The Dynamic Effects of Computerizing VAT Invoices in China*

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September 21, 2023

Abstract

This study examines the short and long-run effects of computerizing VAT transactions on large manufacturing firms in China. Computerization accounts for 13.7% of VAT growth from 1998 to 2007 and 11.7% of China's total 2000 VAT revenue. In the short run, computerization increased tax revenues by reducing VAT evasion from exaggerated deductions. The long-run effect of computerization on tax revenue gains is also positive, but the magnitude of gains is smaller due to a decline in revenue. The results suggest that the revenue decline is at least partly driven by a fall in real output.

Keywords: State Capacity, Tax Enforcement, Tax Compliance
JEL: H25, H26, O12

*We thank Gabrielle Fack, Hanming Fang, Mike Golosov, Anders Jensen, David Lagakos, Magne Mogstad, Dina Pomeranz, Stefanie Stantcheva and Daniel (Yi) Xu for their insights; and the participants of the MIT/Harvard Development Workshop, Northwestern Applied Micro Workshop, University of Zurich Macro and Development Seminar, MSU Development Workshop, University of Chicago Development Lunch, CEPR Development and Taxation Workshop, IMF and Atlanta Federal Reserve Bank's conference on the Chinese Economy, CEPR Development Workshop, M&M Conference at the Chicago Federal Reserve Bank, Fudan University TED Conference, Peking University CCER Summer Institute, Lixin University Workshop on Public Finance, Shanghai Technical University Applied Workshop and Chicago Area Development Mini Conference for useful comments. We are grateful to Carlo Medici, Ludovica Mosillo, Joris Mueller and Zhentao Jiang for excellent research assistance. All mistakes are our own.

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1 Introduction

Increasing tax revenues is a primary concern for developing middle-income economies, which have much lower tax revenues as a share of GDP than rich countries because of relatively limited state capacity and rampant tax evasion (e.g., Besley and Persson, 2013; Burgess and Stern, 1993). An important feature believed to facilitate better enforcement in rich countries is the availability of third-party information trails from transactions (Gordon and Li, 2009; Kleven et al., 2016a). Thus, not surprisingly, the Value Added Tax (VAT) has become one of the most popular forms of tax due to its self-enforcing properties – i.e., the upstream firms are incentivized to understate their sales, but downstream firms are incentivized to overstate their inputs (Gordon and Li, 2009; Kleven et al., 2016b).[1] Policymakers face two challenges. First, tax officials in most developing economies do not have the capacity to link and validate VAT transactions, which severely limits the extent of self-enforcement (Pomeranz, 2015). Second, firms can respond to an increase in VAT enforcement by changing their economic or reporting behavior and offset the tax increase. For example, increased VAT can cause firms to evade other less well-enforced taxes, or reduce real output.

This paper aims to examine the extent to which computerizing VAT transactions can overcome these challenges in China. We directly examine the linking of VAT transactions to provide direct evidence of changes in firm economic behavior in response to an increase in compliance.

VAT transactions were computerized in 2001. Before this, evasion was rampant as it was easy to falsify quantities on the hand-written invoices. Because large or sudden changes in sales triggered audits, evasion was usually accomplished by exaggerating the amount of deductibles. The tremendous number of transactions made it infeasible for tax authorities to manually and systematically link the downstream input and upstream sales receipts. The computerization of VAT was designed to increase tax revenues and reduce evasion. The reform digitized invoices and linked transactions nationwide, which strengthened the information chain for VAT enforcement. It also reduced reporting and documentation costs for firms, and may have allowed tax officials to better target audits by providing better information. These effects will be part of the reduced form estimates we provide.

China is an ideal context to study the effect of linking VAT transactions on tax revenues and firm behavior for several reasons. First, the rapid implementation of a nationwide roll-out in 2001 facilitates identification. Second, the presence of a functional tax administration and the ability to credibly punish evaders means that our estimates of the increase in third-party information are

[1] VAT is one of the most important taxes in the world, contributing to over a quarter of world tax revenue (Keen and Mintz, 2004). According to the United Nations, 166 member nations have a VAT in 2018. 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.

not confounded by other deficiencies in administrative capacity. Similarly, the fact that changes in revenues trigger audits helps us understand the mechanism driving our results. Finally, China is similar to other developing-middle income economies in its need to increase tax revenues and digitize tax collection, and at the same time, the world's second-largest economy. Thus, our findings on real economic responses have relevance for the global economy.

To empirically examine the effect of the computerization of VAT on tax payments, we construct a firm-level panel of annual VAT using the *Annual Survey of Industrial Production* (ASIP), 1998-2007. The ASIP samples the universe of large manufacturing firms in China. The surveys are conducted by National Bureau of Statistics enumerators, who transcribe information from firm records. These data allow us to overcome the lack of administrative tax data from this period.[2] The ASIP provides not only VAT payment from each firm, but also a breakdown of gross VAT and VAT deductibles such that we are able to examine the mechanisms underlying changes in VAT. Our main analysis uses a balanced panel of firms that exist throughout the period that we study to avoid the confounding influences of firm entry and exit.

The first part of the analysis examines the average effect of computerization on VAT. Our empirical strategy exploits two sources of variation. First, we compare outcomes before and after the 2001 reform. Second, we exploit sector-level variation in the amount of non-deductible inputs as a share of sales, henceforth, *non-deductible share* or NDS. Firms with higher NDS had stronger incentives to falsify claims (there is little need to evade VAT if all sales can be offset by legitimately deductible inputs). Thus, higher NDS firms are more intensely treated by the reform. Our approach is similar in spirit to a difference-in-differences strategy, except that the cross-sectional variation is a continuous measure. The baseline specification uses a parsimonious set of controls and includes 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 allow for firms of different sizes to evolve differentially over time, it also controls for the interaction of the firm's average sales and average VAT in the pre-reform period and year fixed effects.

Computerization significantly increased VAT on average in the five-year post period, and did so by reducing deductible inputs. These results are consistent with a pre-period firm evasion strategy of exaggerating inputs. To estimate the magnitude of the increase, we use the full sample of ASIP firms, which yields qualitatively similar estimates to the smaller balanced panel.[3] The magnitudes of the estimates are large. Taken literally, they imply that computerization accounted for 13.7% of VAT revenue growth from 1998-2007.[4] These results are especially economically meaningful

[2]The ASIP has been used by recent studies on corporate income tax (Cai and Liu, 2009) and payroll tax (Li et al., 2021).

[3]The similarity of results in the full cross-section and balanced panel of firms suggests that firms are not avoiding VAT by splitting into smaller firms, as documented in Japan by Onji (2009).

[4]The contribution of the computerization on VAT calculated in our paper for China during the early 2000s is

when one considers that VAT was 47.61% of total tax revenues for China in 2002.[5]

Our estimates are likely to understate the true effect of computerization on tax revenues for two reasons. First, in our sample, even the lowest NDS firms had some non-deductible inputs and were therefore partially treated. Second, computerization likely generated enforcement spillovers along transaction chains to low NDS firms.

The main challenges to a causal interpretation of our baseline estimates are omitted variables: there may be unobserved factors which influence VAT that differ for high and low NDS sectors. Overall, there were few other contemporaneous changes to VAT policy and we find no pre-trends for any of the main outcome variables.[6] However, two major events did take place during this period: China's entry into the World Trade Organization in 2001 and the enterprise reforms that partially privatized historically state-controlled firms during 1998-2003. We address the potential confounding influence of China's WTO accession in several ways. We control for sector-by-year import tariffs and export rebates, pre-period sector-specific export growth rates and sector-year import and export flows. We also show that firms which are more exposed to trade do not drive the main results. To address the influences of the enterprise reforms, we control for firm ownership in the base year interacted with year fixed effects and also show that the effects are similar for state and privately owned firms. Since many reforms during this period were implemented at the province level, we also control for province-year fixed effects. Our results are very robust.

We conduct many additional sensitivity and robustness exercises, such as addressing potential measurement error in our sector-level NDS variable by showing that the results are qualitatively similar if we instrument for the Chinese measure with NDS calculated from data from other countries. We also perform random permutation tests for sectoral NDS and show that our results are unlikely to be an artifact of the variable's distribution. See the paper for these and many other robustness results.

The second part of the analysis examines the dynamic effects of computerization over time on VAT and other firm outcomes from 2002-2007. The long-run response can be different from the short-run response. In the short run, firms can easily change reporting behavior, but will find it difficult to change real economic behavior such as adjusting production inputs. In the long run, firms can change both types of behavior. To estimate the dynamic estimate, we use a similar specification except that we interact base-year NDS with year fixed effects instead of post-reform dummy variables.

comparable to the VAT gap shown in Gebauer and Parsche (2003) and Keen and Smith (2006) for Spain and Greece between 1994 and 1996. The implied elasticity of sales with respect to VAT is -0.92. The value is comparable to the earlier studies (see Section 4.2).

[5] Source: China Tax Policy Department, Ministry of Finance 2007.

[6] There were several changes to VAT after our study period, but none during the period that we study. See Section 2 for more discussion.

We find that VAT revenues experience the largest increase in the first four years after the reform and may decline slightly afterward. However, the decline in later years is statistically insignificant. After the reform, both gross VAT and VAT deductibles decline monotonically over time. We also examine several other measures of firm performance. We find that computerization *reduced* total sales and deductible intermediate inputs and *increased* total factor productivity (TFPR) in the long run.

The long-run results are consistent with a change in real economic behavior or changes in reporting behavior. We investigate both possibilities. We show that the results are consistent with a simple model where firms adjust inputs in the long run. We investigate changes in reporting behavior in the following ways. First, we consider the possibility that firms under-report revenues. This is *prima facie* unlikely because large drops in revenues trigger audits. We also investigate this possibility by examining sales that are ineligible for VAT, which firms have no incentive to under-report. We find that the reform also causes these sales to decline.[7] Second, we consider the most common methods of two-way collusion in the presence of stronger third-party information (i.e., *flying invoices*) (Waseem, 2020). We find no evidence of this in our context. We interpret these results to mean that the long-run decline in revenues is unlikely to be entirely driven by misreporting. See the paper for more evidence and discussion.

Taken together, this study shows that digitizing and linking VAT invoices generated large tax revenue gains for the Chinese government. In the long run, firms responded by scaling down production, but not enough to offset the large tax revenue gains from the increased compliance.

Our study is the first to estimate the dynamic long-run effects of an increase in VAT compliance and present evidence of changes in real economic behavior.[8] We are most closely related to studies of tax compliance in developing countries, where firms have been found to over- and under-pay VAT. For example, a recent study by Almunia et al. (2021) finds that approximately 25% of firms in Uganda misreport sales and inputs so that they over-pay VAT, while the remaining majority misreport to evade VAT. In contexts where firms are believed to systematically under-pay, earlier studies have found that third-party information can improve compliance. Naritomi (2019) finds that providing rewards for consumers to whistle-blow increases VAT in Brazil. Pomeranz (2015) finds that VAT paper trails prevent evasion in Chile. Eissa and Zeitlin (2014) finds that the introduction of electronic billing machines increased VAT in Rwanda. In evaluating the impact of computerization on tax revenues, we are closely related to Jensen et al. (2022), which finds that mapping and

[7] One possible explanation is that firms understate total revenues beyond what is part of VAT in order to evade Enterprise Income Tax (EIT). We rule this out by showing that computerization has no effect on EIT. Similarly, one may be concerned that the negative (though statistically insignificant) effect of computerization on employment is driven by misreporting in an effort to evade payroll tax. We rule this out by showing that computerization has no effect on the wage bill.

