermediate inputs. We find that computerization reduced intermediate inputs over time. The estimates are statistically significant at the 10% level for the second period.

In columns (5) and (6), we examine intermediate and deductible inputs as a share of all inputs. Increased enforcement of VAT causes both measures to decline. The interaction coefficients for deductible inputs are statistically significant for the second and third post-reform periods. Since a decrease in deductible inputs increases VAT payments, this result is important because it goes against the alternative interpretation that the decline in VAT in the third period is due to renewed evasion. We will discuss this in more detail later in the paper.

In column (7), we examine export share as an outcome to see whether firms substitute towards exports to reduce VAT. We find no evidence of such behavior. This pattern is consistent with the belief that there are large fixed costs to exporting (e.g. Das, Roberts, and Tybout, 2007; Roberts and Tybout, 1997). We will return to this result later when we discuss alternative hypotheses.

Taken together, the findings that computerization increases TFP and reduces inputs are consistent with the model presented earlier.

## 6.5 Robustness

The main concern for our identification strategy is that the estimates capture omitted variables and are driven by other differences between firms in high and low VAT share sectors. As we document in Table 2, high and low VAT share sectors indeed differ along many dimensions. Given that we find no pre-trends, omitted factors would only be a concern if they also caused a divergence after computerization. In this section, we discuss potential concerns and show that our main results are unlikely to be confounded by these alternative mechanisms. For brevity, we focus on VAT as a share of sales and VAT as outcome variables.<sup>25</sup>

### 6.5.1 Trade Tariffs and the WTO

Table 2 documents that the export share is similar between high and low VAT share sectors. However, one may still be concerned that China's entry into the World Trade Organization in 2001 confounds our results. This policy change will confound our estimates if entry differentially changed the effective VAT rate according to VAT share. (The economy-wide effect of entry into the WTO is already controlled for by the year fixed effects). To investigate this possibility, we construct measures of import tariffs, export VAT rebates and export duties for each sector and year.<sup>26</sup> Table 5 columns (2)-(4) show that controlling for different combinations of trade tariffs produce similar results to the baseline, which is restated in column (1) for comparison. The magnitude and precision of the estimates are all very similar. Note that the number of observations change slightly because we are unable to obtain data on tariffs for all sector-years.

Another way to address the concern that the main results are confounded by spurious correlations between VAT share and how firms are affected by the WTO accession is to control for average annual growth in exports in a sector prior to computerization (1998-

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<sup>25</sup>The other outcomes are equally robust. The results are available upon request.

<sup>26</sup>Rebate data are from (Garred, 2016). We use the method presented in (Fan, Li, and Yeaple, 2015; Fan, Gao, Li, and Luong, 2018) to obtain output and input tariffs.

2000) and its interaction with year fixed effects. This also addresses the concern that in 2004, there was a change in the central-local-government split in financing VAT export rebates (Bai and Liu, 2017). Column (5) shows that the results from this specification are very similar to the baseline shown in column (1).

### **6.5.2 Competitiveness**

To address the concern that high VAT share sectors may be less competitive (see Table 2), we control for sector-specific HHIs interacted with year fixed effects. This exercise is partly motivated by Cai and Liu (2009), which argues that competition can affect tax evasion.<sup>27</sup> The estimates, reported in column (6), are very robust.<sup>28</sup>

### **6.5.3 Province-Year Fixed Effects**

To address the possibility that there are province-specific policy changes or differences in the implementation of computerization of VAT invoices, or changes in province-specific economic conditions, we control for province-year fixed effects. For example, Chen (2017) argued that the abolition of agricultural taxes in 2005 led tax authorities to supplement their lost income with other tax sources such as VAT. Province-year fixed effects controls for the potentially confounding influences of this reform to the extent that the revenue loss differed across provinces. Similarly, recall that we deflate the main dataset with a national deflator. But one may be concerned that prices change differentially across provinces. Province-year fixed effects control for this. Column (7) shows that our results are very robust.

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<sup>27</sup>They find that competition in the product market increases corporate tax avoidance in China.

<sup>28</sup>Similarly, we can control for average markup in the sector interacted with year fixed effects. The results are similar to the baseline and available upon request.

#### 6.5.4 Global Demand or Supply Shocks

One may also be concerned that the main results spuriously capture differences in global demand or supply shocks between sectors with high and low VAT shares. We address this concern by controlling for the total amount of imports and exports in each sector and year.<sup>29</sup> In columns (8) - (10) of Table 5, we control for sector-year imports, sector-year exports and for both simultaneously. The results are very robust to these additional controls.

#### 6.5.5 Subsequent VAT Reforms

As we discussed in the Section 2, the changes made to VAT in 2008 and 2009 (increasing the number of inputs that qualified for deductions) were piloted in three northeastern provinces (Liaoning, Heilongjiang and Jilin) starting in 2004 (Cai and Harrison, 2017; Liu and Lu, 2015). To investigate whether our main results are confounded by the pilot, we omit all observations from these provinces starting in 2004. Column (11) of Table 5 shows that our results are very robust to this exclusion.

#### 6.5.6 Additional Controls

Recall that Table 2 documents several dimensions for which high- and low-VAT share sectors differ. In Table 6, we control for each of these dimensions. Specifically, we control for the pre-computerization average measures of each variable (TFPR, employment and intermediate inputs) interacted with year fixed effects to allow the influences to vary over time. Recall that the baseline equation already controls for average pre-computerization firm size (i.e., sales) interacted with year fixed effects. This is a very rigorous test. The results are very robust.

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<sup>29</sup>These data are reported by China's General Administration of Customs, 1998-2007

## 6.6 Alternative Interpretations

Recall that our simple model interprets the main findings to mean that computerization increased VAT and led to a contraction of output from firms, which then led to a reduction in VAT gains in the long run. We acknowledge that it is beyond the scope of this paper to be conclusive about the mechanisms and are open to alternative explanations. In this section, we consider two alternatives that seem the most relevant given the existing literature.

### 6.6.1 Do Firms Export More to Decrease VAT Payments?

Given the large number of studies about the relationship between VAT and exports in China, we consider the possibility that firms shifted towards exports, which on average pay lower VATs because of rebates.<sup>30</sup> If it takes time to become an exporter (or to increase exports), this could explain why the effect of computerization on VAT was larger in the second post period than the third post period. Under some assumptions, it can also be consistent with the increase in TFPR and decline in sales. However, Table 4 column (7) shows that computerization has no effect on exports as a share of total sales. The interaction coefficients are positive, but small in magnitude and statistically insignificant.

### 6.6.2 Learning New Ways to Evade

The large literature on tax evasion means that another important alternative to consider is the possibility that after a few years of the newly computerized system, firms learned new methods to evade. If learning takes time, this could explain why the effect of computerization on VAT was larger in the second post period than the third post period. However, it is not fully consistent with our other findings. On the one hand, an increase

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<sup>30</sup>For studies about exports and VAT in China, see for example, Fan, Liu, Qiu, and Zhao (2017); Garred (2014); Chandra and Long (2013); Gourdon, Monjon, and Ponset (2015); Liu and Lu (2015).



in evasion in high VAT share firms is consistent with the decline in sales (Table 3 column 3), since lower sales imply lower VAT payments. On the other hand, it is inconsistent with the decline in intermediate and, in particular, deductible inputs (Table 4 columns 6), since lower deductible inputs imply higher VAT payments. It is also difficult to reconcile evasion with the increase in TFPR (Table 4 columns 1-2).

Nevertheless, to further investigate this alternative mechanism, we divide the sample into sectors for which evasion is presumably easier versus sectors where evasion is presumably more difficult. Since evasion requires the collusion of all upstream and downstream partners, a reasonable assumption is that shorter production chains and fewer inputs increase the ease of evasion. The question we ask is whether the temporal pattern we observe in our main results – that VAT increases, but then declines – is only present in the sectors with shorter production chains or fewer inputs.

Note that the question we pose is different from asking whether computerization had a larger or smaller effect on sectors within which it is easier to evade. This will depend on which group experiences a higher return to the increase in enforcement, for which we have no theoretical or empirical basis to form a prior.

Table 7 columns (1) and (2) present the results for sectors with production chain lengths below and above the sample median. Columns (3) and (4) present results for sectors with input numbers below and above the sample median. Panel A examines VAT / sales as the outcome variable. Panel B examines VAT as the outcome. For VAT / sales, the non-monotonic temporal pattern seems more prominent in the the subsample with short production chains and the subsample with fewer number of inputs (columns (1) and (3) Panel A). However, a similar pattern is present for VAT in the subsample with many inputs (column (4) Panel B). Moreover, the p-values at the bottoms of Panels A and B show that the coefficients in the sub-samples are statistically similar.<sup>31</sup>

The finding that computerization reduces deductible inputs together with the impre-

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<sup>31</sup>These are estimates are generated by Seemingly Unrelated Regressions.

cisely estimated heterogeneous effects show that there is no systematic evidence for the alternative explanation that newly learned evasion is the main driving force behind the temporal patterns that we find.

At the same time, it is important to note that these findings do not imply that there was no evasion after computerization. To understand how firms evaded VAT in the post-reform period, we conducted extensive interviews with managers of manufacturing firms and tax officials in China. The anecdotal evidence suggests that there continues to be some degree of evasion, but interviewees do not believe that there was a systematic increase in evasion over time following computerization because it would have required that the entire chain opt out of the formal sector. This would be particularly difficult for the large firms in our sample.

## **6.7 Additional Results**

### **6.7.1 Spillover Effects in Enforcement**

An interesting question is whether strengthening the VAT information chain had positive spillover effects in the enforcement of other types of taxes. We examine corporate tax payments, which are also reported in our survey data. Table 8, column (1) shows that the interaction coefficients are positive but statistically insignificant. Thus, there is no evidence of positive spillovers.

The result on corporate tax is also interesting for another reason – it provides evidence against the concern that our main finding that computerization increased VAT is confounded by general improvements in tax enforcement.

### **6.7.2 Heterogeneous Effects for Exporters and Importers**

Next, we divide the sample according to export shares and imported input shares. This dimension of heterogeneity is interesting, given the importance of trade to China’s manufacturing sector. We divide the sample according to whether export or import shares in

the sector are lesser or greater than the sample median in 1998-2000.<sup>32</sup> Columns (2) and (3) test whether the treatment effect differed by the pre-period sectoral export share. Note that the sample median export share is zero, which is why the subsample in Table 8 column (2) is much larger than that of column (3). In columns (4) and (5), we test whether the treatment effect differed by the pre-period sectoral imported input share. Panel A examines VAT / sales and Panel B examines VAT as outcomes. The p-values at the bottom of the table show that the estimates from the different sub-samples are statistically similar.

### 6.7.3 Heterogeneous Effects According to Distance from End Consumers

Another interesting dimension of heterogeneity to examine is the distance to the end consumer. Sellers of raw materials are supposed to pay sales taxes, and face incentives to under-report sales, while the purchasers of raw materials face incentives to overstate inputs. This means that firms towards the beginning of the chain should face similar difficulties in evading VAT as firms in the middle of the chain. In contrast, studies such as Pomeranz (2015) have found that in Chile, the strength of enforcement weakens towards the end consumer because the end consumer is not incentivized to ask for receipts.<sup>33</sup> However, whether it is relatively easier for Chinese firms towards the end consumer to evade is unclear. Unlike the Chilean context, the Chinese government incentivizes end consumers to ask for receipts by making each official receipt a lottery ticket. In this sense, the environment is similar to the the Brazilian one studied by Naritomi (2015). However, retailers in our context are not systematically audited by tax authorities to the best of our knowledge.

The p-value at the bottom of Table 8 Panel A columns (6) and (7) show that the effect of computerization on VAT / sales is larger for firms that are closer to the final

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<sup>32</sup>Export shares are calculated using our data. Imported input shares are calculated using Chinese Customs Administration data.

<sup>33</sup>This point has also been made by other studies. See Slemrod (2007) for a discussion.

consumer, which implies that the marginal effect of computerization on tax enforcement was probably larger for such firms. The results for VAT in Panel B are consistent with the results in Panel A, but the estimates in the two subsamples are not statistically different from each other.

#### 6.7.4 All Firms

The main results use a balanced panel of firms, which has advantages for identification and interpretation (e.g., we can control for firm fixed effects, and there are no compositional effects from entry and exit of firms). To address the issue of external validity, we re-estimate our baseline specification using all firms and compare those results to those from the balanced panel. We organize the data to be a panel of sectors.<sup>34</sup> Since the right-hand side variation in equation (2) 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.<sup>35</sup> We weight the regressions with the number of firms in each sector-year cell such that the estimated coefficients and standard errors are numerically identical to a regression using firm-year observations. Table 9 presents the results. For brevity, we focus on VAT / sales, VAT, sales, TFPR and deductible input shares. The estimates, in particular the patterns over time, are very similar to the main results for all outcomes. The magnitudes and precision are also broadly similar. These results suggest that the findings from the balanced sample are most likely generalizable to the Chinese economy (i.e., all large manufacturing firms) as a whole.<sup>36</sup>

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<sup>34</sup>Appendix Table A.2 presents descriptive statistics for firms in the balanced panel and all firms.

<sup>35</sup>Appendix Figure A.1 plots VAT over time for sectors with above and below sample median VAT shares. As with the balanced panel of firms in Figure 3, we observe a parallel increase in VAT between the two groups and a divergence with the high VAT share group experiencing more of an increase after 2001.

<sup>36</sup>Note that we also examined other outcomes such as entry and exit using all firms. However, these estimates are too imprecise to be informative. Moreover, the interpretation of entry and exit from our sample of large manufacturing firms is unclear. For example, exit could simply reflect a change in firm size, which we already examine by looking at output. These results are available upon request.

### 6.7.5 2SLS

Returning to the balanced panel sample, we use the VAT shares calculated from the U.S. input output tables as instruments for VAT shares calculated from pre-computerization Chinese data. This exercise assumes that there is measurement error in the Chinese data and uses the U.S. instruments to correct for the measurement error. The 2SLS estimates show a similar pattern over time to our main results for all of the main outcomes, and are often larger in magnitude. However, the first stage F-statistic is only around seven. The weak first stage can bias the 2SLS estimates and we know of no method for correcting for weak instruments with three endogenous variables. See Appendix Section C.

### 6.7.6 Heterogeneous Effects by Ownership

Ex-ante, the influence of ownership is ambiguous. On the one hand, state-owned firms are better connected to the government, which may make tax evasion easier, even after computerization. This would cause computerization to have smaller effects on state-owned firms. On the other hand, the closer relationship could cause managers, particularly those seeking promotion within the state bureaucracy, to be less willing to evade. If managers interpret computerization as an increase in how much the central government values VAT revenues, then this could cause computerization to have a larger effect on state-owned firms.

We use the official ownership registration definition to divide the sample into two categories: state-owned and domestic privately-owned firms. The estimates in terms of the patterns over time are similar between each sub-sample and the main results. However, the precision and magnitude varies across outcomes and subsamples, and only the estimates for sales are statistically different for the two subsamples (they are negative in both sample, but larger in magnitude for privately owned firms). See Appendix Table A.6. Thus, we conservatively interpret these results as not showing systematic differences

across ownership types.<sup>37</sup>

### 6.7.7 Heterogeneous Effects by Size and Fixed Assets

Given recent studies which find that compliance to tax policy varies by firm size (Bachas and Jensen, 2017; Kleven, Kreiner, and Saez, 2016), we investigate whether the effect of computerization differs for large and small firms in our context. We do not find evidence of systematic differences. We also divide the sample according to the share of fixed assets for the median firm in a sector. Firms using more fixed assets should find it more difficult to adjust inputs over time, which means that computerization would have a smaller negative effect on output and VAT for such firms. The estimates are imprecise and inconclusive. These results are available upon request.

## 7 Conclusion

This paper provides novel and rigorous empirical evidence on the dynamic effects of improved state capacity on taxation by studying the effects of computerizing VAT invoices in China. We find that computerization increases VAT revenues, but the gains seem to decline in the long run as firms contract. At the same time, we observe that productivity increases in the long run in response to the tax increase.

We show that the reduction in long-run VAT gains is not driven by substitution towards exports, which on average pay lower VAT, and unlikely to be due to firms learning new evasion techniques.

We acknowledge that the estimated magnitudes are specific to the context of our study – large Chinese manufacturing firms during 1998-2007. Nevertheless, we believe that the main findings provide generalizable insights for policy makers. First, they show

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<sup>37</sup>The results are similar if we re-define ownership by equity control. Note that the total number of observations in Appendix Table A.6 Panels A and B is less than the sample used in the main exercises. The difference is made up of foreign-owned firms. These results are available upon request and do not alter the conclusion.

that new technologies can be effectively used by governments to significantly increase state capacity and tax revenues. This provides support for the policy implications of recent studies such as Barnwal (2016), Banerjee, Duflo, and Glennerster (2008), Duflo, Hanna, and Ryan (2012) and Muralidharan, Niehaus, and Sukhtankar (2016) with data and a policy reform from a very different context.

Second, the results provide evidence that large tax enforcement increases, and subsequent increases in tax burden, are likely to result in real changes in firm behavior, resulting in lower long-run revenues gains than short-run gains. The results together imply that policymakers face an important trade-off between increased tax revenues and reduced production when considering tax enforcement.

There are several promising questions for future study. An especially important question for developing economies is whether taxation hampers the formalization of firms by causing small firms on the threshold of formality to scale down and exit the formal sector to avoid paying taxes. Our study does not really speak to this question because we only examine very large formal firms, for which even a large decrease in size would not render informal. Nevertheless, this question is central to policy makers since a movement of firms into the informal sector could reduce a government's bureaucratic and regulatory capacity along many dimensions other than taxation. There is little existing evidence and the results are mixed. On the one hand, studies such as Harju, Matikka, and Rauhanen (2015) find that VAT reduces the growth of small firms. On the other hand, studies such as de Paula and Scheinkman (2010) argue that better enforcement of VAT can induce firms to formalize.

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Figure 1: Illustration of Short- and Long-run Responses to VAT

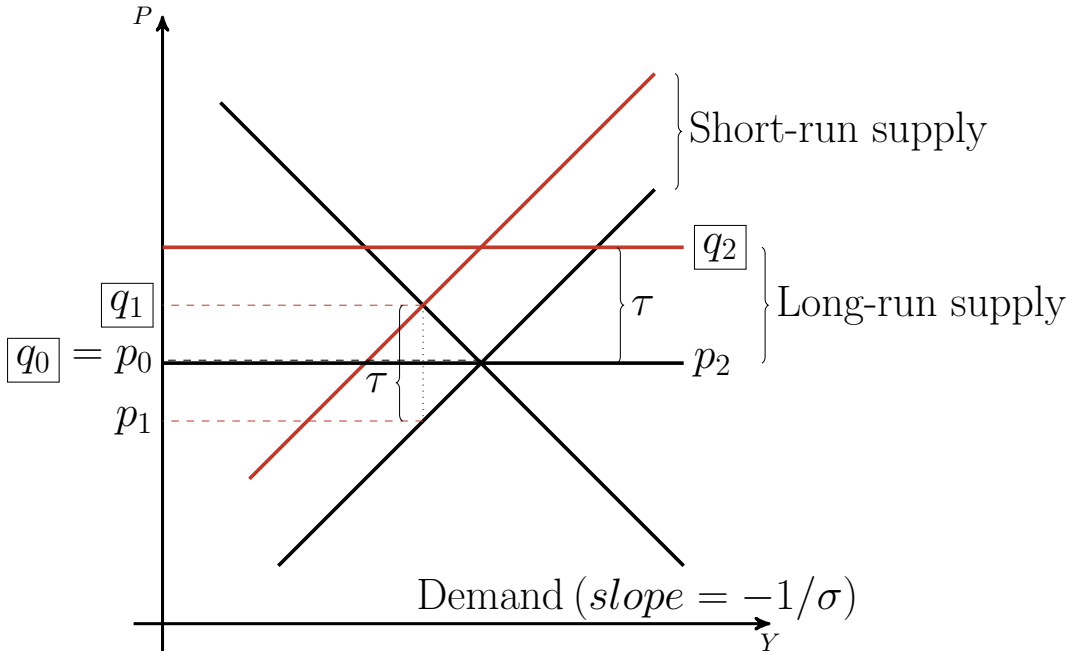


Figure 2: Chinese VAT Share (pre-computerization, 1998-2000) and U.S. VAT Share

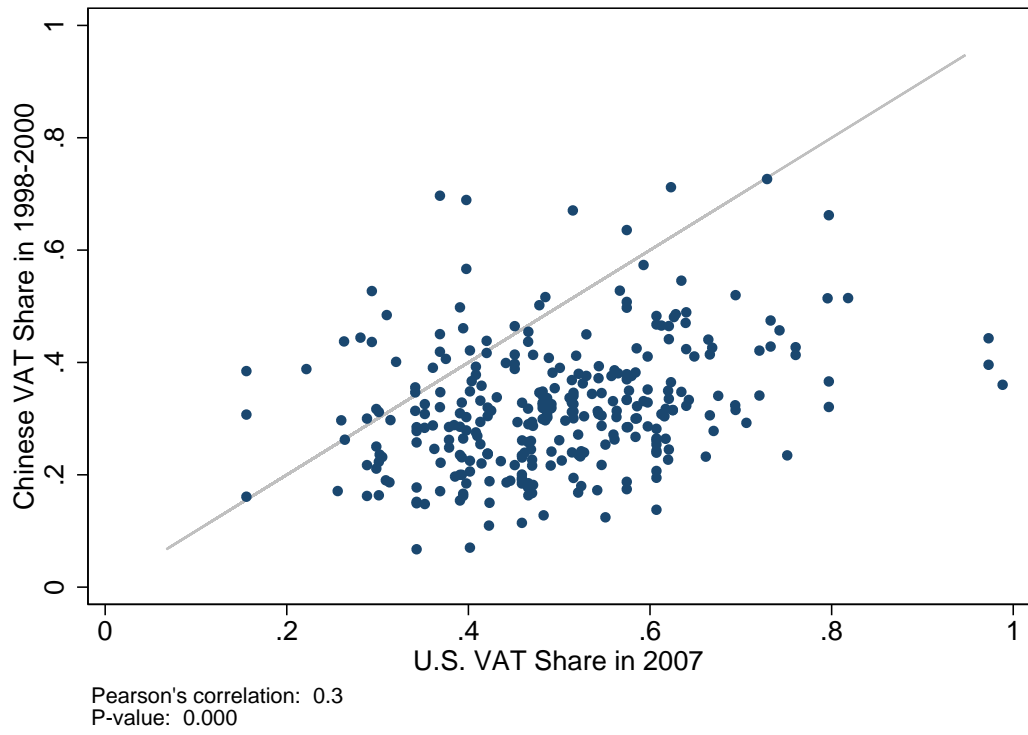
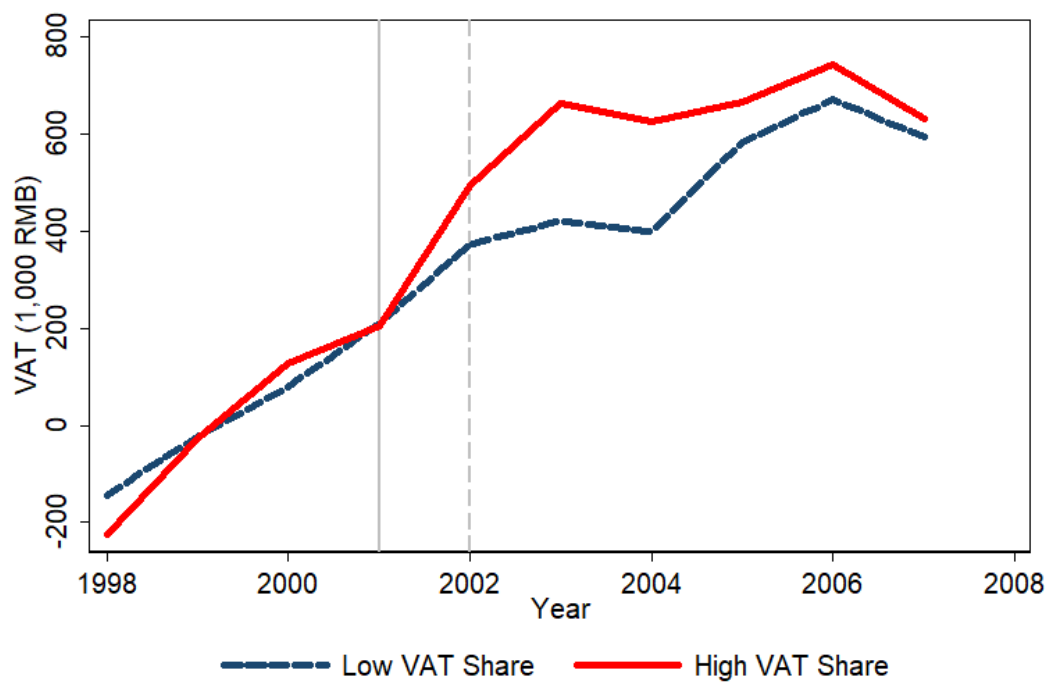
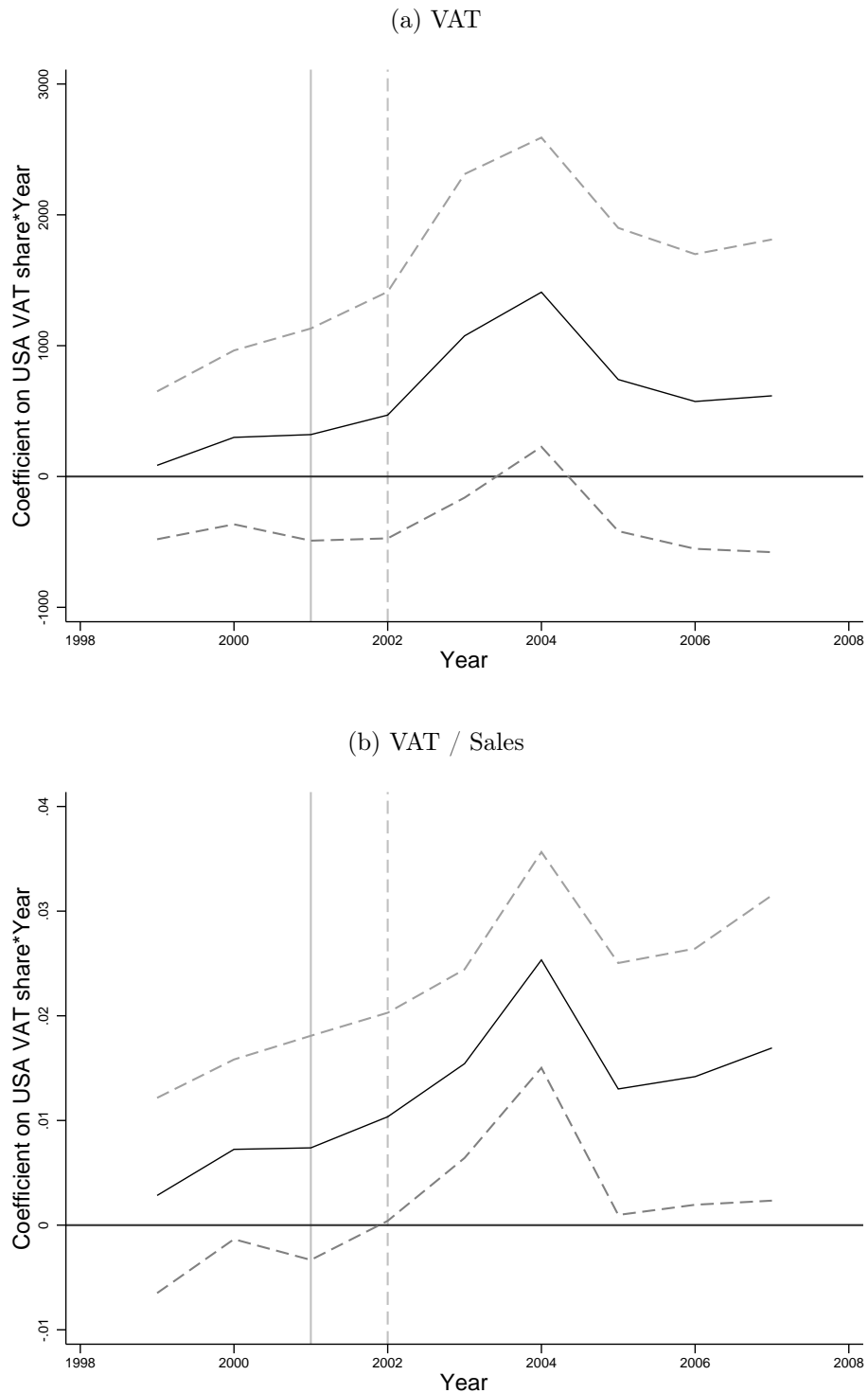


Figure 3: VAT Over Time for Firms with VAT Share Above and Below the Sample Median



*Notes:* The data are normalized to be visually comparable. The pre-computerization mean of each group is subtracted from the value of each year in the group.