[8] Harju et al. (2016) uses te bunching behavior of small Finnish firms around VAT compliance cost thresholds and the fact that bunching does not vary by firm size to infer that there is a reduction in the growth of real output.

revenue management software increased property tax revenues in Ghana.[9] Waseem (2020) exploits variation in tax cuts in Pakistan to find that firms evade VAT by overstating inputs, understating sales and using invoice mills.[10]

In studying tax compliance in China, we complement Fisman and Wei (2004), which detects evasion using customs data discrepancies and Li et al. (2021), which finds evidence that firms offset VAT increases by evading payroll taxes. In contrast to Li et al. (2021), we find no evidence that the increase in VAT caused by the computerization of VAT was offset by a reduction in payroll taxes.[11] Our finding that computerizing VAT transactions has such a strong effect on compliance in China, where tax officials can audit and punish evading firms is consistent with Almunia and Lopez-Rodriguez (2018), which finds that the paper trail and other monitoring efforts are complements in Spain.

This paper is organized as follows. Section 2 discusses the relevant institutional background. Section 3 describes the data. Section 4 presents the empirical strategy and estimates of the average effects of computerization on VAT. Section 5 presents the dynamic effects of computerization and their interpretation. Section 6 concludes.

2 Background

This section summarizes the enforcement environment prior to the computerization reform. We draw on government documents as well as interviews of tax officials and firm managers.

2.1 VAT

China first introduced the VAT in 1994. By 2002, it had become the largest source of tax revenue, representing 47.5% of the total. All formal manufacturing firms were required to register within the VAT system, either as a "small VAT taxpayer" or a "general VAT taxpayer". Within the manufacturing sector, firms with less than one million RMB (120,772 USD) in annual sales were categorized as "small" and larger firms were categorized as "general" (Ministry of Finance,

[9] For an overview of the larger literature, see Andreoni et al. (1998), Slemrod and Yitzhaki (2002), and Saez et al. (2012).

[10] Several studies use notches in the tax system to infer behavior. For example, in Pakistan, see Best et al. (2016); Kleven and Waseem (2013); in Costa Rica, see Bachas and Soto (2018); in China, see Chen et al. (2021b).

[11] We proxy for payroll taxes with the wage bill, which is the main determinant of payroll taxes, because payroll tax data are not available until 2001. Li et al. (2021) instruments for county-level VAT revenue with the decline in county tax revenue driven by the abolition of Agricultural Taxes in 2004; the 2SLS estimate of the instrumented VAT revenue on payroll tax revenue is negative. The main differences between their data and ours are the source of the variation and sample. Although their main sample includes large manufacturers, their results are driven by privately owned, small and cash-constrained firms. Our results are similar across firm ownership and size. These results are in the paper and available upon request.

1993).[12] Because our dataset contains only firms much larger than this cutoff (i.e., annual revenues exceeding five million RMB, or 603,864 USD), we focus the rest of our discussion on general VAT taxpayers.

For general VAT taxpayers, the final VAT bill was 17% of the VAT tax base, which equals the difference between total VAT-eligible sales and total eligible input deductions.[13] In our study period, full deductions were awarded for purchases of manufactured inputs, repair inputs, retail inputs and wholesale inputs. No deductions were given for fixed asset purchases, capital depreciation, abnormal losses, rent, fringe benefits, interests from bank loans and operating expenses (overhead). Labor was not deductible.[14] For any deductible imported inputs, firms could report purchases using VAT completion receipts issued by the customs office (State Council, 1993). Exports were partially exempt from VAT due to rebates that vary by sector and year. There were no other notable changes in the VAT formula or exemptions during the period of our study.

A typical VAT-relevant transaction was a firm-to-firm sale of some input. An official handwritten invoice with carbon copies was generated: one copy for the buying firm and the other one for the selling firm. Registered firms could obtain these invoices from the local tax office, and firms paid VAT and obtained deductions monthly. Each month, a firm representative went to the local tax office and gave the tax official invoices for all VAT-eligible sales from the past month. These are used to calculate VAT obligations, which are paid on the same day. During the same visit, the representative gave the tax official all invoices for VAT-eligible deductibles. The deductions were calculated and paid back on the same day.

In the pre-computerization period, VAT fraud was prevalent (Lu, 1997; Jin, 2002). VAT invoices were handwritten and lacked effective anti-counterfeit technology. Manually cross-checking invoices was prohibitively costly. As a result, firms could exaggerate deductible inputs and be fairly certain that they would not be caught. Similarly, firms could use real invoices of canceled transactions to file for deductions because tax authorities would not know that the other party had never filed the sales.

The main tool for enforcing tax payment was audits. Audits were not random and were triggered by sudden changes in sales or ownership. The main trigger for audits for these firms is revenue changes, and in particular, revenue declines since they are a sign of evasion as well as a cause for political concern. In 2000, the audit rate was 17.9%. In comparison, it was 1.12% in the United States (Internal Revenue Service, 2001). There were more than 10,041 criminal cases in

[12] We use the 1 USD = 8.28 RMB conversion rate from 2000 in this paper.

[13] A reduced rate of 13% was made for basic staples or household necessities such as food, fuel, electricity, books, newspapers and magazines, and primary agricultural products (State Council, 1993); a reduced rate of 10% was applied to procured waste goods; a reduced rate of 7% was applied to transportation costs. These exceptions do not affect our study, which examines large manufacturing firms.

[14] The Appendix provides a detailed list of deductible and non-deductible items.

China that year and over 60% of these cases were related to over-reporting input VAT (page 632 of China's Tax Audit Yearbook, 2003). Very few cases ultimately resulted in penalties because of the difficulty of conclusively proving evasion, or estimating its extent, without a clear paper trail. Hence, computerization complemented audits in enforcing VAT.[15] Throughout the period of study, the procedures for audits and punishments for VAT evasion were unchanged, though computerization likely improved audit efficacy.

2.1.1 Computerization Reform

The goal of computerization, known in China as the second phase of the *Golden Tax Project*, was to improve VAT enforcement with a fully digitized invoice system coupled with a national database of firm VAT filings. The two most important components of this reform were: 1) replacing handwritten invoices with digitally encrypted invoices, and 2) digitally linking transactions (Jin, 2002).

Under the new system, firms had to use new IC smart cards to complete transactions. The IC cards contained basic information of the holding firm. During a transaction, both parties would insert their cards into a computer, which created a unique transaction record. This record took the form of an 84-digit code that encrypted the invoice ID, invoice code, invoice date, buyer's tax ID, seller's tax ID, value and VAT of the transaction.[16] This information would then be stored on both cards and the seller would print the deductible amount on a paper invoice for the buyer.

Under the new system, it was prohibitively difficult to generate false transactions, as the digital records came with a unique ID and QR code. It also became more difficult to change the amount on an invoice, as the value of the transaction was now encoded within the transaction ID. With nationwide linking, it became even harder to unilaterally falsify transactions or amounts without cross-firm collusion.

After the reform, firms continued to pay VAT during monthly visits to local State Administration of Tax (SAT) offices. They presented their IC cards as well as printed copies of the encrypted deduction invoices. As before, the net payment was calculated and made at the tax office the same day of the visit. The deduction invoices were cross-checked with a national database of transactions, effectively linking all transactions (Xu, 2003).

Computerization increased the fixed cost of reporting because it forced firms to adopt new computing equipment. However, because it was much easier for firms to record digital transactions,

[15] To the best of our knowledge, there are no disaggregated data on audits available to researchers. See the Appendix for a discussion about the aggregate audit data.

[16] The technology has continuously improved. For example, in later years, the government extended the 84-digit code into a 108-digit code. In 2011, another improvement permitted the encryption of Chinese characters as well as numerals, so the government added additional information to deduction invoices in a few designated sectors (e.g., gold, gasoline, rare earth, etc.) in three provinces (Shanghai, Shaanxi, and Shenzhen). The information includes the seller's name, the buyer's name, the product name and the quantity sold.

computerization reduced the marginal cost of reporting.

Policymakers claim that the technology had a remarkable deterrence effect on VAT fraud in China, mainly by reducing exaggerated deductions. For example, in February 2001, the number of invoices that tax authorities identified as "problematic" over the total number of invoices audited was 8.51%. By August 2002, it had dropped to 0.062% (Jin, 2002). On January 20, 2003, the former deputy head of SAT reported that the over-invoicing problem had been effectively resolved.[17] Beyond tax officials, it is widely believed by firms and other policymakers that fake invoices have almost completely disappeared.

In interviews conducted by the authors, tax officials discussed the few remaining evasion strategies after the reform. First, a subset of receipts (including procurement receipts for agricultural goods, customs VAT completion receipts, transportation receipts, and waste goods) were not covered by computerization and it was still possible to falsify these invoices. Second, firms could buy genuine invoices on a black market from final consumers who did not wish to claim deductions. Finally, entire value chains could opt for off-book cash transactions, though an immediate switch to cash transactions would trigger an audit.[18] Earlier studies of other middle-income countries have also highlighted the use of *flying invoices*. We discuss this more in Section 5.2.

2.1.2 Timing

Computerization took some time to implement. Starting from January 1, 2000, transactions exceeding 100,000 RMB (12,077 USD) were invoiced using the new encryption software and such large transactions were common for the large manufacturing firms that we study. Handwritten invoices for these large transactions were banned at the end of 2001. Though provinces varied in implementation speed, numerous tax officials at the central, provincial and local levels stated that the system was operational nationwide by July 1, 2001. We interpret 2002 as the first year that the reform became relevant for all provinces (State Administration of Taxation, 2000). In robustness exercises, we control for province-year fixed effects to account for the slight variation in the timing of the roll-out of the program.

2.1.3 Imports, Exports, Other Changes

The VAT payment rules that we have described thus far apply to almost all goods in China. Two notable special cases are imports and exports (State Council, 1993). Import tariffs existed in China throughout this period and were deductible in the same manner as the original input value. Exports

[17] See China Tax Audit Yearbook Committee (2004).

[18] The government aimed to resolve these remaining loopholes through improved enforcement technology. The third phase of the Golden Tax Project was piloted in Chongqing in 2013 and applied nationwide in 2016. It is outside of the scope of our study.

were awarded VAT rebates throughout the period of our study. Chinese export rebates are typically less than the total sum owed – i.e., firms pay some VAT on exports (Chandra and Long, 2013). Both import tariffs and export rebates vary across sectors (products) and over time.

In principle, tax officials are supposed to cross-validate trade flows by linking the customs and VAT data. However, as with other VAT transactions, this rarely occurred prior to computerization due to the administrative burden. Computerization should therefore also increase third-party information for importing and exporting firms.

There were no other changes to VAT in the period that we study, but changes in several other policies did take place. The two main policies that could confound our results are China's entry to the World Trade Organization (WTO) in 2001, and the privatization of state-owned firms, often referred to as "enterprise reforms" during 1998-2003. We discuss these policies in detail and show that they are unlikely to confound our results in the robustness exercises in Subsection 4.6.

3 Data

We use data from the *Annual Survey of Industrial Production* (ASIP), 1998-2007. These data cover large manufacturing firms and have been widely used by studies of Chinese firms. They are generally accepted as accurate and have been used by several recent studies of tax compliance (Cai and Liu, 2009; Li et al., 2021). Our main sample is a balanced panel of firms from 1998-2007 with annual revenues above 5 million RMB (603,865 USD).[19] We also show results with the full sample of firms.

The data contain a rich set of variables related to firm production and inputs. An important advantage for our paper is that it records net VAT payment, gross VAT-eligible sales and VAT-eligible deductions for intermediate inputs. Thus, we can examine the mechanisms through which computerization improves enforcement as well as its effect on VAT payment. The VAT payment variable is inclusive of rebates, such as those awarded for exports.

The ASIP is conducted each year by the National Bureau of Statistics (NBS). NBS officials visit each firm and copy data from firm records to the survey. The data collected in ASIP cannot be used in any legal action against firms (such as tax violations). Thus, the production and balance sheet data (e.g., total output, intermediate inputs, labor inputs) have been accepted by a large number of existing studies (e.g., Hsieh and Klenow, 2009). These data are in a different module of the ASIP than VAT and are typically transcribed from a different firm account book than the one that includes VAT payments.

[19]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.

All of the values in the paper are reported in real terms.[20] To avoid outliers, our sample excludes observations with the top and bottom 1% values of VAT and sales each year.[21] We use 4-digit Chinese Industry Classification sector definitions, and for the purposes of our baseline sample fix firm sectors to be the sector they have when they first appear in the sample.

We calculate pre-computerization sector-level non-deductible shares (NDS) with the *1997 Chinese Input-Output (I-O) Table* obtained from the China's National Bureau of Statistics (1999).[22] The aim of this measure is to capture real differences in evasion incentives across sectors. We do not calculate the measure with pre-reform ASIP data since those data can, in principle, confound real firm-specific differences and evasion. The data for the I-O table are collected in an independent process by a different group from the ASIP and are mainly used to tabulate national statistics and compute national GDP. The statistical office that collects the ASIP data and the one that constructs the I-O tables do not collaborate. The firm-level information used for the construction of the I-O table is not shared with the tax department and it cannot be used as evidence of tax evasion (China's National Bureau of Statistics, 2009). Nevertheless, we consider the possibility that the I-O table data are also confounded after we present the main results and show that our findings are qualitatively robust to using NDS calculated from the I-O tables from other countries as instrumental variables.

The cross-sectional measure of intensity, non-deductible input share $\widetilde{NDS}_s$, is denoted as the following,

$$\widetilde{NDS}_s = \left(\frac{NonDedu\widetilde{ctible\ Inp}uts}{Total\ Sales}\right)_s. \quad (1)$$

This term is the ratio of total non-deductible inputs to total output in sector s. To construct NDS by sector, we map each sector in the input-output tables into two groups, deductible or non-deductible, according to Chinese tax law. In practice, we consider inputs from agricultural, mining and manufacturing industries to be materials, and thus deductible. We treat inputs from service industries, overhead, labor inputs, and value-added to be non-deductible.[23]

[20] 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 results are robust to controlling for province-year fixed effects in the robustness section.

[21] The results are qualitatively similar without dropping the outliers, but slightly less precise. They are available upon request.

[22] In the 1997 Chinese I-O Table, there are 125 total listed inputs, 85 of which are VAT-deductible under Chinese tax law. The transaction-level data used to build the I-O table are not available to researchers.

[23] In a standard input-output table, the sum of all input values should be equal to the value of output. Therefore, to obtain the final measure, we can equivalently 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:

$$\widetilde{NDS}_s = 1 - \sum_{d \in D} Input\ fraction_{sd}. \quad (2)$$

The correlation coefficient between our main measure of pre-computerization NDS calculated from the I-O tables and the measure calculated from ASIP is 0.34 and statistically significant at the 1% level. See Appendix Figure A.1.

3.1 Descriptive Statistics

To illustrate the variation behind our empirical strategy, Figure 1 plots average VAT over time for firms with above and below the sample median of NDS. Since average VAT payments are higher in the high-share group (2.19 million RMB, or 264,492.75 USD) than the low-share group (1.88 million RMB, or 227,053 USD), we normalize the 1998 data to zero for both groups. Consistent with high macro-economic growth, the figure shows that VAT increased throughout the entire sample period for both groups. The trend was similar between the two groups prior to the reform and diverged after 2001, when the high-share group experienced a larger increase. Conceptually, our empirical strategy compares the average difference between the two lines after the reform to the average difference before the reform. The similarity in the pre-reform lines supports the parallel trends assumption of our empirical strategy. The timing of the divergence supports our interpretation that the second difference captures the effects of computerization rather than other changes that occurred before or afterward.

3.2 Correlates of Non-Deductible Share

Since NDS is not randomly assigned, one of the main concerns for our identification strategy is omitted variables. Table 1 documents the differences between high and low-share sectors by estimating the correlation coefficient of NDS 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 firms in sectors with high non-deductible shares on average pay higher VAT, pay higher VAT as a share of sales and pay fewer VAT deductions. On average, firms in high NDS sectors have lower sales, fewer intermediate inputs, and are more productive. In Section 4.6, we show that the main results are robust to controlling for these baseline characteristics interacted with year fixed effects.

Appendix Table A.1 lists the fifty sectors with the highest and lowest values for $\widetilde{NDS}_s$.

4 The Average Effects on VAT

4.1 Baseline

We exploit two sources of variation: time variation from the 2001 introduction of computerization and cross-sector variation in the intensity of the treatment effect. According to tax officials, before computerization, the firms that were the most likely to evade VAT were those with a high level of non-deductible inputs as a share of sales. This was because they had few legitimate deductibles with which to lower VAT obligations (as a share of sales). Thus, the reform intensity was higher – i.e., it increased compliance more – for firms with a higher share of non-deductible inputs.

We document a positive relationship between sector NDS from the I-O data and changes in effective VAT rate, measured by VAT divided by sales. High NDS firms experienced systematically higher increases in VAT divided as a share of sales. A binned scatter plot of these two variables is shown in Appendix Figure A.1, sub-Figure (a).

The baseline equation can be written as the following

$$VAT_{ist} = \alpha + \beta \widetilde{NDS}_s \times Post_t + \Gamma X_{ist} + \tau_t + \phi_i + \varepsilon_{ist}, \tag{3}$$

where VAT paid by firm i, in sector s, and year t, VAT_{ist}, is a function of: the interaction of a dummy which takes the value of one if it is 2002 or later, $Post_t$, and the measure of intensity at the sector level, $\widetilde{NDS}_s$; firm fixed effects, ϕ_i; and year fixed effects, τ_t. We choose 2002 as the start of the post-reform period because hand-written invoices were not banned until the end of 2001. When we examine the dynamic effects, we will allow the effects to differ for each year. Note that sector fixed effects are absorbed by firm fixed effects, as we code each firm's sector as the one it has when first observed. The standard errors are clustered at the sector level.

X_{ist} is a vector of controls. For parsimony, the baseline only includes two measures of firm size to account for the possibility that tax policy varies by firm size (Bachas et al., 2019; Kleven et al., 2016b). The first is the average pre-reform sales, and the second is the average pre-reform firm VAT. We use 1998-2001 values to avoid endogeneity. We then control for each variable interacted with year fixed effects to allow the influences to be completely flexible over time.

We are interested in the estimate of β. If the reform increased compliance and VAT, then $\beta > 0$.

Our identification strategy assumes parallel trends – i.e., absent the reform, the outcomes of interest across sectors with different non-deductible shares would have evolved along parallel trends (conditional on the controls). The descriptive statistics in the previous section support this assumption. We provide additional support after presenting the main results.

We note two caveats to our approach. The first is that we do not have a pure control group. Sectors with low non-deductible shares may still have evaded VAT prior to the reform (albeit less than sectors with higher non-deductible shares). Thus, the reform will also increase their VAT compliance (though less than for sectors with higher non-deductible shares). The second caveat arises from the presence of cross-sector transactions. This is particularly relevant when the transactions become linked: higher compliance in sectors with high NDS will lead to higher compliance in sectors with low NDS. Both caveats will lead to our results to be an underestimate.[24]

Another potential caveat regards the measurement of $\widetilde{NDS}_s$. One might be concerned that, despite the best efforts of the National Bureau of Statistics, the raw data used to generate the 1997 Chinese I-O tables are confounded by evasion and measurement error. To address this issue, we construct NDS measures using Mexican and U.S. input-output tables and use these to instrument for our main measure. We discuss this in Section 4.6.2.

We present scatter plots of pre-2001 ASIP non-deductible share against the U.S. and Mexican I-O measures in Appendix Figure A.1, sub-Figures (c) and (d). The correlation coefficients are respectively 0.34 and 0.22, both with $p < 0.01$. Implementation details are in Appendix Section F and the results are in Subsection 4.6.2.

4.2 Results

Table 2 examines the effect of computerization on VAT. The sample means of the dependent variables are stated at the top of the table. This section focuses on Panel A. Column (1) shows that the effect on gross VAT or VAT-eligible sales is negative, but statistically indistinguishable from zero. Column (2) shows that the reform reduces deductions. The estimate is statistically significant at the 1% level and is larger in magnitude than the estimated reduction in gross VAT in column (1). The reform, on average, reduced VAT deductions by $6,281 \times 1,000$ RMB (6.281 million RMB, or 765,975 USD) for a firm in a sector with no deductibles (i.e., the NDS is 100% of sales) relative to a firm in a sector where all sales are deductible (i.e., the non-deductible share is 0% of sales). In terms of magnitudes, a back-of-the-envelope calculation shows that a firm with the sample mean NDS of 0.4042 would have experienced a 40.99% ($6,281 \times 0.4042/6,194 = 0.4099$) decline in VAT deductions after computerization.

Column (3) shows that the reform increased VAT payment. The estimate is statistically significant at the 1% level. In terms of magnitudes, the treatment effect constitutes 33.4% of the increase in firm VAT from 1998 to 2007 in the balanced panel (see Appendix Section E). Later, in Section 4.4, we examine the full sample of firms to compute the contribution of the reform to the Chinese economy.[25]

[24] Note that an ostensibly reasonable alternative strategy is to use exporting sectors, which are commonly thought of as "exempt" to VAT, as a control group. However, in practice, the VAT rebates for exporting sectors vary over time and across sectors, and there is no one sector that is always VAT exempt. However, in a similar spirit, we will estimate heterogeneous treatment effects of the reform according to the degree of exports.

[25] Using log outcome variables yield consistent results. These tables are available upon request.

These results show that the reform increased VAT paid by firms and that the increase is driven by a decline in deductions. This is consistent with conventional wisdom that the reform mainly impacted firms by removing their ability to falsify invoices for deductions.

Column (4) examines VAT as a share of sales. The denominator is total firm revenues, which is reported in a different module of the firm survey. Since not all sales are VAT eligible, we use total sales in the denominator to normalize by firm size. If VAT payments increase because of a change in enforcement, we may expect it to increase as a share of sales. Indeed, the coefficient is positive and statistically significant at the 1% level.

Another motivation for changing evasion/reporting behavior is the change in reporting costs caused by computerization. As we discussed earlier, computerization reduced the marginal cost of reporting. Since sales were unlikely to be manipulated and pre-period reporting error was concentrated on inputs, this means that firms who were too "lazy" to report deductible inputs will be more likely to report them after computerization (Best et al., 2015). This can contribute to the observed decline in reported VAT deductions if firms with low NDS were more likely to be lazy prior to computerization. If firms with higher NDS were more likely to be lazy, then this would attenuate our estimates.