Figure 4: The Effect of Computerization for Each Year Before and After Computerization



*Notes:* These figures plot the interaction coefficients of VAT Share and year dummy variables (controlling for the interaction of pre-computerization average sales and year fixed effects, and year and firm fixed effects) and their 95% confidence intervals. The sample is a balanced panel of firms, 1998-2007. The reference year is 1998. The coefficients and their standard errors are shown in Appendix Table A.3.

Table 1: Tax Personnel and VAT Share Prior

	Dependent Variable: Ln # of Tax Officials	
	1998-2000 (1)	2001-2007 (2)
Avg. Chinese VAT Share	-13.79*** (1.706)	-12.80*** (1.178)
<i>Beta Coef.</i>	<i>-0.241</i>	<i>-0.270</i>
Ruggedness	-0.0559 (0.0471)	-0.0596* (0.0342)
<i>Beta Coef.</i>	<i>-0.0488</i>	<i>-0.0548</i>
Ln Area (Square km)	0.129*** (0.0285)	0.152*** (0.0253)
<i>Beta Coef.</i>	<i>0.184</i>	<i>0.228</i>
Ln Population (10,000 people)	0.597*** (0.0622)	0.535*** (0.0381)
<i>Beta Coef.</i>	<i>0.627</i>	<i>0.573</i>
Ln # Firms	0.137** (0.0523)	0.121*** (0.0260)
<i>Beta Coef.</i>	<i>0.224</i>	<i>0.220</i>
Observations	91	216
R-squared	0.947	0.899

*Notes:* The sample is a panel of provinces with observations at the province-year level. All regressions control for year fixed effects. The number of tax officials are from the *Tax Yearbook of China*, 1998-2007. Standardized beta coefficients are presented in italics. Robust standard errors are presented in parentheses. \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.



Table 2: Correlates of VAT Share and Firm Characteristics

Dependent Var: VAT Share	
VAT	-0.0581
VAT / Sales	.2963***
TFPR Hsieh Klenow	0.1035
TFPR DLW	0.0163
Sales	-.2429***
Employment	-0.0532
Intermediate Inputs	-.2867***
Export Share	0.0835
HHI	.1095*

*Notes:* This table presents the standardized bivariate correlation coefficients between VAT share and the variables listed in each row. Each observation is a sector-level average calculated from a balanced panel of firms, 1998-2000. \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

Table 3: The Effect of Computerization on VAT

	Dependent Variables				
	(1)	(2)	(3)	(4)	(5)
	VAT/Sales (Fraction)	VAT (1000 RMB)	Sales (1000 RMB)	VAT Gross (1000 RMB)	VAT Deductions (1000 RMB)
<b>Dep Var Mean (pre-2001)</b>	<b>0.0495</b>	<b>2061</b>	<b>46211</b>	<b>7155</b>	<b>5103</b>
VAT share x 2001-2002 ( $\beta_1$ )	0.00466*	234.8	-4,750	-664.4	-901.4*
	(0.00271)	(230.8)	(3,612)	(599.1)	(462.5)
<i>Beta Coef.</i>	0.0323	0.0176	-0.0172	-0.0146	-0.0247
VAT share x 2003-2005 ( $\beta_2$ )	0.0139***	926.5**	-12,529**	-2,069*	-2,992***
	(0.00369)	(406.0)	(6,353)	(1,192)	(937.8)
<i>Beta Coef.</i>	0.108	0.0775	-0.0505	-0.0508	-0.0915
VAT share x 2006-2007 ( $\beta_3$ )	0.0115**	435.4	-25,616*	-4,628*	-5,040**
	(0.00495)	(425.9)	(13,475)	(2,437)	(2,110)
<i>Beta Coef.</i>	0.0770	0.0316	-0.0897	-0.0986	-0.134
Observations	61,308	61,308	61,308	61,308	61,308
R-squared	0.658	0.781	0.770	0.734	0.688
H0: $\beta_1 = \beta_2$ (p-value)	0.00400	0.00400	0.0650	0.109	0.00500
H0: $\beta_2 = \beta_3$ (p-value)	0.496	0.130	0.197	0.155	0.182

Notes: The sample is a balanced panel of firms, 1998-2007. All regressions include average sales (1998-2000)  $\times$  year FE, year and firm FEs. Normalized beta coefficients are in italics. Standard errors are clustered at the sector level. \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table 4: The Effect of Computerization on TFPR, Output and Input and Export Share

	Dependent Variables								
	Intermediate			Intermediate Inputs as a					
	TFPR (HK)	TFPR (DLW)	Employees (#)	Share of Total Input	Share of Total Input	Export Share	Export Share		
(1)	(2)	(3)	(4)	All	Deductible	(5)	(6)	(7)	
<b>Dep Var Mean</b>	<b>1.100</b>	<b>0.143</b>	<b>290.6</b>	<b>32087</b>	<b>0.838</b>	<b>0.785</b>	<b>0.106</b>		
VAT share x 2001-2002 ( $\beta_1$ )	0.00871** (0.00418)	0.00148 (0.0338)	-2.557 (28.55)	-4,498 (2,764)	0.00227 (0.00989)	0.0212 (0.0436)	0.0205 (0.0177)		
<i>Beta Coef.</i>	<i>0.0226</i>	<i>0.000634</i>	<i>-0.00145</i>	<i>-0.0237</i>	<i>0.00472</i>	<i>0.00921</i>	<i>0.0156</i>		
VAT share x 2003-2005 ( $\beta_2$ )	0.0111* (0.00628)	0.118 (0.0745)	-31.82 (47.15)	-8,640* (4,572)	-0.0209 (0.0222)	-0.161*** (0.0452)	0.0111 (0.0196)		
<i>Beta Coef.</i>	<i>0.0322</i>	<i>0.0565</i>	<i>-0.0201</i>	<i>-0.0509</i>	<i>-0.0483</i>	<i>-0.0782</i>	<i>0.00944</i>		
VAT share x 2006-2007 ( $\beta_3$ )	0.0140* (0.00836)	0.327*** (0.115)	-46.96 (70.69)	-10,269 (8,720)	-0.0542 (0.0342)	-0.293*** (0.0812)	0.0354 (0.0378)		
<i>Beta Coef.</i>	<i>0.0352</i>	<i>0.136</i>	<i>-0.0258</i>	<i>-0.0525</i>	<i>-0.109</i>	<i>-0.123</i>	<i>0.0262</i>		
Observations	61,308	61,308	61,308	61,308	61,308	61,308	61,308		
R-squared	0.940	0.806	0.821	0.788	0.686	0.407	0.817		
H0: $\beta_1 = \beta_2$ (p-value)	0.409	0.0400	0.293	0.186	0.123	0.00100	0.430		
H0: $\beta_2 = \beta_3$ (p-value)	0.317	0.00100	0.608	0.789	0.0200	0.0190	0.317		

Notes: The sample is a balanced panel of firms, 1998-2007. All regressions include average sales (1998-2000)  $\times$  year FE, year and firm FEs. Normalized beta coefficients are presented in italics. Standard errors are clustered at the sector level. \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table 5: The Effect of Computerization on VAT – Robustness to Export/Import Intensity, Province-Year-Specific Shocks, and Global Demand Shocks

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
		Export Rebates, Import and	Import and Export Duties	Export Rebates	Export FE	Growth 1998- 2000 × Year FE	Province FE × Year FE	Import and Export FE	Export FE	Import and Export FE	Export FE
Controls:	Baseline	Export Rebates, Import and Duties	Import and Export Duties	Export Rebates	Export FE	Growth 1998- 2000 × Year FE	Province FE × Year FE	Import and Export FE	Export FE	Import and Export FE	Export FE
VAT share x 2001-2002 ( $\beta_1$ )	0.00461* (0.00267)	0.00413 (0.00282)	0.00410 (0.00277)	0.00466* (0.00272)	0.00460* (0.00267)	0.00466* (0.00271)	0.00497* (0.00254)	0.00456* (0.00267)	0.00454* (0.00265)	0.00444* (0.00264)	0.00451* (0.00269)
VAT share x 2003-2005 ( $\beta_2$ )	0.0138*** (0.00373)	0.0130*** (0.00358)	0.0129*** (0.00353)	0.0139*** (0.00378)	0.0139*** (0.00371)	0.0139*** (0.00369)	0.0136*** (0.00363)	0.0135*** (0.00369)	0.0135*** (0.00374)	0.0129*** (0.00367)	0.0133*** (0.00371)
VAT share x 2006-2007 ( $\beta_3$ )	0.0114** (0.00490)	0.0105** (0.00478)	0.0105** (0.00473)	0.0114** (0.00493)	0.0117** (0.00471)	0.0115** (0.00495)	0.0112** (0.00477)	0.0108** (0.00479)	0.0108** (0.00473)	0.00966** (0.00460)	0.0108** (0.00495)
Observations	61,308	61,284	61,284	61,284	61,308	61,308	61,301	61,308	61,308	61,308	60,667
R-squared	0.658	0.658	0.658	0.658	0.658	0.658	0.663	0.658	0.658	0.658	0.661
H0: $\beta_1 = \beta_2$ (p-value)	0.00500	0.00400	0.00400	0.00400	0.00400	0.00400	0.00300	0.00600	0.00700	0.01000	0.00700
H0: $\beta_2 = \beta_3$ (p-value)	0.513	0.484	0.500	0.486	0.534	0.496	0.483	0.470	0.443	0.368	0.501
	B. Dependent Variable: VAT										
VAT share x 2001-2002 ( $\beta_1$ )	230.6 (233.3)	254.8 (245.9)	248.1 (245.9)	242.3 (232.4)	221.0 (221.6)	234.8 (230.8)	266.2 (231.0)	233.6 (232.9)	233.5 (233.2)	238.6 (232.7)	239.7 (233.7)
VAT share x 2003-2005 ( $\beta_2$ )	921.8** (409.2)	887.4** (413.4)	868.5** (413.3)	948.4** (407.5)	910.9** (398.1)	926.5** (406.0)	965.8** (434.8)	942.3** (409.2)	933.3** (405.7)	966.7** (406.2)	943.6** (416.0)
VAT share x 2006-2007 ( $\beta_3$ )	435.5 (427.0)	338.5 (432.1)	333.2 (430.4)	424.4 (428.4)	423.3 (416.6)	435.4 (425.9)	491.2 (475.7)	471.2 (434.1)	461.2 (432.3)	520.7 (446.4)	395.9 (434.7)
Observations	61,308	61,284	61,284	61,284	61,308	61,308	61,301	61,308	61,308	61,308	60,667
R-squared	0.781	0.781	0.781	0.781	0.781	0.781	0.786	0.781	0.781	0.781	0.782
H0: $\beta_1 = \beta_2$ (p-value)	0.00400	0.00600	0.00600	0.00300	0.00400	0.00400	0.00600	0.00300	0.00300	0.00200	0.00400
H0: $\beta_2 = \beta_3$ (p-value)	0.137	0.0930	0.0960	0.115	0.138	0.130	0.161	0.154	0.159	0.192	0.105

Notes: The sample is a balanced panel of firms, 1998-2007. All regressions include average sales (1998-2000) × year FE, year and firm FEs. Additional controls are stated in the column headings. Standard errors are clustered at the sector level. \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table 6: The Effect of Computerization on VAT – Robustness to Additional Controls

	(1)	(2)	(3)	(4)	(5)
Controls:	Baseline	TFPR (HK) × 1998-2000 × Year FE	TFPR (DLW) × 1998-2000 × Year FE	Employment × 1998-2000 × Year FE	Intermediate Input 1998-2000 × Year FE
A. Dependent Variable: VAT/Sales					
VAT share x 2001-2002 ( $\beta_1$ )	0.00461* (0.00267)	0.00489* (0.00262)	0.00464* (0.00267)	0.00502* (0.00256)	0.00486* (0.00260)
VAT share x 2003-2005 ( $\beta_2$ )	0.0138*** (0.00373)	0.0136*** (0.00362)	0.0137*** (0.00347)	0.0141*** (0.00384)	0.0143*** (0.00355)
VAT share x 2006-2007 ( $\beta_3$ )	0.0114** (0.00490)	0.0119** (0.00482)	0.0112** (0.00457)	0.0116** (0.00493)	0.0118** (0.00482)
Observations	61,308	61,308	61,308	61,308	61,308
R-squared	0.658	0.658	0.658	0.658	0.658
H0: $\beta_1=\beta_2$ (p-value)	0.00500	0.00300	0.00300	0.00400	0.00300
H0: $\beta_2=\beta_3$ (p-value)	0.513	0.592	0.499	0.480	0.488
B. Dependent Variable: VAT					
VAT share x 2001-2002 ( $\beta_1$ )	230.6 (233.3)	158.1 (222.9)	228.6 (232.6)	220.2 (239.9)	235.7 (237.5)
VAT share x 2003-2005 ( $\beta_2$ )	921.8** (409.2)	893.2** (393.9)	915.8** (407.9)	884.0** (419.1)	945.1** (410.7)
VAT share x 2006-2007 ( $\beta_3$ )	435.5 (427.0)	563.1 (409.7)	428.4 (426.8)	434.8 (424.6)	444.5 (426.1)
Observations	61,308	61,308	61,308	61,308	61,308
R-squared	0.781	0.781	0.781	0.781	0.781
H0: $\beta_1=\beta_2$ (p-value)	0.00400	0.00200	0.00400	0.00500	0.00300
H0: $\beta_2=\beta_3$ (p-value)	0.137	0.232	0.139	0.133	0.122