Our results imply that the elasticity of sales with respect to the VAT rate is -0.92.[26] Prior work of other contexts found the following elasticities: Buettner and Madzharova (2021) finds an elasticity of sales with respect to the VAT rate of -0.49 for French restaurants, Benzarti and Carloni (2019) finds an elasticity of -0.16 among Finnish hairdressers, and Kosonen (2015) finds an elasticity of -0.10 for home appliances in EU countries.

Our baseline specification assumes that the treatment effect is increasing with NDS. We can examine this assumption by creating dummy variables for the quartiles of NDS and estimating a specification like the baseline except that the main explanatory variables are the quartile dummy variables interacted with post. We show the VAT and VAT/Sales results are increasing with quartiles of NDS in Appendix Table A.2.

We discuss Panels B through E in Section 4.6.2.

4.3 Heterogeneous Treatment Effects

Exporting vs Non-exporting firms Exporting firms are eligible for VAT rebates before and after the reform. Thus, computerization should have limited effect on exporting firms. To investigate this, we compute the export share for each firm-year by dividing total exports by total revenues. We define non-exporters as firms that always have no exports and exporters as firms that ever have an export share of 50% or greater. Columns (1) and (2) in Panel A of Table 3 show that the positive

[26] See Appendix Section E for calculations.

effect of computerization on VAT is much larger and statistically significant for non-exporting firms. The coefficient in column (1) is 1,892 and is statistically significant at the 1% level. For exporters, it is much smaller in magnitude and statistically insignificant.[27]

In Panel A columns (3) and (4), we divide the sample according to the pre-period sectoral import input share. We divide firms into those that import above and below the pre-2001 -median. We find that computerization increased VAT for both types of firms, but the increase is much larger for firms that import relatively little.

The estimates show that the reform increased VAT more for firms with less trade exposure and go against the concern that our findings are confounded by changes in global trade patterns. If that were the case, omitting the sectors that import or export more should weaken our results.

State-Owned versus Private Firms Given the difference in the amount of government attention and political connections between state-owned and privately owned firms, we divide the sample by ownership using the same ownership definition as in the earlier robustness exercises. The estimates in Table 3, Panel A columns (5) and (6) show that the estimates are statistically larger for privately owned firms than for state-owned firms. This could mean that private firms evaded more VAT prior to the computerization, or that state-owned firms had more leeway to evade after the reform due to their political connections to local tax officials.

Firm Size In Table 3, Panel B, columns (1) and (2), we allow the effects of computerization to vary by firm size. This is motivated by recent studies which find that firm size influences evasion (Bachas et al., 2019; Kleven et al., 2016b). We divide the sample into firms with average 1998-2001 total revenues that are above and below the sample median of this measure. The impact of computerization is similar for large and small firms.[28] Note that the firms in our sample are all very large. If evasion differs for very small firms, we would not observe that in our data.

Pre-period County VAT Revenue Share In Table 3, Panel B, columns (3) and (4), we examine whether the treatment effect differs by the extent of pre-period county VAT revenue share. We divide the baseline sample by the 2001 share of county-level revenue from VAT. We find that counties with lower pre-period VAT revenue shares exhibit a moderately larger treatment effect.

[27] Export shares are calculated using our data. Imported input shares are calculated using Chinese Customs Administration data. Note that the sample median export share is zero, which is why the subsample in Table 3 column (2) is much larger than that of column (3). During the time period of study, the customs data were not linked automatically to the computerized VAT data (State Administration of Taxation, 2004). Cross-checking across the VAT and customs tax systems began in 2017 (State Administration of Taxation, 2017).

[28] We also divide the sample according to the share of fixed assets for the median firm in a sector and find no difference. These results are not presented for brevity.

Distance to the End Consumer Earlier studies of other contexts have found that the self-enforcing incentives of VAT differ for upstream firms than those closer to the consumer (Almunia and Lopez-Rodriguez, 2018; Mittal and Mahajan, 2017; Naritomi, 2019; Pomeranz, 2015, e.g.,).[29] We use a sector-level measure of distance from the final consumer and test whether computerization increases VAT more for downstream firms. In Table 3 Panel B columns (5) and (6), we find that downstream firms exhibit a slightly larger treatment effect, but the difference with upstream firms is not statistically significant. One reason for this muted difference could be that the overall variation in distance from the final consumer may not be large among large manufacturers. Our sample of large manufacturing firms does not include firms that typically interact with consumers directly, like retailers or service firms, and the pairwise correlation between sectoral "upstreamness" and sectoral NDS is small and imprecise, at 0.0316 with $p = 0.2461$.

4.4 All Firms

To estimate the aggregate impact of computerization, we estimate the baseline with the full sample of firms that includes entry and exit. We replace firm fixed effects with sector fixed effects. We find qualitatively and quantitatively similar results. The coefficient on VAT in Table 7 column (5) is $1,634$ and statistically precise at 1% level. It is similar to the baseline coefficient of $1,839$.

We use the full sample estimates to calculate that the computerization of VAT contributed to 13.7% of average VAT growth from 1998 to 2007 and 11.65% of China's VAT revenues in 2000.[30]

Note that the full sample estimates are also interesting because they go against the possibility that firms split into smaller firms to fall below the VAT threshold and pay a lower rate.[31] Splitting would be consistent with the observed reductions in production after computerization. This is unlikely to occur for our sample of large manufacturing firms. Falling below the threshold for VAT would trigger immediate official scrutiny for such large firms. Our full sample estimates support this prior. If firms were splitting, we would expect the full sample VAT result to be smaller in magnitude than that of the balanced panel.

4.5 Changing Sectors

Firms could have also shifted to sectors with lower effective VAT burdens. We investigate this by examining an indicator for whether a firm switched sectors after the reform.[32] Table 7 column (6)

[29] Also, see Slemrod (2007) for a discussion.

[30] See Appendix Section E for calculations.

[31] Onji (2009) finds that large firms split into smaller ones to avoid VAT payment in Japan.

[32] Note that our baseline measure of sector is time-invariant; we use each firm's first observed sector. The baseline non-deductible measure is assigned using this time-invariant measure. The 4-digit sector ID is assigned by the NBS official based on the share of production of each of the the top three products of the firm.

shows that computerization increased the probability of changing sectors in the balanced panel of firms. The result is similar if we use a Logit specification (column 7). The change in firm size and sectors can reflect real and/or reporting changes. We will discuss this more in Section 5.2.

4.6 Robustness

4.6.1 Omitted Variables

WTO Entry The main caveat for identification is omitted variables. An important and potentially confounding event was China's entry into the WTO in 2001 and the ensuing changes in tariffs and trade flows. Though the economy-wide effect of entry into the WTO is absorbed by year fixed effects, the event could still confound our estimates if entry differentially changed VAT rebates, sales, or productivity for firms with high versus low NDS.

We investigate this possibility in several ways. First, recall our earlier result that computerization has little effect on exporting firms. This is reassuring and supports our interpretation that the baseline is not confounded by trade exposure. Second, we control for import tariffs, export VAT rebates and export duties for each sector and year.[33] Table 4 Panel A column (2) shows that the results are very similar in magnitude to the baseline. Note that the number of observations changes slightly because of the limited availability of the tariff data. Third, we address sector-specific differences in export growth by controlling for average export growth rates in each sector in the pre-reform years interacted with year fixed effects. The coefficient in Panel A column (3) is very similar to the baseline. Third, we control for the total amount of imports and exports in each four-digit Chinese Industrial Code sector and year.[34] The estimate in Panel A column (4) is very robust to these additional controls. Panel A column (1) reports the baseline for comparison.

State and Private Ownership Another relevant policy change during our period was the privatization of state-owned firms, often referred to as "enterprise reforms", which took place during 1998-2003. The manufacturing sector transitioned from mostly publicly (state) owned to partly privately (not state) owned and some state firms closed down entirely.[35] To avoid potentially confounding effects from firm entries and exits, our analysis focuses on a panel of firms that exist throughout the period of our study.

We also address this by controlling for ownership interacted with year fixed effects. This addresses the possibility that privately owned firms and state-owned firms may have evolved differently over time or that state-owned firms were affected by the reform differently from privately

[33] Rebate data are from Garred (2018). We use the method presented in Fan et al. (2015, 2018) to obtain output and input tariffs.

[34] These data are reported by China's General Administration of Customs, 1998-2007.

[35] See, for example, Hsieh and Song (2017) for a detailed discussion.

owned firms. For example, the enterprise reforms are usually considered to have taken place during 1998-2003. During this period, many state-owned firms were restructured, shut down, or privatized (e.g., Hsieh and Song, 2017).[36] One may naturally wonder whether such restructuring confounds the VAT reform that we study. Panel A column (5) shows that the estimates when controlling for ownership-year fixed effects are very similar to the baseline.

Competition Table 4 Panel A column (6) shows that our estimates are very similar if we control for the competitiveness of the sector measured using the Herfindahl-Hirschman Index (HHI) variable interacted with year fixed effects, which has been shown by Cai and Liu (2009) to influence corporate income tax evasion.

Province-Specific Policies To address the possibility that there are province-specific policy changes or differences in the implementation of the reform (e.g., some provinces used the linked transaction database before others), 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. In 2004, the central government changed how it split the burden of VAT export rebates with province and local governments (Chandra and Long, 2013; Bai and Liu, 2017). Both reforms are national policy changes, but may have different effects across provinces depending on the degree to which the province relied on agricultural taxes or VAT.

Another potential concern arises from the granting of preferential corporate income tax rates to Western provinces in 2001.[37] To the extent that firms substitute tax evasion between VAT and corporate income tax, this could confound our estimates.

One may also be concerned that prices change differentially across provinces since we deflate the variables with a national deflator.

To address the concern of province-year-specific confounders, we control for province-year fixed effects. Panel A column (7) shows that our results are robust.

VAT Pilot Provinces As we discussed in Section 2, further changes in VAT policy made in 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, 2011; Liu and Mao, 2019; Liu and Lu, 2015). To investigate whether our main results are confounded by the

[36] We categorize official state-owned firms, collective ventures, and joint ventures as *state-owned* firms. We categorize private enterprises and limited-liability companies as *private* firms.

[37] The Western provinces are Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaaxi, Gansu, Ningxia, Qinghai, Xinjiang, Inner Mongolia and Guangxi.

pilot, we omit all observations from these provinces starting in 2004. Panel B column (1) of Table 4 shows that the resulting estimate is very similar to the baseline.

Local Enforcement We also consider the possibility that the distance between a firm and the county seat (where tax officials have offices) influences its propensity and ability to evade VAT Fan et al. (2020). We address the concern that distance is correlated with NDS by controlling for the interaction of the (travel) distance to the county seat and year fixed effects. The estimates in Panel B column (2) are similar to the baseline.[38]

Relatedly, in Panel B column (3), we control for the pre-period share of county revenues from VAT to address the possibility that counties relying more on VAT revenues in the pre-period may have been different in unobservable ways. The coefficient and precision are similar to the baseline.

Within-Sector Variation In Panel B column (4), we address the possibility that the I-O tables may have used sector-level averages to impute input and output composition. However, some sectors may have had higher or lower within-sector variation in NDS share. To account for the possibility that high or low-variation sectors are not systematically different, we control for the within-sector standard deviation of firm NDS values. The baseline result remains precise and of similar magnitude.

Correlates of Non-Deductible Share Earlier in the paper, we document several correlates in Table 1. To esnsure that these characteristics do not confound our results, we control for these firm-level characteristics interacted with year fixed effects in Table 4 Panel B column (5). Specifically, we compute each firm's 1998-2000 average value of VAT, VAT deductions, sales, intermediate inputs and TFPR and separately interact each with year fixed effects. We find that our main result remains precise, positive, and similar in magnitude.

4.6.2 Measurement Error in NDS

The baseline estimates calculate NDS with data from the 1997 Chinese I-O Table to capture real differences across sectors that would affect the incentives to evade VAT. We assumed that this measure avoided measurement error from the effects of evasion under pre-period Chinese tax rules. For measurement error in NDS to overturn our main finding, it would need to distort the ranking of NDS across sectors. This seems *prima facie* unlikely. Nevertheless, to be cautious, we check the validity of our finding by using non-deductible shares calculated from Mexican and U.S. Input-Output Tables as instrumental variables. The logic is that Mexican and U.S. NDS across sectors

[38] We have fewer observations in this exercise due to missing addresses for some firms.

will reflect real differences across sectors, but not capture the effects of evasion under pre-period Chinese tax rules.

We begin by using NDS constructed from the 2000 I-O tables of Mexico, another middle-income economy, as an instrument.[39] Table 2 Panels B and C present the 2SLS and reduced form results. They are similar to the baseline in sign and statistical precision for VAT deductions, VAT payment and VAT as a share of sales. The magnitudes are, if anything, larger. Next, we use data from the 2007 U.S. I-O Tables to construct an alternative instrument. We use 2007 because it is the year that reports data at a disaggregated level (405 sectors), which allows for a better mapping to the Chinese tables. Table 2 Panels D and E present the 2SLS and reduced form estimates. The signs are consistent with the main results. The magnitudes are larger and statistical precision varies across columns. These estimates indicate that the main OLS results are not likely due to measurement error in the explanatory variable.

In Appendix Table A.3, we test whether the 2SLS and reduced form estimates using Mexican and U.S. NDS are confounded by trade exposure between China and these two countries. To do so, we sort sectors by trade exposure, as measured by the ratio of total bilateral trade between Mexico and China (imports plus exports) to total production in Mexico for that sector and year. Then, we omit from the sample the top 25% most exposed sectors. We repeat this process for U.S. to China trade flows. We find that the main results are robust to omitting sectors highly exposed to bilateral trade.

4.6.3 Random Permutations of NDS

To test whether our baseline estimates are spuriously generated by the distribution of sectoral NDS, we perform a random permutation test. We generate counterfactual sector-level NDS shares using the distribution of values in the true data and re-estimate Baseline Equation 3. We perform 500 iterations for the outcome variables: VAT, sales, employees, intermediate inputs and TFPR (DLW) and plot histograms of the coefficients of $\widetilde{NDS}_s \times Post_t$ in Appendix Figure A.2. We then perform an analogous permutation for the timing of treatment years. For each of the five outcomes above, we randomly reassign the introduction of computerization across the years in our sample and estimate the baseline regression for 500 iterations. The resulting distributions of counterfactual coefficients are presented in Appendix Figure A.3. We find that our baseline estimates are highly unlikely to be generated by random chance.

[39] The correlation coefficient between Mexican and Chinese NDS is 0.366, with a standard error of 0.0689. See the Appendix Section F for a detailed discussion of implementation.

4.6.4 Clustered Standard Errors

The baseline estimates cluster the standard errors at the 4-digit sector level. Table 4 Panel B column (6) presents clustered standard errors at the 2-digit sector level. Because there are just 29 2-digit sectors in our sample, we estimate wild bootstrapped standard errors (Cameron et al., 2008; Roodman, 2019). The p-values show that the estimates remain statistically significant at the 1% level.

5 The Dynamic Effects on VAT and Firm Behavior

This section investigates the dynamic effects of computerization, which can change over time. In the short run, computerization will impact a firm's reporting behavior by forcing firms to reduce falsified deductions. This leads to higher VAT payments. This effect continues in the longer run. But with time, a firm can also respond in other ways. The first is to change its economic behavior by adjusting inputs or outputs to avoid VAT. This is hard to do in the short run, but most aspects of production can be adjusted in the longer run. In addition, the firm can learn new ways of evading VAT via two-sided collusion or start to evade other taxes (e.g., payroll taxes, corporate income taxes).

In the analysis below, we present the dynamic estimates and then investigate the plausibility that they are due to changes in economic behavior and/or reporting behavior.

5.1 Real Economic Changes

To guide the investigation of economic effects, we develop a simple model of dynamic firm behavior that generates empirically testable predictions. The model also motivates the firm outcomes that we examine other than VAT.

5.1.1 Conceptual Framework

To understand the potential implications of the increase in taxes on the economic behavior of the firm, we develop a simple theoretical framework. The formal model is presented in Appendix Section G. The intuition is summarized here.

Demand is downward-sloping and short-run supply is upward-sloping. Pre-tax prices and tax-exclusive prices are trivially equal in period 0, $q_0 = p_0$. When the tax, τ, is imposed, the supply shifts upwards by the amount of the tax, since the marginal cost of production has increased by τ. This shift increases the pre-tax equilibrium price to $q_1 > q_0$. The tax-exclusive price received by producers is p_1, with $q_1 = (1+\tau)\, p_1$. The figure shows that the tax-exclusive 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 2 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 tax-inclusive price will be $q_2 > q_1 > q_0$, while the long-run tax-exclusive price will be $p_2 = p_0$. Figure 2 illustrates the key intuition.

The simple 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 calls 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 additional 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 that of periods zero and one, such that $0 = \text{taxes}_0 < \text{taxes}_2 < \text{taxes}_1$.[40] 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, σ, is greater than 1, sales decline each period, $q_2y_2 < q_1y_1 < q_0y_0$. Fourth, labor and intermediate inputs decline each period, $l_0 > l_1 > l_2$ and $k_0 \geq k_1 > k_2$.

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).[41] See Appendix Section G.

Note that our model uses logged quantities for tractability. However, we have thus far presented our results in levels to simplify the accounting exercises in Section 4 and will continue to do so for comparability. The results are robust to using logged dependent variables; these are available upon request.

[40] $\text{Taxes}_t = \tau p_t y_t = \tau q_t y_t / (1+\tau)$.

[41] Note that because our empirical strategy 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.

5.1.2 Dynamic Estimates

The first prediction of the simple model is that tax revenues should increase after the reform, but the long-run level – though still positive – will be slightly lower than the short-run level. We examine this by estimating an OLS equation similar to the baseline, except that we divide the seven-year post-reform period into three sub-periods: 2002-2003, 2004-2005, and 2006-2007. Table 5 column (3) shows that the reform increases VAT payment in all three post-reform periods. The revenues rise from the first period to the second period, which most likely reflects the phasing in of computerization. Then, consistent with the theory, it declines in the third period. However, the decline is statistically insignificant (see the p-value at the bottom of the table) and the magnitude of the coefficient in the third period $(2,047)$ is still large and very similar to the one in the peak period $(2,267)$. These results show that the decline in VAT predicted by the theory is small in magnitude and the positive impact on VAT revenue persists over time.

As with the earlier estimates, we also examine gross VAT and eligible deductions in columns (1) and (2). The estimates for gross VAT are negative, but statistically indistinguishable from zero. The estimates for deductions are negative, statistically significant starting in 2002 and larger in magnitude than the decline in sales. Column (4) examines VAT as a share of sales. The temporal patterns are similar. The magnitudes of the coefficients increase from the first period to the second period, and then remain nearly the same in the third period.

Table 6 examines other firm outcomes. Recall that these outcomes are reported in a different module of the ASIP and recorded from a different set of firm accounting records than the VAT variables. Column (1) examines total sales, which are the annual revenues of the firms. As the sample mean on top of the table shows, this is on average four times larger than VAT eligible sales since it includes revenues from items that are not part of VAT.

In column (2), we find that the component of sales that is not part of the VAT base, which we call "ineligible sales", also declines.[42]

Column (3) examines the number of employees as a proxy for labor input because the large amount of non-wage compensation in large Chinese firms makes the wage bill a poor proxy for labor input. Columns (4)-(5) examine intermediate inputs, first in levels, and then as a share of total inputs. As with sales, this includes intermediate inputs that are not eligible for VAT.

Column (6) examines intermediate inputs which are deductible from VAT as a share of total inputs. The results show that the reform reduced sales, intermediate inputs and deductible input share. The estimate on number of employees is negative but not statistically significant.

The coefficients for sales and intermediate inputs in columns (1) and (4) are statistically sig-

[42]We compute ineligible sales in two steps. First, we take VAT Gross, which is separately reported in the firm data, and divide by 17%. This yields the implied sales tax base. Then, we subtract this implied sales tax base from total sales. The result represents the portion of sales that is not included in the VAT tax base.

nificant in periods 2 and 3. They are also increasing in magnitude over time. The p-values at the bottom of the table show that the increases from period 1 to 3 and from periods 2 to 3 are statistically significant at the 5% level. These results are consistent with the fact that it takes time to adjust real production and that it becomes easier to adjust in the longer run.

In column (7), we examine total factor productivity of revenue (TFPR) calculated with the methodology of De Loecker and Warzynski (2012), which accounts for endogenous markups. We find that the reform increases productivity. Since productivity is intuitively output normalized by inputs, this conceptually reflects the fact that the reform reduced inputs more than it reduced output.

The results are consistent with model predictions.[43]

Figure 3 presents the year-by-year effects to allow us to examine pre-trends and dynamic effects at more granular units of time. For brevity, we focus on the outcomes with clear predictions from the model. We re-estimate the baseline equation except that we replace the interaction term $\widetilde{NDS}_s \times Post_t$ with the interaction of $\widetilde{NDS}_s$ and each year dummy variable. 2001 is the reference year. The coefficients and standard errors are presented in Appendix Table A.4.

Figure 3a shows that there is no pre-trend for VAT. All of the coefficients prior to 2001 are statistically zero. After 2001, the effect of computerization increases over time until around 2005, after which there is a slight decline. These estimates are consistent with the predictions of the model. Moreover, they show that the long-run decline in VAT is quantitatively unimportant.

Figures 3b – 4f examine total sales, the number of employees, total intermediate inputs and TFPR. For each outcome, the estimate is statistically zero prior to computerization and we see a change in the direction predicted by the model after the reform – output, the number of employees and intermediate inputs decline, although the estimates for employees are imprecise. TFPR starts to increase in 2003. The lack of pre-trends supports the parallel trends assumption.

The effect timings are consistent with real economic changes and harder to explain with only a change in reporting behavior. For example, VAT deductions, sales, and intermediate inputs in Tables 5 and 6 all decline steadily in the six years after computerization. Because computerization represented a discontinuous increase in enforcement, the reporting compliance response should take place quite rapidly and not continue in the longer-run.

5.1.3 Robustness

We subject the dynamic effects to the same large set of controls from Section 4.6. Appendix Tables A.6 and A.7 show that these additional controls do not substantially change the magnitudes or the temporal patterns of the estimates. We also show that the estimates are qualitatively similar if we

[43] Appendix Table A.5 presents the average effects of computerization on firm outcomes for comparison.

instrument for the Chinese NDS with Mexican and U.S. NDS in Appendix Tables A.8 and A.9. The 2SLS estimate has three endogenous variables (the interactions of Chinese NDS with each of the three time periods) and three instruments (the interactions of Mexican or U.S. NDS with each of the three time periods).