Notes: The sample is a balanced panel of firms, 1998-2007. All regressions include average sales (1998-2000) × year FE, year and firm FEs. Additional controls are stated in the column headings. Standard errors are clustered at the sector level. \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table 7: The Heterogeneous Effects of Computerization by Ease of Evasion

	(1)	(2)	(3)	(4)
Sample Restrictions:	Production chain length < median	Production chain length > median	Number of inputs < median	Number of inputs > median
A. Dependent Variable: VAT / Sales				
<b>Dep Var Mean</b>	<b>0.0540</b>	<b>0.0448</b>	<b>0.0481</b>	<b>0.0513</b>
VAT share x 2001-2002 ( $\beta_1$ )	0.00166 (0.00367)	0.0126*** (0.00405)	0.000232 (0.00334)	0.00880** (0.00400)
VAT share x 2003-2005 ( $\beta_2$ )	0.00891** (0.00421)	0.0253*** (0.00686)	0.0115** (0.00551)	0.0164*** (0.00538)
VAT share x 2006-2007 ( $\beta_3$ )	0.00210 (0.00531)	0.0322*** (0.00953)	0.00918 (0.00740)	0.0167** (0.00676)
Observations	31,190	30,118	38,840	30,872
R-squared	0.690	0.608	0.645	0.657
H0: $\beta_1=\beta_2$ (p-value)	0.0520	0.00700	0.00700	0.00700
H0: $\beta_2=\beta_3$ (p-value)	0.119	0.134	0.677	0.911
H0: col 1 = col 2 (SUR p-value)	0.135		0.382	
B. Dependent Variable: VAT				
<b>Dep Var Mean</b>	<b>2301</b>	<b>1811</b>	<b>1981</b>	<b>2185</b>
VAT share x 2001-2002 ( $\beta_1$ )	215.9 (307.3)	258.9 (391.2)	-164.0 (254.2)	480.3 (346.1)
VAT share x 2003-2005 ( $\beta_2$ )	1,201** (561.6)	382.7 (539.5)	507.3 (536.3)	1,182** (515.7)
VAT share x 2006-2007 ( $\beta_3$ )	980.4** (453.8)	-345.3 (853.3)	161.2 (591.7)	270.5 (572.3)
Observations	31,190	30,118	38,840	30,872
R-squared	0.808	0.746	0.763	0.789
H0: $\beta_1=\beta_2$ (p-value)	0.00400	0.689	0.689	0.689
H0: $\beta_2=\beta_3$ (p-value)	0.447	0.264	0.464	0.0620
H0: col 1 = col 2 (SUR p-value)	0.214		0.631	

Notes: The sample is a balanced panel of firms, 1998-2007. Additional sample restrictions are stated in the column headings. All regressions include average sales (1998-2000)  $\times$  year FE, year and firm FEs. Standard errors are clustered at the sector level. \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table 8: Spillover Effects and Heterogeneous Effects for Exporters and Importers

Sample Restrictions:	Non-Exporters		Exporters		Imported input		Imported input		Distance from			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)		
	pre-2001 export share < median		pre-2001 export share > median		share > median		share < median		final consumer < median		final consumer > median	
	A. Dependent Variable											
	Corporate Tax (1000 RMB)											
	VAT/Sales											
<b>Dep Var Mean</b>	<b>3666</b>	<b>0.0509</b>	<b>0.0397</b>	<b>0.0536</b>	<b>0.0455</b>	<b>0.0512</b>	<b>0.0479</b>					
VAT share x 2001-2002 ( $\beta_1$ )	13.27 (162.5)	0.00382 (0.00315)	-0.00411 (0.00848)	0.00615* (0.00359)	0.00509 (0.00443)	0.00856** (0.00379)	-0.00101 (0.00381)					
VAT share x 2003-2005 ( $\beta_2$ )	124.5 (297.9)	0.0137*** (0.00407)	0.0109 (0.00903)	0.0181*** (0.00502)	0.00936 (0.00590)	0.0177*** (0.00411)	0.00580 (0.00650)					
VAT share x 2006-2007 ( $\beta_3$ )	214.0 (372.0)	0.00974* (0.00531)	0.0103 (0.0105)	0.0148* (0.00759)	0.00938 (0.00732)	0.0101 (0.00626)	0.0112 (0.00779)					
Observations	61,308	43,708	5,346	30,666	30,666	31,092	31,236					
R-squared	0.508	0.666	0.587	0.674	0.625	0.682	0.642					
H0: $\beta_1 = \beta_2$ (p-value)	0.538	0.0160	0.0260	0.00700	0.284	0.284	0.284					
H0: $\beta_2 = \beta_3$ (p-value)	0.734	0.363	0.915	0.532	0.995	0.156	0.123					
H0: col 1 = col 2 (SUR p-value)		0.488		0.160		0.00874						
<b>Dep Var Mean</b>	<b>1932</b>	<b>1440</b>	<b>1928</b>	<b>2192</b>	<b>1928</b>	<b>2165</b>	<b>1947</b>					
VAT share x 2001-2002 ( $\beta_1$ )	182.4 (213.0)	-31.70 (392.7)	83.56 (375.2)	538.1* (273.0)	500.4 (334.0)	39.01 (278.4)						
VAT share x 2003-2005 ( $\beta_2$ )	589.1 (400.4)	1,199* (636.7)	779.6 (658.5)	1,324*** (392.9)	740.4 (466.1)							
VAT share x 2006-2007 ( $\beta_3$ )	-26.70 (390.5)	1.030 (863.8)	316.3 (530.8)	868.7 (863.2)	431.5 (746.7)							
Observations	43,708	5,346	30,666	30,666	31,092	31,236						
R-squared	0.762	0.768	0.772	0.799	0.771	0.771						
H0: $\beta_1 = \beta_2$ (p-value)	0.140	0.0350	0.0550	0.00400	0.00400	0.00400						
H0: $\beta_2 = \beta_3$ (p-value)	0.107	0.706	0.174	0.477	0.630	0.630						
H0: col 1 = col 2 (SUR p-value)		0.609	0.487			0.840						

Notes: The sample is a balanced panel of firms, 1998-2007. Additional sample restrictions are stated in the column headings. All regressions include average sales (1998-2000)  $\times$  year FE, year and firm FEs. Standard errors are clustered at the sector level. \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table 9: The Effect of Computerization on Firm Outcomes – All Firms

	Dependent Variables					
	(1)	(2)	(3)	(4)	(5)	(6)
	VAT/Sales (Fraction)	VAT (1000 RMB)	Sales (1000 RMB)	TFPR (HK)	TFPR (DLW)	Deductible Inputs as a Share of Total Input
<b>Dep Var Mean</b>	<b>0.0482</b>	<b>1926</b>	<b>45367</b>	<b>1.095</b>	<b>0.103</b>	<b>0.906</b>
VAT share x 2001-2002 ( $\beta_1$ )	0.00269 (0.00249)	92.77 (229.9)	-6,401* (3,418)	0.0110** (0.00435)	-0.00212 (0.0340)	-0.0228 (0.0472)
<i>Beta Coef.</i>	0.0304	0.0140	-0.0438	0.0364	-0.00105	-0.0157
VAT share x 2003-2005 ( $\beta_2$ )	0.0130*** (0.00383)	826.3** (384.0)	-14,355** (6,453)	0.0142** (0.00661)	0.127* (0.0755)	-0.121* (0.0635)
<i>Beta Coef.</i>	0.169	0.143	-0.113	0.0538	0.0724	-0.0957
VAT share x 2006-2007 ( $\beta_3$ )	0.0112** (0.00485)	348.6 (440.8)	-27,833** (13,811)	0.0164** (0.00814)	0.346*** (0.117)	-0.222** (0.0925)
<i>Beta Coef.</i>	0.126	0.0524	-0.191	0.0539	0.172	-0.152
Observations	2,952	2,952	2,952	2,952	2,952	2,952
R-squared	0.884	0.854	0.809	0.986	0.965	0.768
H0: $\beta_1 = \beta_2$ (p-value)	0.00300	0.00100	0.0670	0.341	0.0260	0.105
H0: $\beta_2 = \beta_3$ (p-value)	0.603	0.120	0.166	0.397	<0.001	0.153

Notes: The sample is a balanced panel of sectors, 1998-2007. The regression is weighted by the number of firms in each sector-year cell. All regressions include average sales (1998-2000)  $\times$  year FE, year and firm FEs. Standard errors are clustered at the sector level. \*\*\* p<0.01, \*\* p<0.05, \* p<0.1



# ONLINE APPENDIX – Not for Publication

## 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* were 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 of whether they originate from a domestic or international seller, can be deducted from the VAT duty. Full deductions are allowed for manufactured inputs, repair inputs, retail inputs, and wholesale inputs. Partial deductions are allowed for some “necessity goods” (including agricultural products, oils, gas, book, fertilizers, salt, and etc.) at a rate of 13%, 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. 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 broader change was not made until 2009.

## B Data

We follow the standard procedure for cleaning the Manufacturing Censuses, as first used in Cai and Liu (2009). We drop observations for which any reported sub-component of assets is greater than total assets, as well as observations 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, 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.

Second, we remove the influence of extreme outliers, which are likely to represent coding errors in these self-reported data. We drop the top and bottom 1% of observations for the variables VAT and sales.

## C 2SLS

In this section, we use data from 1998-2000 of the *Annual Survey of Industrial Production* to measure VAT share, and use the measures calculated from the U.S. input-output tables as instruments. Specifically, there are three interaction instruments for three endogenous interaction variables. The first stage is shown in Appendix Table A.4, and the instrumented second-stage results are shown in Appendix Table A.5. They are broadly similar to the reduced form estimates that we have focused on so far, although the 2SLS estimates are generally larger in magnitude and more precise.

The 2SLS estimates have advantages and disadvantages. One advantage is that the magnitudes of the coefficients are easier to interpret than the reduced form estimates, and that the instrumented estimates remove bias from measurement error in the OLS estimates (Angrist and Pischke, 2008). The disadvantage is that the first stage is weak

(the F-statistic in Appendix Table A.4 is 7.22), which could bias the 2SLS estimates. We know of no way to correct for weak instruments with multiple endogenous variables.

## D A Model of VAT Enforcement

### D.1 Benchmark

We present here a simple model that generates all of the main temporal effects. Throughout, we consider one sector, populated by identical, perfectly competitive firms. 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  $r$  and  $w$ . The pre-tax price of output of the sector is  $q$ , and the tax-inclusive price of the output of the sector is  $p$ , with  $q = (1 + \tau)p$ . Demand for the output of the sector is given by  $y = q^{-\sigma}$  where  $\sigma > 0$  is the elasticity of demand.

We assume that there are three periods. In period 0, there is no tax on the sector,  $\tau_0 = 0$ . The tax is introduced in period 1, and  $\tau_2 = \tau_1$ . Period 1 represents "short run", when only one factor,  $l$ , can be adjusted freely. Period 2 represents "long run", when both factors can be adjusted. We assume that neither  $k$  nor  $l$  can be deducted from VAT, so that VAT is a pure sales tax. In addition, we assume that sector is "small", so that  $r$  and  $w$  are not affected by the introduction of taxes on the given sector. Sector prices  $q$  and  $p$  will naturally be affected by taxation.

There are a few important points regarding these assumptions. (i) It is straightforward to write a full GE model with multiple sectors, so that tax on sector  $i$  are economy-wide and affect  $r, w$ . It requires much more algebra, but the results are the same as in this model, just less transparent. (ii) It is similarly straightforward to add intermediate inputs that can be deducted from the VAT, so that technology is  $k^\alpha l^{1-\alpha-\beta} x^\beta$ , where  $x$  is the deductible input. All the results from the simpler model below will hold, but again there will be more algebra, and, moreover, one must take a stand on whether  $x$  is adjusted in the long or short run. After we present the baseline model, we will show

that all of the main insights follow through with extensions, and demonstrate that the results follow through under monopolistic competition.

Also note that while we will refer to  $k$  as capital in the model, it does not correspond to the "assets" in the data (which do not change much), but rather to inputs that firms can change over time (e.g. intermediate inputs). Later, we will extend this model to three factors, one of which can be adjusted in period 1 and 2, another in period 2 only, and third that can never to be changed. All the key results will hold.

### D.1.1 Period 0

Consider the cost function in period 0:

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

The first order conditions will be:

$$[k] : r = \eta \alpha k^{\alpha-1} l^{1-\alpha},$$

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

These conditions yield the optimal capital-labor ratio:

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

We can also obtain marginal costs:

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

In equilibrium, we have

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

where  $\omega$  does not depend on anything under firm's control.

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

$$p_0 = C'_0(y_0).$$

Consumer demand gives  $y_0 = q_0^{-\sigma} = p_0^{-\sigma}$ . We substitute this object into the expression above to obtain

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

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

$$y_0 = \omega^{-\sigma}.$$

Since  $y_0 = k_0^\alpha l_0^{1-\alpha} = \left(\frac{k_0}{l_0}\right)^\alpha l_0 = \left(\frac{\alpha}{1-\alpha} \frac{w}{r}\right)^\alpha l_0$ , we also obtain an expression for labor:

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

We can find  $k_0$  and  $p_0$  from the above equations.

### D.1.2 Short-run equilibrium

Suppose a VAT is introduced. Since under our assumptions, firms cannot deduct anything, so the VAT is equivalent to a sales tax. Suppose that in the short run, the firm cannot adjust  $k$ , so that  $k_1 = k_0$ .

Then we have

$$\begin{aligned} C_1(y) &= \min_l rk_0 + wl, \\ \text{s.t. } y &= k_0^\alpha l^{1-\alpha}, \end{aligned}$$

which gives

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

Therefore, marginal costs are

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

Competition gives

$$p_1 = C'_1(y).$$

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

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

We are interested in deriving the effect of taxation on inputs, prices, sales, tax revenues, and TFPR. The sales that we observe in the data is  $qy$ ; tax revenues are  $\tau py$ ; and TFPR is  $\frac{qy}{k^\alpha l^{1-\alpha}} = q$ .

**Lemma 1.** *In the short run,  $y_1 < y_0$ ,  $p_1 < p_0$ ,  $l_1 < l_0$ ,  $q_1 > q_0$ ,  $TFPR_1 > TFPR_0$ , and  $taxes_1 > taxes_0 = 0$ . 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  $\tau p_1 y_1 = \tau (1 + \tau)^{-\sigma} p_1^{1-\sigma} > 0$ , so tax revenues increase.

Sales are  $q_1 y_1 = q_1^{1-\sigma}$ , they decline if  $\sigma > 1$ .

Labor goes down  $l_1 < l_0$ .

Capital does not change  $k_1 = k_0$ .

TFPR is equal to  $q$  in this model, so TFPR goes up. ■

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

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

### D.1.3 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

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

This gives us

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

Therefore,

$$p_2 = p_0 > p_1.$$

Since

$$\begin{aligned} q_2 &= (1 + \tau) p_2, \\ q_1 &= (1 + \tau) p_1 > p_0, \\ q_0 &= p_0, \end{aligned}$$

this implies that

$$q_2 > q_1 > q_0,$$

$$TFPR_2 > TFPR_1 > TFPR_0.$$

**Remark 2.** *The intuition behind this result is as follows: since not all factors can be adjusted immediately, the marginal costs fall: there is too much capital relative to labor in the short run, so the marginal cost of labor (the only factor that can be adjusted in period 1) is low. Therefore, the tax-inclusive price falls, although less than one for one*

with the tax rate, so that pre-tax price  $q$  increases. Over time, as firms adjust other factors, their marginal costs rise. This implies that  $p$  rises, and therefore,  $q$  rises even further. Since TFPR is just  $q$ , the same is true about TFPR.

Demand is

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

Therefore,

$$y_2 < y_1 < y_0.$$

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

$$q_2^{1-\sigma} < q_1^{1-\sigma} < q_0^{1-\sigma},$$

$$\text{sales}_2 < \text{sales}_1 < \text{sales}_0.$$

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  $\sigma > 1$ , that

$$0 = \text{taxes}_0 < \text{taxes}_2 < \text{taxes}_1.$$

**Remark 3.** *The intuition behind 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,  $y$  falls faster than  $q$  raises, 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 are increased from 0 to  $\tau$ ) and then falls between periods 1 and 2 (since sales fall between periods 1 and 2).*

Finally, we examine what happens to labor. We have

$$l_0 > l_1 \text{ and } l_0 > l_2.$$

The remaining comparison of interest is between  $l_1$  and  $l_2$ .



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

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

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

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  $\sigma > 1$ , we have  $k_2^{\alpha/\sigma-\alpha} > k_0^{\alpha/\sigma-\alpha}$  and therefore  $l_2^{(\alpha-1)/\sigma-\alpha} > l_1^{(\alpha-1)/\sigma-\alpha}$ . Since  $\alpha < 1$ , this implies that  $l_2 < l_1$ . Therefore we have

$$l_0 > l_1 > l_2.$$

**Remark 4.** *The intuition for this result comes from the following observation. We know from the Le Chatelier Principle (Samuelson, 1949) that the short-run elasticity of labor should be 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 price increases which, all things being equal, call for more inputs. If demand is elastic, prices react little to changes in output, and the first effect dominates.*

#### D.1.4 Empirical Implications

This model has several empirically testable implications. First, tax revenues will increase from period zero to period one, and then decline in period 2 to a level between the levels of period 0 and one:  $0 = \text{taxes}_0 < \text{taxes}_2 < \text{taxes}_1$ . Second, the pre-tax price, or *TFPR*, increases every period,  $q_2 > q_1 > q_0$ . Third, sales decline each period,  $q_2 y_2 < q_1 y_1 < q_0 y_0$ . Fourth, labor inputs decline each period,  $l_0 > l_1 > l_2$  and  $k_0 \geq k_1 > k_2$ . The empirical analysis will examine whether these implications are borne out in the data.

In the following sections, we show that these results hold when we introduce a third deductible good, allow for monopolistic competition, and endogenize input prices.

## D.2 Intermediate goods

Suppose we have technology  $k^\alpha l^{1-\alpha-\beta} x^\beta$  where  $x$  can be deducted from the VAT. Let the price of  $x$  be  $z$ . The profits of the firm without VAT are

$$qy - rk - wl - zx,$$

and profits with VAT tax  $\tau$  are

$$\begin{aligned} & (1 - \tau) [qy - zx] - rk - wl, \\ = & (1 - \tau) qy - rk - wl - (1 - \tau) zx. \end{aligned}$$

Note that we have changed the pricing convention. Before, we used  $(1 + \tau)p = q$ , where  $p$  is tax-inclusive price. Now we use  $p = (1 - \tau)q$ , where  $q$  is pre-tax price. The connection to the data is more clear with this notation, since we directly observe  $q$ .

### D.2.1 Period 0

Consider the cost function in period 0:

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

It obviously gives

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

This gives optimal capital-labor ratio

$$\begin{aligned}\frac{k_0}{l_0} &= \frac{\alpha}{1 - \alpha - \beta} \frac{w}{r}, \\ \frac{x_0}{l_0} &= \frac{\beta}{1 - \alpha - \beta} \frac{w}{z}.\end{aligned}$$

We also have marginal costs

$$\begin{aligned}C'_0(y_0) &= \omega_0 = \frac{w}{(1 - \alpha - \beta) k_0^\alpha l_0^{-\alpha - \beta} x_0^\beta} \\ &= \frac{w}{(1 - \alpha - \beta) \left(\frac{k_0}{l_0}\right)^\alpha \left(\frac{x_0}{l_0}\right)^\beta} \\ &= \frac{w}{(1 - \alpha - \beta) \left(\frac{\alpha}{1 - \alpha - \beta} \frac{w}{r}\right)^\alpha \left(\frac{\beta}{1 - \alpha - \beta} \frac{w}{z}\right)^\beta}.\end{aligned}$$

Competitive firms set the tax-inclusive price to equal its marginal cost. Since there are no taxes in period 0, we have

$$q_0 = \omega_0.$$

Then, the first order conditions immediately imply

$$rk_0 = \alpha q_0 y_0,$$

$$zx_0 = \beta q_0 y_0,$$

$$wl_0 = (1 - \alpha - \beta) q_0 y_0.$$

Finally, the quantities are determined from the downward sloping demand curve

$$y_0 = q_0^{-\sigma}.$$

This equation gives

$$\begin{aligned} \left(\frac{k_0}{l_0}\right)^\alpha \left(\frac{x_0}{l_0}\right)^\beta l_0 &= \left[ \frac{w}{(1-\alpha-\beta) \left(\frac{k_0}{l_0}\right)^\alpha \left(\frac{x_0}{l_0}\right)^\beta} \right]^{-\sigma}, \\ l_0 &= \left(\frac{w}{1-\alpha-\beta}\right)^{-\sigma} \left(\frac{k_0}{l_0}\right)^{\alpha(\sigma-1)} \left(\frac{x_0}{l_0}\right)^{\beta(\sigma-1)}, \end{aligned}$$

or

$$l_0 = \left(\frac{w}{1-\alpha-\beta}\right)^{-\sigma} \left(\frac{\alpha}{1-\alpha-\beta} \frac{w}{r}\right)^{\alpha(\sigma-1)} \left(\frac{\beta}{1-\alpha-\beta} \frac{w}{z}\right)^{\beta(\sigma-1)}.$$

It then follows that

$$\begin{aligned} k_0 &= \frac{\alpha}{1-\alpha-\beta} \frac{w}{r} l_0, \\ x_0 &= \frac{\beta}{1-\alpha-\beta} \frac{w}{z} l_0. \end{aligned}$$

### D.2.2 Period 2

We analyze period 2 before period 1, since period 2 is almost identical to period 0. With VAT, the firm's profits are

$$\begin{aligned} &(1-\tau)[qy - zx] - rk - wl, \\ &= (1-\tau)qy - rk - wl - (1-\tau)zx. \end{aligned}$$

So the cost function is

$$\begin{aligned} C_2(y) &= \min_{k,l,x} rk + wl + (1-\tau)zx, \\ s.t. \ y &= k^\alpha l^{1-\alpha-\beta} x^\beta. \end{aligned}$$

and now the tax-inclusive price is equal to the marginal cost:

$$\begin{aligned}(1 - \tau) q_2 &= C'_2(y_2) = \omega_2, \\ q_2 &= \frac{C'_2(y_2)}{1 - \tau} = \frac{\omega_2}{1 - \tau}.\end{aligned}$$

So we have

$$\begin{aligned}\frac{k_2}{l_2} &= \frac{\alpha}{1 - \alpha - \beta} \frac{w}{r}, \\ \frac{x_2}{l_2} &= \frac{\beta}{1 - \alpha - \beta} \frac{w}{(1 - \tau) z}.\end{aligned}$$

$$\begin{aligned}\omega_2 &= \frac{w}{(1 - \alpha - \beta) \left(\frac{k_2}{l_2}\right)^\alpha \left(\frac{x_2}{l_2}\right)^\beta} \\ &= \frac{w}{(1 - \alpha - \beta) \left(\frac{\alpha}{1 - \alpha - \beta} \frac{w}{r}\right)^\alpha \left(\frac{\beta}{1 - \alpha - \beta} \frac{w}{(1 - \tau) z}\right)^\beta} \\ &= (1 - \tau)^\beta \omega_0.\end{aligned}$$

Finally,

$$y_2 = q_2^{-\sigma} = \left(\frac{\omega_2}{1 - \tau}\right)^{-\sigma}$$

gives

$$\begin{aligned}\left(\frac{k_2}{l_2}\right)^\alpha \left(\frac{x_2}{l_2}\right)^\beta l_2 &= (1 - \tau)^\sigma \left[ \frac{w}{(1 - \alpha - \beta) \left(\frac{k_2}{l_2}\right)^\alpha \left(\frac{x_2}{l_2}\right)^\beta} \right]^{-\sigma}, \\ l_2 &= (1 - \tau) \left(\frac{w}{1 - \alpha - \beta}\right)^{-\sigma} \left(\frac{k_2}{l_2}\right)^{\alpha(\sigma-1)} \left(\frac{x_2}{l_2}\right)^{\beta(\sigma-1)}\end{aligned}$$

or

$$\begin{aligned} l_2 &= (1 - \tau)^{\sigma(1-\beta)+\beta} \left( \frac{w}{1 - \alpha - \beta} \right)^{-\sigma} \left( \frac{\alpha}{1 - \alpha - \beta} \frac{w}{r} \right)^{\alpha(\sigma-1)} \left( \frac{\beta}{1 - \alpha - \beta} \frac{w}{z} \right)^{\beta(\sigma-1)} \\ &= (1 - \tau)^{\sigma(1-\beta)+\beta} l_0. \end{aligned}$$

Similarly, we have

$$\begin{aligned} k_2 &= \frac{\alpha}{1 - \alpha - \beta} \frac{w}{r} l_2 = (1 - \tau)^{\sigma(1-\beta)+\beta} k_0, \\ x_2 &= \frac{\beta}{1 - \alpha - \beta} \frac{w}{(1 - \tau)z} l_2 = (1 - \tau)^{(\sigma-1)(1-\beta)+\beta} x_0. \end{aligned}$$

This result generates clear predictions about the long run.

**Lemma 5.** *Suppose  $\sigma > 1$ . Then,*

1.  $TFPR_2 > TFPR_0$ ,
2.  $sales_2 < sales_0$ ,
3.  $k_2 < k_0, x_2 < x_0, l_2 < l_0, \omega_2 < \omega_0$ ,
4.  $0 = taxes_0 < taxes_2$ .

**Proof.** 1. In our model  $TFPR \equiv \frac{qy}{k^\alpha l^{1-\alpha-\beta} x^\beta} = q$ . We have

$$q_2 = \frac{\omega_2}{1 - \tau} = \frac{(1 - \tau)^\beta \omega_0}{1 - \tau} = (1 - \tau)^{(\beta-1)} q_0 > q_0.$$

2. In our model,  $sales = qy = q^{1-\sigma}$ . We have, when  $\sigma > 1$ ,

$$q_2^{1-\sigma} = \left[ (1 - \tau)^{(\beta-1)} q_0 \right]^{1-\sigma} = (1 - \tau)^{(1-\beta)(\sigma-1)} q_0^{1-\sigma} < q_0^{1-\sigma}.$$

3. We have

$$\frac{k_2}{k_0} = \frac{l_2}{l_0} = (1 - \tau)^{\sigma(1-\beta)+\beta} < 1$$

and

$$\frac{x_2}{x_0} = (1 - \tau)^{(\sigma-1)(1-\beta)+\beta} < 1.$$

Note that the latter follows from  $\sigma > 1$ . And we showed the result about  $\omega$  earlier.

4. Note that in our model, collected taxes are  $taxes = \tau [qy - zx]$ . So

$$taxes_2 = \tau [q_2 y_2 - z x_2] = \tau [q_2 y_2 - \beta q_2 y_2] = \tau (1 - \beta) q_2 y_2 > 0 = taxes_0.$$

■

### D.2.3 Period 1

Now consider period 1 problem. We assume that intermediate goods can be adjusted in period 1, which simplifies the analysis.<sup>38</sup>

We have

$$\begin{aligned} C_1(y) &= \min_{l,x} r k_0 + w l + (1 - \tau) z x, \\ s.t. \ y &= k_0^\alpha l^{1-\alpha-\beta} x^\beta. \end{aligned}$$

Which gives

$$[l] : w = \omega (1 - \alpha - \beta) k_0^\alpha l^{-\alpha-\beta} x^\beta,$$

$$[x] : (1 - \tau) z = \omega \beta k_0^\alpha l^{1-\alpha-\beta} x^{\beta-1}.$$

We have

$$\frac{x_1}{l_1} = \frac{\beta}{1 - \alpha - \beta} \frac{w}{(1 - \tau) z}.$$

As before, we have

$$q_1 = \frac{C'_1(y_1)}{1 - \tau} = \frac{\omega_1}{1 - \tau}.$$

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<sup>38</sup>If they cannot, there is a lot more algebra involved although the result about taxes will hold under additional assumption about the parameters.