5.1.4 Increasing Exports

In addition to the economic responses described in the simple model, a firm can avoid VAT by increasing export share, since exports were eligible for VAT rebates. In column (1) of Table 7, we find that export shares did not increase due to the treatment.[44] This is consistent with conventional wisdom about the high fixed costs of exporting.

5.2 Reporting Changes

This section investigates the possibility that firms developed new strategies to evade or avoid VAT after computerization, or that increased enforcement in VAT led firms to reallocate their efforts to evade or avoid other taxes. Our investigation is motivated by past studies about taxes in China and the larger literature on VAT in other contexts.

Under-reporting Sales

After computerization increased the difficulty of exaggerating deductibles, firms may have shifted to understating sales. As we discussed earlier, sudden declines in sales triggered audits. To reduce the risk of audits, firms can gradually reduce their sales over time. This could produce patterns similar to the dynamic estimates on sales shown in Table 6 column (1).

To investigate whether new and gradually increasing under-reporting is the main driver of our dynamic estimates on sales, we separately examine sales eligible and ineligible for VAT.[45] Firms have an incentive to under-report eligible sales, but not ineligible sales. In fact, firms had strong incentives to re-classify eligible sales as ineligible sales to reduce VAT and maintain steady overall revenue to avoid audits. Thus, to investigate the role of sales mis-reporting as a method of VAT evasion in the long run, we examine the dynamic effects of computerization on ineligible sales.

Table A.10 column (2) shows that ineligible sales decrease and the decline grows in magnitude and becomes statistically precise five to six years after computerization. This implies that decline in total sales in column (3) is at least partly due to a change in economic behavior. Since ineligible

[44] This result holds if the sample is restricted to firms who ever exported prior to 2001. This result is available upon request.

[45] We compute ineligible sales in two steps. First, we take VAT Gross, which is separately reported in the firm data and divide by 17%. This yields the implied sales tax base. Then, we subtract this implied sales tax base from total sales. The result represents the portion of sales that is not included in the VAT tax base.

sales are only part of the total sales, the results do not completely rule out under-reporting. In practice, it is possible that both mechanisms are at play: over the long run, firms responded to increased tax compliance by adjusting real economic behavior and gradually understating sales.

Two-sided Collusion As we discussed earlier in the Background Section, after the computerization of VAT invoices, evasion required firms in the same value chain to collude. The officials and firm managers that we interviewed did not provide examples of this in China, but in other contexts, studies have documented the possibility of conducting two-sided collusion with *flying invoices* (Waseem, 2020).[46] Intermediate firms would report some of their sales to a retailer as sales to an exporter. Though the retailer loses tax credit from this loss of reported purchases, keeping some input "off the books" would allow it more scope to understate its revenues. For the exporter, additional input costs reduce its tax burden.

This strategy could generate a decline in VAT over time, though it would not directly generate our other results, such as the decrease in sales and ineligible sales or the productivity increase. To directly test whether flying invoices were a form of adaptation in our context, we examine whether the impact of computerization on inputs was more positive for exporting firms. We consider firms with export shares of greater than 0, 0.5, and 0.9. The results presented in Table 8 show that inputs among exporters do not increase. It is therefore unlikely that flying invoices were a major form of adaptation in this context.

Enterprise Income Tax and Payroll Tax

Beside VAT, the two other important taxes paid by firms are the enterprise (corporate) tax and the payroll tax. Firms may evade these taxes more when they find it more difficult to evade VAT. [47] During this period, the enterprise tax was levied on profits, with rates between 15% and 33%, depending on firm ownership (Cai and Liu, 2009; Chen et al., 2021a). In column (2) of Table 7, we find that enterprise tax did not decline in response to VAT computerization. This result remains the same in column (3) when adding province-year fixed effects, which absorb changes in enterprise tax rates awarded to western provinces as part of the 2001 "Develop the West" campaign.

Payroll tax rates were unchanged during the period of our study. They were levied on workers' wages and required employers to contribute 20% for pensions and 6-10% for health care. Direct

[46] See also Naritomi (2019) and Pomeranz (2015).

[47] Off-setting tax evasion has been documented by several recent studies. Li et al. (2021) find that counties that lost more revenues from the abolition of the Agricultural Tax in 2005 experienced increases in VAT and reductions in payroll taxes. They interpret this as evidence of offsetting tax evasion. In other contexts, Carrillo et al. (2017) and Slemrod et al. (2017) find that more accurate reporting of firm revenues did not substantially increase business income tax because firms offset the increase in revenues by reporting more costs. Naritomi (2019) finds no evidence of offsetting in Brazil.

data on payroll tax payments are only reported after 2001, so we test for evasion using firms' payroll tax base: the total wage bill. Column (4) of Table 7 shows that wage bills did not decline after computerization. These results also indicate that there were no large spillovers from VAT computerization onto the enforcement of EIT and payroll taxes.

6 Conclusion

Tax enforcement is a central concern for all governments, particularly those of developing countries. The perennial questions for policymakers are how to improve enforcement and how much firms can offset the enforcement by changing their reporting or economic behaviors.

The results of this paper show that computerizing VAT transactions led to tremendous gains in Chinese government tax revenues. And although firms responded in the long-run by reducing output and moving into sectors with lower VAT liability, the tax revenue gains persisted.

It is important to keep in mind that the estimates of this study are specific to our context. In particular, there are two features of our environment worth noting. The first is that we study very large manufacturing firms. Unlike small firms, they cannot easily exit the formal sector to avoid taxes.[48] The second is that Chinese tax authorities are able to punish firms for tax evasion. The increase in third-party information would be much less useful if it were not backed by credible enforcement. Therefore, our results are most relevant for large firms in middle-income countries that have some degree of state capacity.

For decades, international public finance programs have invested in using new technology to increase state capacity: 75% of tax-related World Bank projects in the 1990s involved record computerization, and 12.8% of the World Bank's Global Tax Program budget in 2021 was still devoted to digitization (World Bank, 2012; World Bank, 2022). Our findings suggest that these initiatives are likely to generate tax revenue gains.

[48] Bruhn and McKenzie (2014) reviews this literature. Also, see dePaula and Scheinkman (2010), which theorizes that taxation could increase formalization in developing countries.

Table 1: Correlates of Non-Deductible Share and Pre-Reform Firm Characteristics

Pre-Reform Sector Mean	Sector-Level Non-Deductible Share
VAT	.1924***
VAT Gross	-.0764
VAT Deductions	-.159**
Sales	-.1443**
Employees	.0071
Wage Bill	.0325
Intermediate Inputs	-.1774**
Export Share	-.0778
TFPR DLW	.2412***

Notes: This table presents the standardized bivariate correlation coefficients between the non-deductible share and the sector mean of key variables measured in 1998-2000. *** p<0.01, ** p<0.05, * p<0.1

Table 2: The Average Effect of Computerization on VAT

	Dependent Variable			
	(1)	(2)	(3)	(4)
	VAT Gross (1,000 RMB)	VAT Deductions (1,000 RMB)	VAT (1,000 RMB)	VAT/Sales
Dep Var Mean	**7,758**	**6,194**	**2,043**	**0.0418**
	A. OLS			
Non-deductible share × Post-2002	-3,974	-6,281***	1,839***	0.0228***
	(2,492)	(2,144)	(568.2)	(0.00579)
Observations	180,103	180,103	180,103	180,103
R-squared	0.628	0.503	0.702	0.570
	B. Mexico: 2SLS			
Non-deductible share × Post-2002	-6,133	-13,313**	4,938**	0.0563**
	(6,634)	(6,108)	(2,242)	(0.0230)
Observations	180,026	180,026	180,026	180,026
Kleibergen-Paap F-statistic	10.63	10.63	10.63	10.63
	C. Mexico: Reduced Form			
U.S. Non-deductible share × Post-2002	-1,258	-2,732**	1,013***	0.0115***
	(1,331)	(1,088)	(385.8)	(0.00385)
Observations	180,026	180,026	180,026	180,026
R-squared	0.628	0.503	0.702	0.570
	D. U.S. 2SLS			
Non-deductible share × Post-2002	-13,545***	-16,575***	2,218	0.0500***
	(5,031)	(4,190)	(1,562)	(0.0143)
Observations	180,103	180,103	180,103	180,103
Kleibergen-Paap F-statistic	32.53	32.53	32.53	32.53
	E. U.S. Reduced Form			
Non-deductible share × Post-2002	-3,428***	-4,194***	561.3	0.0126***
	(1,304)	(1,064)	(384.3)	(0.00331)
Observations	180,103	180,103	180,103	180,103
R-squared	0.628	0.503	0.701	0.570

Notes: The sample is a balanced panel of firms covering 1998-2007. All regressions include firm fixed effects, year fixed effects and the interactions of year fixed effects with average pre-reform firm sales and average pre-reform firm VAT. Standard errors are clustered at the sector level. *** p<0.01, ** p<0.05, * p<0.1 In Panels B (D), the instrument is U.S. (Mexico) non-deductible share x post-2002.

Table 3: The Heterogeneous Effects of Computerization on VAT

	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent Variable: VAT (1,000 RMB)					
	Panel A					
	Non-Exporters (exports/total sales never > 0%)	Exporters (exports/total sales ever > 50%)	Imported input share < median	Imported input share > median	State Owned	Privately Owned
Dep Var Mean	**1790**	**1626**	**2077**	**2009**	**1706**	**2233**
Non-deductible share × Post-2(	1,892***	972.7	2,658***	1,073*	1,381***	2,159***
	(554.4)	(628.5)	(964.4)	(547.1)	(446.7)	(627.0)
Observations	81,825	54,898	90,507	89,596	65,406	64,718
R-squared	0.709	0.623	0.717	0.684	0.759	0.754
	Panel B					
	Sales < median	Sales > median	2001 County VAT Revenue Share > median	2001 County VAT Revenue Share < median	Distance to final consumer < median	Distance to final consumer > median
Dep Var Mean	**1742**	**2340**	**1964**	**2105**	**2044**	**2043**
Non-deductible share × Post-2(	2,676***	2,243**	1313**	2,304***	2,788***	1,203*
	(504.2)	(949.3)	(575.0)	(695.1)	(926.3)	(627.8)
Observations	89,289	90,814	72264	72,439	93,273	86,830
R-squared	0.686	0.707	0.718	0.709	0.717	0.685

Notes: The sample is a balanced panel of firms covering 1998-2007. All regressions include firm fixed effects, year fixed effects and the interactions of year fixed effects with average pre-reform firm sales and average pre-reform firm VAT. Standard errors are clustered at the sector level. *** p<0.01, ** p<0.05, * p<0.1

Table 4: The Average Effect of Computerization on VAT – Robustness to Additional Controls