Hence, we have

$$\begin{aligned} wl_1 &= (1 - \alpha - \beta)(1 - \tau)q_1y_1, \\ (1 - \tau)zx_1 &= \beta(1 - \tau)q_1y_1. \end{aligned}$$

The marginal costs are

$$\begin{aligned} \omega_1 &= C'_1(y_1) = \frac{1}{1 - \alpha - \beta} \frac{w}{k_0^\alpha l_1^{-\alpha - \beta} x_1^\beta} \\ &= \frac{1}{1 - \alpha - \beta} \frac{w}{k_0^\alpha l_1^{-\alpha} \left(\frac{x_1}{l_1}\right)^\beta}. \end{aligned}$$

We find  $l_1$  as before, using the demand curve:

$$\begin{aligned} y_1 &= \left[ \frac{\omega_1}{1 - \tau} \right]^{-\sigma}, \\ k_0^\alpha l_1^{1 - \alpha} \left(\frac{x_1}{l_1}\right)^\beta &= (1 - \tau)^\sigma \left[ \frac{1}{1 - \alpha - \beta} \frac{w}{k_0^\alpha l_1^{-\alpha} \left(\frac{x_1}{l_1}\right)^\beta} \right]^{-\sigma}. \end{aligned}$$

Therefore,

$$\begin{aligned} l_1^{1 - \alpha + \sigma\alpha} &= (1 - \tau)^\sigma \left( \frac{w}{1 - \alpha - \beta} \right)^{-\sigma} k_0^{\alpha(\sigma - 1)} \left(\frac{x_1}{l_1}\right)^{\beta(\sigma - 1)} \\ &= (1 - \tau)^\sigma \left( \frac{w}{1 - \alpha - \beta} \right)^{-\sigma} k_0^{\alpha(\sigma - 1)} \left( \frac{\beta}{1 - \alpha - \beta} \frac{w}{(1 - \tau)z} \right)^{\beta(\sigma - 1)} \\ &= (1 - \tau)^{\sigma + \beta(1 - \sigma)} \left( \frac{w}{1 - \alpha - \beta} \right)^{-\sigma} k_0^{\alpha(\sigma - 1)} \left( \frac{\beta}{1 - \alpha - \beta} \frac{w}{z} \right)^{\beta(\sigma - 1)}. \end{aligned}$$

This equation gives the following useful intermediate result.

**Lemma 6.** *Suppose  $\sigma > 1$ . Then*

1.  $l_0 > l_1 > l_2$ ,
2.  $y_0 > y_1 > y_2$ ,



3.  $\omega_1 < \omega_2 < \omega_0$  and  $\omega_0 < \frac{\omega_1}{1-\tau} < \frac{\omega_2}{1-\tau}$ .

**Proof.** 1. The previous equation should also hold in period 2 when capital stock is set at its optimal value  $k_2$ , i.e.

$$l_2^{1-\alpha+\sigma\alpha} = (1-\tau)^{\sigma+\beta(1-\sigma)} \left( \frac{w}{1-\alpha-\beta} \right)^{-\sigma} k_2^{\alpha(\sigma-1)} \left( \frac{\beta}{1-\alpha-\beta} \frac{w}{z} \right)^{\beta(\sigma-1)}$$

which implies

$$\begin{aligned} \left( \frac{l_2}{l_1} \right)^{1+(\sigma-1)\alpha} &= \left( \frac{k_2}{k_0} \right)^{\alpha(\sigma-1)} \\ \frac{l_2}{l_1} &= \left( \frac{k_2}{k_0} \right)^{\frac{\alpha(\sigma-1)}{1+(\sigma-1)\alpha}}. \end{aligned}$$

Since  $k_2 < k_0$  this implies  $l_2 < l_1$ .

Similarly, the analogous equation should hold in period 0 (when  $\tau = 0$ ) so that

$$\begin{aligned} \left( \frac{l_1}{l_0} \right)^{1+(\sigma-1)\alpha} &= (1-\tau)^{\sigma+\beta(1-\sigma)} = (1-\tau)^{\sigma(1-\beta)+\beta} \\ \frac{l_1}{l_0} &= (1-\tau)^{\frac{\sigma(1-\beta)+\beta}{1+(\sigma-1)\alpha}} < 1. \end{aligned}$$

Therefore  $l_1 < l_0$ .

2. For output, we have

$$\begin{aligned} \frac{y_1}{y_0} &= \left( \frac{l_1}{l_0} \right)^{1-\alpha} \left( \frac{x_1/l_1}{x_0/l_0} \right)^{\beta} \\ &= (1-\tau)^{\frac{\sigma(1-\beta)+\beta}{1+(\sigma-1)\alpha} (1-\alpha) - \beta} \\ &= (1-\tau)^{\sigma \frac{1-\alpha-\beta}{1+(\sigma-1)\alpha}} < 1. \end{aligned}$$

Therefore,  $y_1 < y_0$ .

Using the fact that  $\frac{x_1}{l_1} = \frac{x_2}{l_2}$ , we have

$$\frac{y_2}{y_1} = \frac{k_2^\alpha l_2^{1-\alpha}}{k_0^\alpha l_1^{1-\alpha}}.$$

Since we showed already that  $\frac{k_2}{k_0} < 1$  and  $\frac{l_2}{l_1} < 1$ , this implies that  $y_2 < y_1$ .

3. For marginal costs, we have

$$\begin{aligned} \frac{\omega_1}{\omega_2} &= \frac{\frac{1}{1-\alpha-\beta} \frac{w}{k_0^\alpha l_1^{-\alpha} \left(\frac{x_1}{l_1}\right)^\beta}}{\frac{w}{(1-\alpha-\beta) \left(\frac{k_2}{l_2}\right)^\alpha \left(\frac{x_2}{l_2}\right)^\beta}} = \left(\frac{k_2}{k_0} / \frac{l_2}{l_1}\right)^\alpha = \left(\frac{k_2}{k_0}\right)^\alpha \left[1 - \frac{\alpha(\sigma-1)}{1+(\sigma-1)\alpha}\right] \\ &= \left(\frac{k_2}{k_0}\right)^{\frac{\alpha}{1+\alpha(\sigma-1)}} < 1. \end{aligned}$$

Thus,  $\omega_1 < \omega_2$ . We showed already that  $\omega_2 < \omega_0$ , which implies  $\omega_1 < \omega_0$ .

Moreover,

$$\frac{\omega_1}{\omega_0} = \frac{\frac{1}{1-\alpha-\beta} \frac{w}{k_0^\alpha l_1^{-\alpha-\beta} x_1^\beta}}{\frac{1}{1-\alpha-\beta} \frac{w}{k_0^\alpha l_0^{-\alpha-\beta} x_0^\beta}} = \frac{l_0^{-\alpha-\beta} x_0^\beta}{l_1^{-\alpha-\beta} x_1^\beta} = \left(\frac{l_1}{l_0}\right)^\alpha (1-\tau)^\beta$$

or

$$\frac{\omega_1 / (1-\tau)}{\omega_0} = (1-\tau)^{\frac{\sigma(1-\beta)+\beta}{1+(\sigma-1)\alpha} \alpha - (1-\beta)} = (1-\tau)^{-\frac{1-\beta-\beta\alpha}{1+\alpha(\sigma-1)}},$$

which implies that  $\frac{\omega_1}{1-\tau} > \omega_0$ .

With this lemma, we can extend all the results of the simple model. ■

**Lemma 7.** *Suppose  $\sigma > 1$ . Then*

1.  $TFPR_2 > TFPR_1 > TFPR_0$ ,
2.  $sales_0 > sales_1 > sales_2$ ,
3.  $0 = taxes_0 < taxes_2 < taxes_1$ .

**Proof.** 1. Since  $TFPR = q = \frac{\omega}{1-\tau}$ , from the previous lemma we have

$$q_0 < q_1 < q_2.$$

2. Sales are  $qy = q^{1-\sigma}$ , so with  $\sigma > 1$  we have, from the previous equation

$$sales_0 > sales_1 > sales_2.$$

3. Taxes revenues are  $\tau(qy - zx)$ . Since

$$\frac{zx_1}{q_1y_1} = \frac{zx_2}{q_2y_2} = \beta,$$

it becomes

$$taxes = (1 - \beta)\tau \times sales.$$

Since  $\tau_0 = 0$ , and  $sales_1 > sales_2$ , we get

$$0 = taxes_0 < taxes_2 < taxes_1.$$

■

### D.3 Monopolistic competition

Here, we will extend the analysis to allow firms to have market power and set prices. We will focus on the benchmark economy without intermediate goods for simplicity.

Firms will be monopolistically-competitive, as in the Dixit-Stiglitz model. There is a continuum of firms, each firm produces a differentiated good.<sup>39</sup> Consumers buy all these goods, so their budget constraint is

$$\int_0^1 q(i) c(i) di = wl + m,$$

where  $m$  is non-labor income.

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<sup>39</sup>We assume that the variety set is  $[0,1]$  because we assume that  $y = Y$  and  $q = Q$ .

Consumer preferences in each period are given by

$$\frac{Y^{1-1/\sigma}}{1-1/\sigma} - l,$$

where

$$Y = \left( \int_0^1 y(i)^{1-1/\varepsilon} di \right)^{\frac{\varepsilon}{\varepsilon-1}}.$$

Here,  $\varepsilon > 1$  is the elasticity of substitution between goods.

Standard results imply that demand for good  $i$  is determined by equation

$$y(i) = \left( \frac{q(i)}{Q} \right)^{-\varepsilon} Y,$$

where the aggregate price satisfies

$$Q = \left( \int_0^1 q(i)^{1-\varepsilon} di \right)^{\frac{1}{1-\varepsilon}}.$$

The aggregate demand can be found from

$$\max_{Y,l} \frac{Y^{1-1/\sigma}}{1-\sigma} - l,$$

$$YQ = wl + m$$

which gives

$$Y^{-1/\sigma} = Q/w.$$

Wage  $w$  can be taken to be a numeraire, and it is without loss of generality to set  $w = 1$ .

### D.3.1 Firm's problem

We will do things in "partial" equilibrium so that the interest rate  $r$  is fixed (equivalent to a GE model in which there are international capital markets with a rental rate of

capital given by  $r$ ). We will relax this assumption in another extension. In equilibrium, firm  $i$  will take for now  $Q$ ,  $Y$ , and  $r$  as given ( $w = 1$  always) and chooses  $q$  ( $i$ ) to maximize its profits, taking into account consumer's demand. So the firm in period 0 solves

$$\max_{q,y,l,k} qy - wl - rk,$$

s.t.

$$\begin{aligned} y &= \left(\frac{q}{Q}\right)^{-\varepsilon} Y, \\ y &= k^\alpha l^{1-\alpha}. \end{aligned}$$

We have

$$[l] : w = \omega(1 - \alpha)k^\alpha l^{-\alpha},$$

$$[k] : r = \omega\alpha k^{\alpha-1} l^{1-\alpha},$$

$$[y] : q = \lambda + \omega,$$

$$[q] : qy = \lambda\varepsilon \left(\frac{q}{Q}\right)^{-\varepsilon} Y.$$

The first two equations give us the usual conditions

$$\begin{aligned} \frac{k_0}{l_0} &= \frac{\alpha}{1 - \alpha} \frac{w}{r}, \\ \omega_0 &= \frac{w}{(1 - \alpha)k_0^\alpha l_0^{1-\alpha}} = \frac{w}{(1 - \alpha) \left(\frac{\alpha}{1 - \alpha} \frac{w}{r}\right)^\alpha}. \end{aligned}$$

Note that  $\omega_0$  has the same meaning as before: the marginal cost of producing an extra unit of good.

In equilibrium, since all firms are identical, we have

$$q = Q, y = Y.$$

Therefore, the last two optimality conditions become

$$q_0 = \lambda_0 + \omega_0,$$

$$q_0 = \lambda_0 \varepsilon.$$

This gives us

$$q_0 = q_0 \varepsilon - \omega_0 \varepsilon = \frac{\varepsilon}{\varepsilon - 1} \omega_0.$$

This equation is the standard condition that the optimal price is equal to a markup  $\frac{\varepsilon}{\varepsilon - 1} > 1$  times the marginal cost,  $\omega_0$ . As  $\varepsilon \rightarrow \infty$ , goods become more and more substitutable and we converge to the perfect competition case considered in the benchmark model.

The consumer's optimality condition  $Y^{-1/\sigma} = Q/w$  (together with normalization  $w = 1, y = Y, q = Q$ ) gives

$$y_0 = q_0^{-\sigma} = \left( \frac{\varepsilon}{\varepsilon - 1} \right)^{-\sigma} \omega_0^{-\sigma}.$$

So the analysis goes through the same way as before, except now everything is multiplied by a markup.

Given that, we will verify that markup is the same in periods 1 and 2. In that case, then all the analysis thus far goes through without any changes.

Period 2's problem is

$$\max_{q,y,l,k} (1 - \tau) qy - wl - rk,$$

s.t.

$$\begin{aligned}y &= \left(\frac{q}{Q}\right)^{-\varepsilon} Y, \\y &= k^\alpha l^{1-\alpha}.\end{aligned}$$

These give the optimality conditions.

We have

$$[l] : w = \omega(1 - \alpha) k^\alpha l^{-\alpha},$$

$$[k] : r = \omega \alpha k^{\alpha-1} l^{1-\alpha},$$

$$[y] : (1 - \tau) q = \lambda + \omega,$$

$$[q] : (1 - \tau) q y = \lambda \varepsilon \left(\frac{q}{Q}\right)^{-\varepsilon} Y.$$

So we have, as before, (the case  $\beta = 0$ ) from the first two equations:

$$\omega_2 = \omega_0.$$

The last two give us

$$q_2 = \frac{\varepsilon}{\varepsilon - 1} \frac{\omega_2}{1 - \tau}.$$

This expression is the same as we had before, modulo a markup.

Finally, period 1 problem is

$$\max_{q,y,l} (1 - \tau) q y - w l - r k_0.$$

with

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

$$[y] : (1 - \tau) q = \lambda + \omega,$$

$$[q] : (1 - \tau) qy = \lambda \varepsilon \left( \frac{q}{Q} \right)^{-\varepsilon} Y.$$

Note that again we have

$$q_1 = \frac{\varepsilon}{\varepsilon - 1} \frac{\omega_1}{1 - \tau}.$$

So the marginal costs are the same as in the baseline, and price is just a constant markup over those costs. Given that, all the steps in the proofs of the baseline economy should go through with minimal modifications.

## D.4 Multiple sectors, fixed capital

Now, we will assume that there are 2 sectors, and that the capital stock is in fixed net supply. Other than that, we return to our baseline model of perfect competition. So consumers will solve

$$\max \mu^{\frac{1}{\sigma}} \frac{y^{1-1/\sigma}}{1 - 1/\sigma} + (1 - \mu)^{\frac{1}{\sigma}} \frac{Y^{1-1/\varepsilon}}{1 - 1/\sigma} - l,$$

s.t.

$$qy + QY = wl + r\bar{k} + \Pi,$$

where  $\bar{k}$  is the total capital stock and capital letters denote "the other" sector, not affected by taxes. Here,  $\mu \in (0, 1)$ . The case  $\mu = 0$  corresponds to what we have done before: sector 1 is small, so nothing there affects taxes. Here,  $\Pi$  denotes profits of the firms. For simplicity, we assume that the production function is the same in the two sectors.

The capital stock is in fixed supply and is rented out by consumers to the firms at a rate  $r$ . If the sector-level demands for capital are  $k$  and  $K$ , then the market clearing



condition for the capital stock is

$$k + K = \bar{k}.$$

Once again, everything will be in units of labor, so we normalize  $w = 1$ .

The two sectors are identical in period 0, but the VAT tax will be applied to the first sector in period 1.

Given our normalizations, demand is again given by

$$y = \mu q^{-\sigma}, Y = (1 - \mu) Q^{-\sigma}.$$

#### D.4.1 Period 0

The analysis goes like before except now  $l_0$  is not given by

$$\begin{aligned} \left(\frac{k_0}{l_0}\right)^\alpha l_0 &= \mu \left[ \frac{w}{(1 - \alpha) \left(\frac{k_0}{l_0}\right)^\alpha} \right]^{-\sigma}, \\ l_0 &= \mu \left(\frac{w}{1 - \alpha}\right)^{-\sigma} \left(\frac{k_0}{l_0}\right)^{\alpha(\sigma-1)}, \end{aligned}$$

or

$$l_0 = \mu \left(\frac{w}{1 - \alpha}\right)^{-\sigma} \left(\frac{\alpha w}{1 - \alpha r_0}\right)^{\alpha(\sigma-1)},$$

and

$$\begin{aligned} k_0 &= \frac{\alpha w}{1 - \alpha r_0} l_0 \\ &= \mu \left(\frac{w}{1 - \alpha}\right)^{-\sigma} \left(\frac{\alpha w}{1 - \alpha r_0}\right)^{\alpha(\sigma-1)+1}. \end{aligned}$$

Demand in the other sector is

$$K_0 = (1 - \mu) \left(\frac{w}{1 - \alpha}\right)^{-\sigma} \left(\frac{\alpha w}{1 - \alpha r_0}\right)^{\alpha(\sigma-1)+1}.$$

This allows us to find the rental rate  $r_0$  from

$$\begin{aligned} \mu \left( \frac{w}{1-\alpha} \right)^{-\sigma} \left( \frac{\alpha w}{1-\alpha r_0} \right)^{\alpha(\sigma-1)+1} + (1-\mu) \left( \frac{w}{1-\alpha} \right)^{-\sigma} \left( \frac{\alpha w}{1-\alpha r_0} \right)^{\alpha(\sigma-1)+1} &= \bar{k}, \\ \left( \frac{w}{1-\alpha} \right)^{-\sigma} \left( \frac{\alpha w}{1-\alpha r_0} \right)^{\alpha(\sigma-1)+1} &= \bar{k}. \end{aligned}$$

This equation gives us  $r_0$ .

#### D.4.2 Period 1

In period 1, taxes are introduced but capital cannot be adjusted, so we simply assume that  $r_1 = r_0$ . Since capital stock cannot move, the rental rate is strictly-speaking indeterminate, but small refinements of this set up should give  $r_1 = r_0$ .

Since  $(r, w)$  are the same in period 1 as in period 0, the problems of the two sectors are unchanged. The whole characterization of the period 1 problem of the sector affected by the VAT tax goes without any changes. The labor demand in sector 1 is given by

$$l_1^{1-\alpha+\sigma\alpha} = \mu (1-\tau)^\sigma \left( \frac{w}{1-\alpha} \right)^{-\sigma} k_0^{\alpha(\sigma-1)}.$$

#### D.4.3 Period 2

We have, following the same steps as before

$$\begin{aligned} l_2 &= \mu (1-\tau)^\sigma \left( \frac{w}{1-\alpha} \right)^{-\sigma} \left( \frac{\alpha w}{1-\alpha r_2} \right)^{\alpha(\sigma-1)} \\ &= (1-\tau)^\sigma \left( \frac{r_2}{r_0} \right)^{\alpha(\sigma-1)} l_0. \end{aligned}$$

and

$$\begin{aligned}
k_2 &= \frac{\alpha}{1-\alpha} \frac{w}{r_2} l_2 \\
&= \mu (1-\tau)^\sigma \left( \frac{w}{1-\alpha} \right)^{-\sigma} \left( \frac{\alpha}{1-\alpha} \frac{w}{r_2} \right)^{\alpha(\sigma-1)+1} \\
&= \left[ (1-\tau)^\sigma \left( \frac{r_0}{r_2} \right)^{\alpha(\sigma-1)+1} \right] \mu \left( \frac{w}{1-\alpha} \right)^{-\sigma} \left( \frac{\alpha}{1-\alpha} \frac{w}{r_0} \right)^{\alpha(\sigma-1)+1} \\
&= \left[ (1-\tau)^\sigma \left( \frac{r_0}{r_2} \right)^{\alpha(\sigma-1)+1} \right] k_0.
\end{aligned}$$

Capital in the other sector is

$$K_2 = (1-\mu) \left( \frac{w}{1-\alpha} \right)^{-\sigma} \left( \frac{\alpha}{1-\alpha} \frac{w}{r_2} \right)^{\alpha(\sigma-1)+1}.$$

So the market clearing condition is

$$[\mu (1-\tau)^\sigma + (1-\mu)] \left( \frac{w}{1-\alpha} \right)^{-\sigma} \left( \frac{\alpha}{1-\alpha} \frac{w}{r_2} \right)^{\alpha(\sigma-1)+1} = \bar{k}.$$

Equivalently

$$\begin{aligned}
[\mu (1-\tau)^\sigma + (1-\mu)] \left( \frac{r_0}{r_2} \right)^{\alpha(\sigma-1)+1} \left( \frac{w}{1-\alpha} \right)^{-\sigma} \left( \frac{\alpha}{1-\alpha} \frac{w}{r_0} \right)^{\alpha(\sigma-1)+1} &= \bar{k}, \\
[\mu (1-\tau)^\sigma + (1-\mu)] \left( \frac{r_0}{r_2} \right)^{\alpha(\sigma-1)+1} &= 1,
\end{aligned}$$

or

$$(1-\tau)^\sigma \left( \frac{r_0}{r_2} \right)^{\alpha(\sigma-1)+1} = \frac{(1-\tau)^\sigma}{\mu (1-\tau)^\sigma + (1-\mu)}.$$

Therefore we have

**Lemma 8.**  $(1 - \tau)^\sigma \left(\frac{r_0}{r_2}\right)^{\alpha(\sigma-1)+1}$  is strictly increasing in  $\mu$  with

$$(1 - \tau)^\sigma \leq (1 - \tau)^\sigma \left(\frac{r_0}{r_2}\right)^{\alpha(\sigma-1)+1} \leq 1,$$

with left and right inequalities holding as equality for  $\mu = 0$  and  $\mu = 1$  respectively.

Therefore, we have

**Lemma 9.** Suppose  $\sigma > 1$ . Then  $k_2 \leq k_0, l_2 \leq l_1, sales_2 \leq sales_1, taxes_2 \leq taxes_1, TFPR_2 \geq TFPR_1$ , where inequality holds as equality only if  $\mu = 1$ . The inequalities reverse for sector 2.

**Proof.** The previous lemma and our equation for capital imply that  $k_2 \leq k_0$ . The labor supply  $l_1$  and  $l_2$  can be written (see Lemma 6) as

$$\begin{aligned} l_1^{1-\alpha+\sigma\alpha} &= \mu(1-\tau)^\sigma \left(\frac{w}{1-\alpha}\right)^{-\sigma} k_0^{\alpha(\sigma-1)}, \\ l_2^{1-\alpha+\sigma\alpha} &= \mu(1-\tau)^\sigma \left(\frac{w}{1-\alpha}\right)^{-\sigma} k_2^{\alpha(\sigma-1)}. \end{aligned}$$

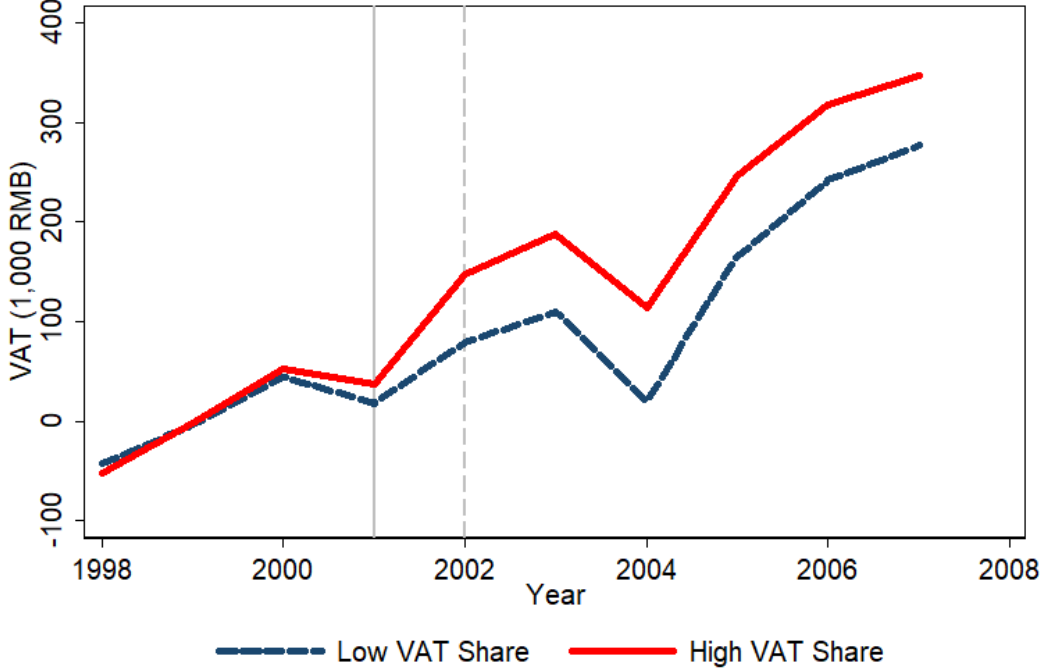
Therefore,  $l_2 \leq l_1$  with strict inequality if  $\mu < 1$ . Since  $y_t = k_t^\alpha l_t^{1-\alpha}$ , and both  $k$  and  $l$  decrease in period 2,  $y_2 \leq y_1$ . We have  $sales_t = q_t y_t = \mu^{\frac{1}{\sigma}} y_t^{\frac{\sigma-1}{\sigma}}$ , therefore  $sales_2 \leq sales_1$ . Taxes are given by  $taxes_t = \tau \times sales_t$ , so we get the result on sales. Since we can also write  $sales_t = \mu q_t^{1-\sigma}$  and  $TFPR_t = q_t$ , we get that  $TFPR_2 \geq TFPR_1$ .

Since total capital is fixed, we must have  $K_2 \geq K_0$  and the same steps prove reverse inequalities for sector 2 (which obviously does not have taxes). ■

This step completes the proof, since we already know what happens in period 1. Note that  $\mu = 0$  is the same case as our baseline model (it is easier to see it, if we redefine all variables as ratios to  $\mu$  and look at the limit as  $\mu \rightarrow 0$ ). In this case, sector 1 is so small, so that any reallocation of capital from sector 1 to sector 2 has no effect on price  $r$ . The lemma above shows that all the insights continue to generalize in the 2 sector GE model

where interest rate  $r$  is endogenously determined and is affected by the reallocation. The mechanism is the same as in the benchmark case: as long as there is some reallocation in period 2 of capital due to re-optimization, capital  $k_2$  will decrease in period 2, further depressing labor demand  $l_2$  and output  $y_2$ , leading to lower sales and tax revenues in sector 1. In the limit case,  $\mu = 1$ , sector 2 is negligibly small and cannot absorb any capital. As a result, with fixed capital stock, rental rates  $r_2$  must fall sufficiently to prevent any re-allocation of capital from sector 1, in which case, period 1 and period 2 become identical.

Figure A.1: VAT Over Time of Firms with VAT Share Above and Below the Sample Median – All Firms



*Notes:* The data are normalized to be visually comparable. The pre-computerization mean of each group is subtracted from the value of each year in the group.