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Dependent Variable: VAT (1,000 RMB)						
	Panel A						
	Baseline	Export Rebates, Import and Export Duties	Export Growth 1998-2000 x Year FE	Sector-Year Imports and Exports	Ownership Category x Year FE	HHI 1998-2000 x Year FE	Province FE x Year FE
Non-deductible share × Post-2002	1,839***	1,712***	1,858***	1,793***	1,844***	1,848***	1,767***
	(568.2)	(540.8)	(562.1)	(546.1)	(553.7)	(567.2)	(561.2)
Observations	180,103	180,012	180,103	180,103	180,102	180,103	180,075
R-squared	0.702	0.702	0.702	0.702	0.702	0.702	0.706
	Panel B						
	Liaoning, Jiling and Heilongjiang 2004-2007	Firm Distance from County Seat x Year FE	2001 Share of County Revenues from VAT	Sectoral SD of Firm NDS x Year FE	Pre-Reform Firm Correlates x Year FE	2-Digit Sector Clustered SE, Wild Bootstraps	
Non-deductible share × Post-2002	1,834***	1,990***	1,836***	1,624***	1,877***	1,839***	
	(575.0)	(576.0)	(576.3)	(578.6)	(574.8)	[0.008]	
Observations	177,026	158,820	145,036	158,812	180,148	180,103	
R-squared	0.703	0.710	0.711	0.710	0.703	0.702	

Notes: The sample is a balanced panel of firms covering 1998-2007. Column (2) pre-reform correlates are firm-level averages from 1998-2000 of VAT, VAT deductibles, sales, intermediate inputs, and TFPR DLW. Each variable is separately interacted with year fixed effects. All regressions include firm fixed effects, year fixed effects and the interactions of year fixed effects with average pre-reform firm sales and average pre-reform firm VAT. Standard errors are clustered at the sector level. Standard errors are reported in parentheses, while p-values are reported in brackets. *** p<0.01, ** p<0.05, * p<0.1

Table 5: The Dynamic Effects of Computerization on VAT

	Dependent Variable			
	(1)	(2)	(3)	(4)
	VAT Gross	VAT Deductions	VAT	VAT/Sales
Non-deductible share × 2002-2003 ($\beta 1$)	-1,341	-2,743**	1,203**	0.0158***
	(1,432)	(1,081)	(551.9)	(0.00492)
Non-deductible share × 2004-2005 ($\beta 2$)	-4,583*	-5,612***	2,267***	0.0261***
	(2,347)	(2,105)	(594.4)	(0.00696)
Non-deductible share × 2006-2007 ($\beta 3$)	-5,962	-10,388***	2,047***	0.0264***
	(4,299)	(3,774)	(720.8)	(0.00693)
Observations	180,103	180,103	180,103	180,103
R-squared	0.628	0.503	0.702	0.570
H0: $\beta 1=\beta 2$ (p-value)	0.0620	0.0770	0.00700	0.0190
H0: $\beta 2=\beta 3$ (p-value)	0.571	0.0250	0.556	0.919
H0: $\beta 1=\beta 3$ (p-value)	0.216	0.0250	0.147	0.0510

Notes: The sample is a balanced panel of firms covering 1998-2007. All regressions include firm fixed effects, year fixed effects and the interactions of year fixed effects with average pre-reform firm sales and average pre-reform firm VAT. Standard errors are clustered at the sector level. *** p<0.01, ** p<0.05, * p<0.1

Table 6: The Dynamic Effects of Computerization on Firm Behavior

	Dependent Variable						
	Sales (1,000 RMB)	Ineligible Sales (1,000 RMB)	Employees (persons)	Intermediate Inputs (1,000 RMB)	Intermediate Inputs as a Share of Total Inputs (1,000 RMB)		TFPR DLW
					All	Deductible	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dep Var Mean	**58545**	**6776**	**355.2**	**40590**	**0.835**	**0.764**	**6.329**
Non-deductible share × 2002-2003 ($\beta 1$)	-11,020	-3,093	-24.65	-8,237	0.00140	-0.0897	-0.0925
	(7,901)	(4,023)	(47.44)	(5,761)	(0.0182)	(0.0656)	(0.276)
Non-deductible share × 2004-2005 ($\beta 2$)	-26,978**	-4,042	-39.81	-19,923**	-0.0277	-0.224**	2.435***
	(13,228)	(4,860)	(70.87)	(9,702)	(0.0315)	(0.101)	(0.678)
Non-deductible share × 2006-2007 ($\beta 3$)	-50,019**	-16,964***	-40.97	-31,200**	-0.0728	-0.451***	4.937***
	(24,328)	(6,141)	(93.27)	(14,406)	(0.0454)	(0.145)	(1.215)
Observations	180,103	180,103	180,103	180,103	180,103	180,103	180,103
R-squared	0.769	0.306	0.817	0.788	0.639	0.145	0.660
H0: $\beta 1=\beta 2$ (p-value)	0.101	0.820	0.657	0.0920	0.0890	0.0800	<0.001
H0: $\beta 2=\beta 3$ (p-value)	0.0830	0.0290	0.969	0.0900	0.00900	0.0140	<0.001
H0: $\beta 1=\beta 3$ (p-value)	0.0710	0.0290	0.777	0.0600	0.0170	0.00300	<0.001

Notes: The sample is a balanced panel of firms covering 1998-2007. All regressions include firm fixed effects, year fixed effects and the interactions of year fixed effects with average pre-reform firm sales and average pre-reform firm VAT. Standard errors are clustered at the sector level. *** p<0.01, ** p<0.05, * p<0.1

Table 7: The Average Effect of Computerization on Corporate Income Tax, Moving Sectors, Export Share

	Dependent Variable						
	Export Share	Enterprise Income Tax (1000 RMB)	Enterprise Income Tax (1000 RMB), Control for Province-Year FE	Wage Bill (1,000 RMB)	VAT (Full Sample)	Indicator for Sector Change	Indicator for Sector Change (Logit)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dep Var Mean	**0.212**	**603.98**	**603.98**	**3847.5**	**1538**	**0.084**	**0.204**
Non-deductible share × Post-2002	-0.0477	308.1	409.7	338.1	1,634***	0.079**	1.423***
	(0.0493)	(275.1)	(267.7)	(897.7)	(408.7)	(0.035)	(0.419)
Observations	180,103	180,103	180,103	180,103	711,643	161,512	66,933
R-squared	0.834	0.459	0.466	0.733	0.612	0.240	

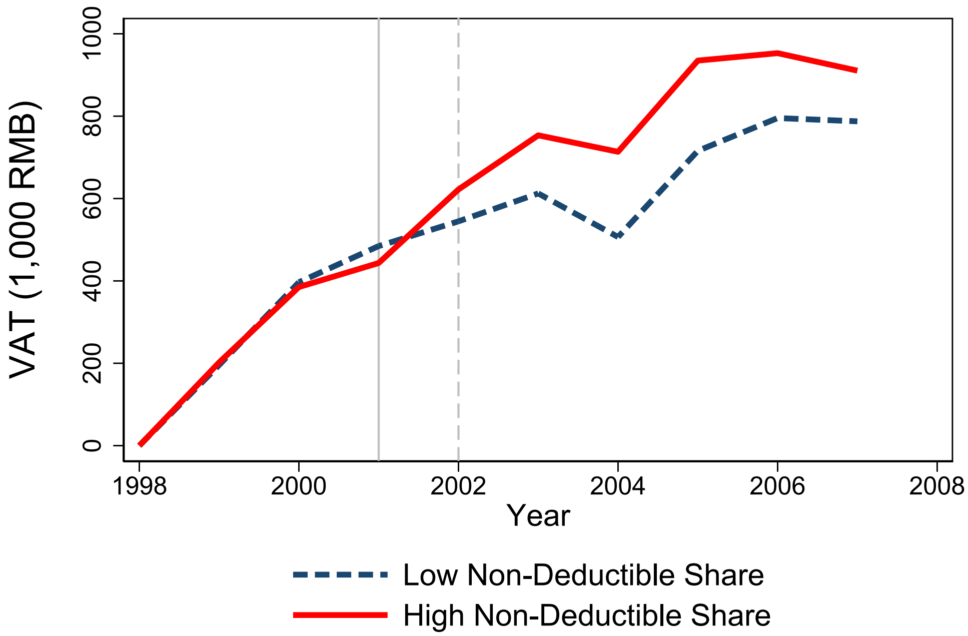
Notes: The sample is a balanced panel of firms covering 1998-2007. All regressions include firm fixed effects, year fixed effects and the interactions of year fixed effects with average pre-reform firm sales and average pre-reform firm VAT. Standard errors are clustered at the sector level. *** p<0.01, ** p<0.05, * p<0.1

Table 8: The Average Effect of Computerization on Inputs Among Exporters

	Export Share > 0		Export Share > 0.5		Export Share > 0.9	
	Total Inputs	Intermediate Inputs	Total Inputs	Intermediate Inputs	Total Inputs	Intermediate Inputs
	(1)	(2)	(3)	(4)	(5)	(6)
Dep Var Mean	**47378**	**40590**	**47378**	**40590**	**47378**	**40590**
Non-deductible share × Post-2002	-20,525	-19,718	-27,253	-24,688	-43,118**	-40,594**
	(18,412)	(17,582)	(19,630)	(18,551)	(21,024)	(19,360)
Observations	65,255	65,255	34,248	34,248	21,055	21,055
R-squared	0.843	0.831	0.846	0.836	0.846	0.839

Notes: The sample is a balanced panel of firms covering 1998-2007. All regressions include firm fixed effects, year fixed effects and the interactions of year fixed effects with average pre-reform firm sales and average pre-reform firm VAT. Standard errors are clustered at the sector level. *** p<0.01, ** p<0.05, * p<0.1

Figure 1: VAT Levels over Time for Firms with Non-deductible Shares Above and Below the Sample Median



Notes: For each of the two groups of firms, the 1998 mean is subtracted from the yearly value.

Figure 2: Illustration of Short- and Long-run Responses to VAT

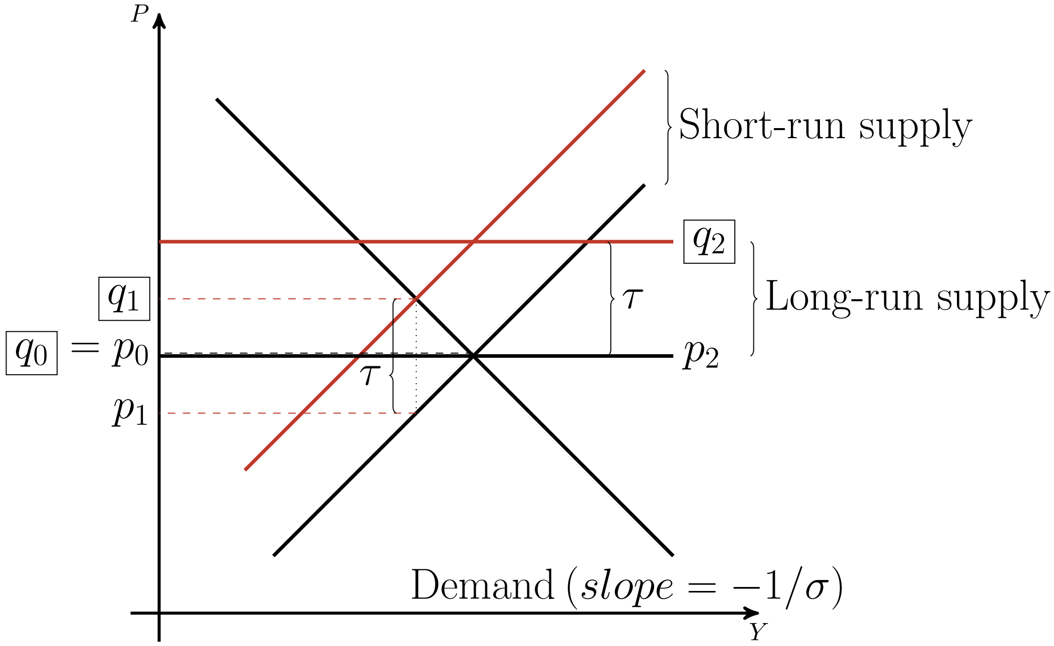
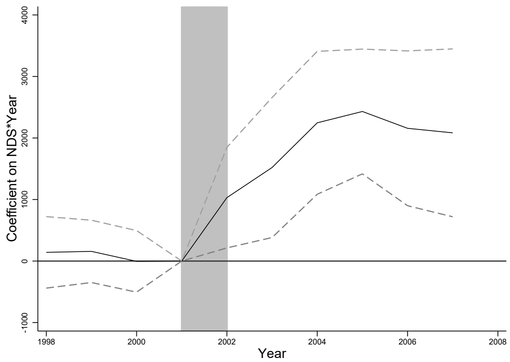
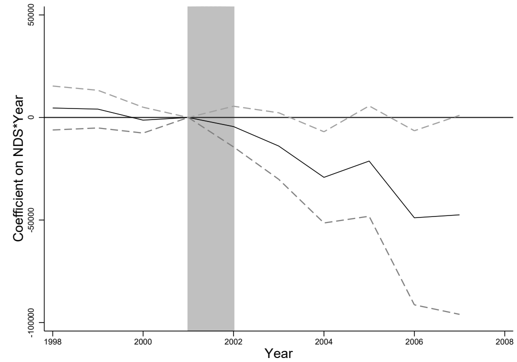