Table A.1: Sectors with the Lowest and Highest VAT Shares

50 Sectors with Lowest VAT Share		50 Sectors with Highest VAT Share	
(1)	(2)	(3)	(4)
Sector Name	VAT Share	Sector Name	VAT Share
Cane Sugar	0.16	Chinese Musical Instruments	0.97
Beet Sugar	0.16	Recording Media	0.82
Copper Smelting	0.26	Other Tobacco Processing	0.80
Dry Processing Of Aquatic Products	0.26	Cigarette	0.80
Soy Sauce, Sauce	0.28	Tobacco Leaf Re-Baking	0.80
Passenger Car	0.29	Electric Vacuum Devices	0.80
Heavy Truck	0.29	Semiconductor Device	0.80
Radar Special Equipment and Components	0.29	Biological Products	0.76
Small Car	0.29	Manufacture Of Chemical Preparations	0.76
Other Railway Transport Equipment	0.29	Carbonated Beverage	0.73
Cotton	0.30	Livestock Machinery	0.72
Analytical Instruments	0.30	Communication Terminal Equipment	0.69
Seasonings	0.30	Specific Equipment Repair	0.69
Frozen Aquatic Products Processing	0.30	Special Equipment For Plastics	0.68
Cutting Tool	0.31	Steel Rolling, Processing	0.67
Laboratory Instruments and Apparatus	0.31	Other Refractory Products	0.67
Manufacture Of Organic Chemical Materials	0.31	Books, Newspapers and Periodicals	0.67
Canned Poultry	0.31	Packaging and Decorations	0.67
Other Boilers and Prime Mover	0.34	Manufacture Of Pesticides, Original Drugs	0.66
Internal Combustion Engine	0.34	Agricultural Machinery and Equipment	0.65
Steam Turbine	0.34	Radio and Television Equipment	0.64
Paint	0.34	Cement Products	0.64
Acrylic Fiber	0.34	Chemical Drug	0.63
Other Synthetic Fiber	0.34	Chinese Herbal Medicine	0.63
Polyester Fiber	0.34	Other Cement Products	0.63
Viscose Fiber	0.34	Radar Machines	0.62
Nylon Fiber	0.34	Transmission Equipment	0.62
Vinyon Fiber	0.34	Metal Cutting Machine Tools	0.62
Chemical Fiber Pulp	0.34	Notebooks	0.62
Micro-cars	0.35	Piping and Plumbing	0.62
Other Food Categories	0.35	Computers	0.62
Soy Products	0.35	Chemical Reagents, Additives	0.62
Other Condiments	0.35	Candy	0.61
Locomotive & Rolling Stock Parts	0.36	Other Confectionery and Confectionery	0.61
Other Vehicle Parts	0.36	Garment	0.61
Sawn Timber Processing	0.36	Linen Textile	0.61
Wood Processing	0.36	Other Fur Products	0.61
Dairy Processing	0.37	Fur Tanning	0.61
Special Vehicles and Modified Cars	0.37	Special Linen Textile	0.61
Steel Making	0.37	Other Hemp Textile	0.61
Starch and Starch Products	0.38	Fur Clothing	0.61
Metallurgical Special Equipment	0.38	Footwear	0.61
Ginning	0.39	Ramie Textile	0.61
Top Processing	0.39	Sports Equipment	0.60
Wool	0.39	Ball	0.60
Vinegar	0.39	Washing Machine	0.59
Other Plastic Products	0.39	Fishery Machinery	0.59
Magnesium Smelting	0.40	Automotive Instrumentation	0.58
Antimony Smelting	0.40	Other General Instrument and Meters	0.58
Other Light Non-Ferrous Metal Smelting	0.40	Special Instrumentation Devices	0.58

Notes: Manufacturing sectors are defined by four-digit Chinese Industrial Codes. VAT share is calculated from U.S. Input Output Tables. See the text for a detailed description.

Table A.2: Descriptive Statistics

	Balanced Panel			All Firms		
	(1) N	(2) Mean	(3) Std. Dev.	(4) N	(5) Mean	(6) Std. Dev.
VAT Share 1998-2000 Chinese Data	61308	0.317	0.100	2990	0.295	0.096
VAT Share U.S. Data	61308	0.503	0.118	2990	0.492	0.118
VAT (1000 RMB)	61308	2061	2900	2990	1310	625
VAT/Sales	61308	0.050	0.031	2990	0.039	0.010
Sales (1000 RMB)	61308	46211	60126	2990	37066	14309
TFPR HK	61308	0.091	0.084	2990	0.127	0.078
TFPR DLW	61308	0.143	0.507	2990	0.125	0.393
Employment (# workers)	61308	291	383	2990	222	127
Wage Bill (1000 RMB)	61308	3015	4265	2990	2130	1050
Deductible Input Share	61308	0.838	0.105	2990	0.854	0.036
Export Share	58829	0.063	0.191	2990	0.171	0.178
Imported Input Share	61308	0.272	0.598	2990	0.263	0.629
State-owned	61308	0.419	0.493	2990	0.257	0.211
Privately-owned	61308	0.426	0.495	2990	0.581	0.214
Foreign Owned	61308	0.154	0.361	2990	0.160	0.101
Corporate taxes	61308	561	1617	2990	349	190

*Notes:* Columns (1)-(3) present descriptive statistics from a balanced panel of firms. Each observation is a firm and year. Columns (4)-(6) uses the full sample of firms. Each observation is a sector and year; the statistics are weighted by the number of firms in each sector-year cell to be numerically equivalent to a sample with observations at the firm-year level.



Table A.3: The Effect of Computerization by Year

	Dependent Variable	
	VAT/Sales (1)	VAT (2)
VAT Share x 1999	0.00284 (0.00476)	85.51 (288.3)
VAT Share x 2000	0.00724* (0.00438)	299.3 (339.0)
VAT Share x 2001	0.00738 (0.00546)	320.6 (413.7)
VAT Share x 2002	0.0104** (0.00507)	469.5 (480.8)
VAT Share x 2003	0.0154*** (0.00460)	1,075* (631.0)
VAT Share x 2004	0.0253*** (0.00526)	1,409** (603.0)
VAT Share x 2005	0.0130** (0.00614)	741.3 (591.3)
VAT Share x 2006	0.0142** (0.00624)	573.4 (574.6)
VAT Share x 2007	0.0169** (0.00744)	616.8 (609.7)
Observations	61,308	61,308
R-squared	0.658	0.781
2001-2007 Joint p-value	<0.001	0.0240

*Notes:* The sample is a balanced panel of firms, 1998-2007. All regressions include average sales (1998-2000)  $\times$  year FE, year and firm FEs. Standard errors are clustered at the sector level. \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$

Table A.4: First Stage Estimates – Chinese VAT Share (pre-computerization, 1998-2000) instrumented by U.S. VAT Share

Dependent Variables: VAT share (measured using 1998-2000 Chinese data) x Post Period Stated in Column Headings	(1)	(2)	(3)
	x 2001-2002	x 2003-2005	x 2006-2007
VAT share x 2001-2002	0.414*** (0.0890)	0.00331** (0.00156)	0.00277*** (0.00100)
VAT share x 2003-2005	0.00144 (0.00127)	0.420*** (0.0885)	-1.69e-05 (0.00118)
VAT share x 2006-2007	0.00427*** (0.00153)	0.00311* (0.00179)	0.411*** (0.0873)
Observations	61,308	61,308	61,308
R-squared	0.935	0.936	0.935
Kleibergen Papp F-Statistic		7.220	

*Notes:* The sample is a balanced panel of firms, 1998-2007. All regressions include average sales (1998-2000) × year FE, year and firm FEs. Standard errors are clustered at the sector level. \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table A.5: The 2SLS Effects of Computerization on VAT

	Dependent Variables					
	VAT/Sales (Fraction) (1)	VAT (1000 RMB) (2)	Sales (1000 RMB) (3)	TFPR (HK) (4)	TFPR (DLW) (5)	Deductible Inputs as a Share of Total Inputs (6)
VAT share x 2001-2002 ( $\beta_1$ )	0.0114 (0.00790)	573.6 (570.1)	-11,410 (9,106)	0.0218*** (0.00811)	-0.00518 (0.0858)	0.0636 (0.116)
VAT share x 2003-2005 ( $\beta_2$ )	0.0351*** (0.0120)	2,336** (954.2)	-31,583* (17,365)	0.0280** (0.0127)	0.298 (0.189)	-0.407*** (0.131)
VAT share x 2006-2007 ( $\beta_3$ )	0.0293* (0.0170)	1,098 (1,109)	-66,152* (35,589)	0.0359** (0.0181)	0.849** (0.329)	-0.758*** (0.265)
Observations	61,308	61,308	61,308	61,308	61,308	61,308
H0: $\beta_1 = \beta_2$ (p-value)	0.00600	0.00200	0.0970	0.380	0.0580	0.00800
H0: $\beta_2 = \beta_3$ (p-value)	0.496	0.110	0.183	0.286	0.00500	0.0420

Notes: The sample is a balanced panel of firms, 1998-2007. All regressions include average sales (1998-2000)  $\times$  year FE, year and firm FEs. Standard errors are clustered at the sector level. \*\*\* p<0.01, \*\* p<0.05, \* p<0.1 The endogenous explanatory variables are the three post-reform indicators interacted with Chinese 1998-2000 VAT share; the instruments are the three post-reform indicators interacted with U.S. VAT share.

Table A.6: The Heterogeneous Effects of Computerization by Ownership

	Dependent Variables							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	VAT/Sales	VAT	Sales	TFPR (HK)	TFPR (DLW)	Intermediate Input	Inputs as a Share of Total Input	Inputs as a Share of Total Input
A. State Owned								
<b>Dep Var Mean</b>	<b>0.0507</b>	<b>1668</b>	<b>37452</b>	<b>1.105</b>	<b>1.376</b>	<b>27099</b>	<b>0.836</b>	<b>0.747</b>
VAT share x 2001-2002 ( $\beta_1$ )	0.00119 (0.00306)	335.1 (249.7)	-2,155 (3,491)	0.00585 (0.00377)	0.0135 (0.0425)	-2,158 (2,780)	0.00532 (0.0121)	0.0911 (0.0651)
<i>Beta Coef.</i>	<i>0.00821</i>	<i>0.0251</i>	<i>-0.00779</i>	<i>0.0152</i>	<i>0.00580</i>	<i>-0.0114</i>	<i>0.0110</i>	<i>0.0396</i>
VAT share x 2003-2005 ( $\beta_2$ )	0.0149*** (0.00444)	963.6** (424.8)	-3,271 (7,487)	0.00816 (0.00546)	0.218** (0.0853)	-1,051 (5,640)	-0.0187 (0.0243)	-0.158*** (0.0598)
<i>Beta Coef.</i>	<i>0.115</i>	<i>0.0806</i>	<i>-0.0132</i>	<i>0.0236</i>	<i>0.104</i>	<i>-0.00619</i>	<i>-0.0432</i>	<i>-0.0766</i>
VAT share x 2006-2007 ( $\beta_3$ )	0.0169*** (0.00562)	183.8 (597.3)	-21,565 (20,921)	0.00969 (0.00764)	0.419*** (0.140)	-4,617 (11,355)	-0.0504 (0.0443)	-0.274* (0.155)
<i>Beta Coef.</i>	<i>0.113</i>	<i>0.0133</i>	<i>-0.0755</i>	<i>0.0243</i>	<i>0.174</i>	<i>-0.0236</i>	<i>-0.101</i>	<i>-0.115</i>
Observations	25,181	25,181	25,181	25,181	25,181	25,181	25,181	25,181
R-squared	0.683	0.805	0.798	0.962	0.842	0.814	0.744	0.407
H0: $\beta_1=\beta_2$ (p-value)	0.00400	0.0190	0.840	0.552	0.00600	0.788	0.185	0.00300
H0: $\beta_2=\beta_3$ (p-value)	0.639	0.128	0.298	0.666	0.0210	0.691	0.196	0.352
B. Privately Owned								
<b>Dep Var Mean</b>	<b>0.0471</b>	<b>2098</b>	<b>48865</b>	<b>1.100</b>	<b>13.10</b>	<b>33089</b>	<b>0.844</b>	<b>0.824</b>
VAT share x 2001-2002 ( $\beta_1$ )	-0.000305 (0.00444)	-173.3 (327.9)	-15,041** (7,258)	0.0129 (0.00835)	0.0683 (0.0509)	-13,577** (5,248)	-0.00419 (0.0145)	0.0115 (0.0618)
<i>Beta Coef.</i>	<i>-0.00211</i>	<i>-0.0130</i>	<i>-0.0544</i>	<i>0.0335</i>	<i>0.0293</i>	<i>-0.0717</i>	<i>-0.00870</i>	<i>0.00500</i>
VAT share x 2003-2005 ( $\beta_2$ )	0.00395 (0.00569)	608.5 (516.5)	-24,788** (11,232)	0.0190* (0.0109)	0.169* (0.0922)	-18,997*** (7,172)	-0.0177 (0.0254)	-0.114 (0.0876)
<i>Beta Coef.</i>	<i>0.0305</i>	<i>0.0509</i>	<i>-0.100</i>	<i>0.0549</i>	<i>0.0808</i>	<i>-0.112</i>	<i>-0.0411</i>	<i>-0.0556</i>
VAT share x 2006-2007 ( $\beta_3$ )	-0.00151 (0.00687)	113.0 (580.3)	-40,489*** (15,366)	0.0209 (0.0138)	0.419*** (0.128)	-20,161** (9,152)	-0.0433 (0.0367)	-0.193** (0.0889)
<i>Beta Coef.</i>	<i>-0.0101</i>	<i>0.00820</i>	<i>-0.142</i>	<i>0.0527</i>	<i>0.174</i>	<i>-0.103</i>	<i>-0.0870</i>	<i>-0.0812</i>
Observations	25,733	25,733	25,733	25,733	25,733	25,733	25,733	25,733
R-squared	0.695	0.806	0.811	0.943	0.820	0.822	0.720	0.465
H0: $\beta_1=\beta_2$ (p-value)	0.280	0.0290	0.126	0.153	0.107	0.181	0.427	0.0150
H0: $\beta_2=\beta_3$ (p-value)	0.301	0.137	0.100	0.620	0	0.844	0.0910	0.279
H0: State = Private (SUR p-value)	0.0724	0.765	0.0792	0.765	0.395	0.196	0.924	0.220

Notes: The sample is a balanced panel of firms covering 1998-2007. A firm's ownership is defined its legal registration. All regressions include average sales (1998-2000)  $\times$  year FE, year and firm FEs. Standard errors are clustered at the sector level. \*\*\* p<0.01, \*\* p<0.05, \* p<0.1