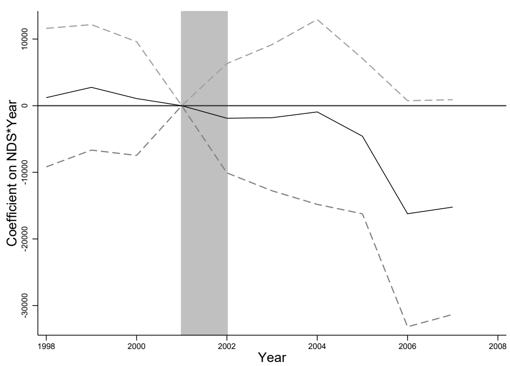
Figure 3: The Yearly Effect of Computerization on VAT, Revenue, Employment, Intermediate Inputs, Productivity

(a) VAT

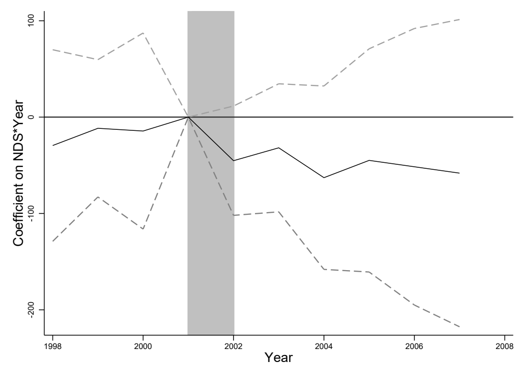


(b) Sales

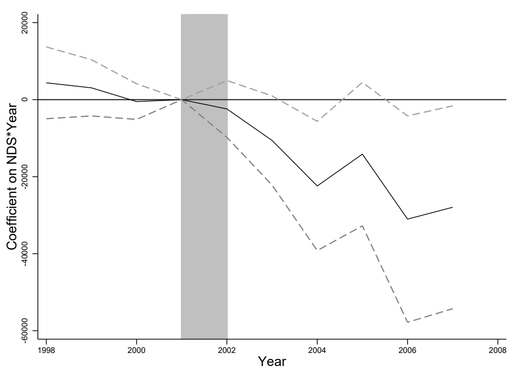




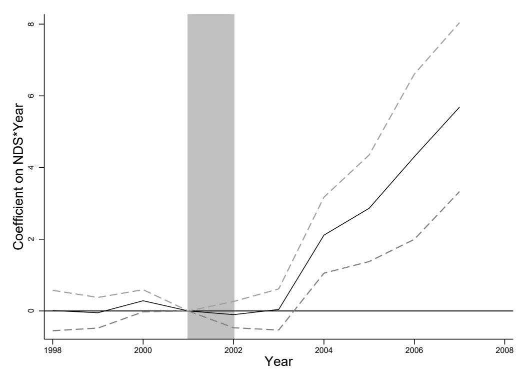
(c) Ineligible Sales



(d) Employees



(e) Intermediate Inputs



(f) TFPR (DLW)

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APPENDIX

A Other Enforcement Mechanisms (Audits)

The Chinese State Administration for Taxation (SAT) is a large bureaucracy. This fact can be observed in data reported by the China Tax Audit Yearbook Committee (2007). On average, there are $12,688$ tax officials per province during the period that we study. Notably, it did not decline after computerization. On average, the SAT conducted $22,999$ audits per province per year.[49]

The China Tax Audit Yearbook Committee (2007) also reports the number of audits that indicate problematic behavior and the number of cases that are fined. On average, the percentage of problematic cases before computerization is 7.7% of all filings (China Tax Audit Yearbook Committee, 2007). However, very few of these are prosecuted and the fines are moderate. For example, in 1997, the penalty as a share of the SAT's estimate of unpaid taxes was below 5%, which was lower than the interest rate (China Tax Audit Yearbook Committee, 2002); in 2002, among the 112,984 tax-fraud cases investigated by tax officials, only 2,658 cases were prosecuted (China Tax Audit Yearbook Committee, 2003). This is reportedly due to the difficulty of providing conclusive evidence and the inability of the tax authority to accurately estimate the amount of evasion without the true transaction amounts or linked transactions.

Additionally, we test whether the allocation of tax officials changed after computerization in Appendix Table A.11. 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 province average non-deductible share, as well as other variables that might 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.[50] The data are at the province and year level. To focus on cross-province variation, we control for year fixed effects.

Column (1) shows pre-2002 correlations. The coefficient for province average non-deductible 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, have a higher population, and have a greater firm density have more tax officials.[51]

[49] The personnel data are reported by the *Tax Yearbooks of China*; the audit rate data are reported by the *Tax Audit Yearbooks of China*.

[50] 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.

[51] Since we also control for province size, we interpret the coefficients on population and firms as the effect of

Note that the R-squared in column (1) is 0.875, implying that our crude controls explain 87% of the cross-province variation in tax personnel. Moreover, the standardized coefficient for non-deductible share, which estimates the effect in terms of standard deviations, shows that a one standard deviation increase in VAT share reduces the number of tax officials by 0.28 standard deviations. This is sizable in terms of magnitude.

In column (2), we examine the post-computerization period. The estimates share signs, though the negative correlation between province non-deductible share and tax officials somewhat attenuates after 2002 to a standardized beta coefficient of -0.07.

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 may have been some change in the allocation of tax officers after computerization was introduced.

B 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 were 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, books, fertilizers, and salt) 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, capital (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, experimented with variants of VAT reforms in eight sectors in 2004 that allowed for deductions of fixed asset purchases. However, this did not affect other regions until 2009.

population and firm densities.

C Data

The unit of observation in the *Annual Survey of Industrial Production* (ASIP) is the firm. Because of varying English translations, these data are referred to also as the Census of Manufacturing Firms or the Annual Survey of Manufacturers. Subsidiaries are coded as separate entities as long as they are unique legal units.[52] The inclusion and exclusion criteria for non-state-owned firms are asymmetric. The dataset includes all state-owned manufacturing firms (regardless of size) and non-state manufacturing firms with sales greater than five million RMB (603,865 USD).

The five-million RMB revenue threshold for non-state-owned firms is not systematically imposed: we observe non-state-owned firms below this threshold (with no apparent pattern in firm attributes). To avoid selective sampling, we impose a uniform cutoff and drop all observations with less than five million RMB (603,865 USD) in revenues.

Otherwise, we follow the standard procedure for cleaning the ASIP data, as first done by 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 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.

We construct measures of non-deductible share for several countries using the World Input-Output Tables (Dietzenbacher et al., 2013; Timmer et al., 2016). We use input-output tables from the year 2000 to construct these alternative country non-deductible shares, as that is the first available year for which the tables are reported with 56 sectors. For years prior to 2000, the World Input-Output Tables are reported at an aggregation of 35 sectors. We create a correspondence between the 56 input sectors and whether each sector would legally be considered a non-deductible input type under Chinese tax law in the year 2000. Then, we compute the sector-and-country-specific share of each industry's inputs that are not deductible.

D Productivity Estimation

We estimate total factor revenue productivity (TFPR DLW) using the method of De Loecker and Warzynski (2012), which is itself based on the method of Ackerberg et al. (2015).

Productivity is obtained as a residual from a value-added production function for each two-digit sector in the Chinese Industrial Codes. We deflate the nominal values of output and inputs separately using sector-level price indices. For the production function, we assume a translog

[52] For regulatory reasons, most subsidiaries are separate legal entities in China.

form, $y = \beta_{1l}l + \beta_{1k}k + \beta_{2l}l^2 + \beta_{2k}k^2 + \beta_{1lk}lk$ as do De Loecker and Warzynski (2012) for their specification IV. They show that productivity is highly robust to the choice of production function. We replicate our main results using alternative choices of production function, and results are available upon request.

We use log real capital as our measure of capital as in Brandt et al. (2012), intermediate inputs as our measure of material inputs, and number of employees as our measure of employment.

We estimate total factor revenue productivity HK (TFPR HK) in the same manner as Hsieh and Klenow (2009).

E Magnitude Calculations

We benchmark our treatment effect in two ways. First, we multiply the full sample coefficient on VAT, $1,634$, by the difference in NDS between the mean and minimum of the full sample, or $(0.397–0.244) = 0.153$, which yields an average treatment effect of 250.0 thousand RMB. The average in-sample firm VAT bill increased from $3,590$ to $5,416$ thousand RMB from 1998 to 2007, an increase of $1,826$ thousand RMB. Our treatment effect represents 13.7% of the average growth in VAT over our sample.

Another way to benchmark the treatment effect is to compute the share of China's 2000 total VAT revenue it represents. To do so, we multiply the average full sample treatment effect by the average number of firms in the full sample per year, 711,643 firms / 10 years $= 71,164$. We obtain $250.0 \times 71,164 = 17.79$ billion RMB. We then divide this value by China's total VAT revenue in 2000, 455.3 billion RMB, yielding 3.91%. However, this value should be scaled by the share of China's manufacturing sector included in our sample. To obtain this value, we divide the total manufacturing value-added in our full-ASIP cross-section, which equals $1,487,844$ million RMB, by total value-added GDP from manufacturing in 2001, $4,385,430$ million RMB. We find that our sample covers 33.9% of manufacturing in China, as $4,385,430/1,487,844 = 0.339$. We find that our VAT treatment effect represents 11.65% of all VAT revenues in China in 2000.

We also compute these figures for the balanced panel results. We find that the average treatment effect is $1,839 \times (0.398 - 0.244) = 284.3$ thousand RMB. In the balanced sample, the average VAT bill increased from $1,492$ to $2,342$ thousand RMB from 1998 to 2007, an increase of 850 thousand RMB. Therefore, the balanced panel treatment effect represents 33.4% of the increase in VAT over our sample. In the balanced panel, there are $18,010$ firms per year. The total treatment effect is $284.3 \times 18,010 = 5,120,497.5$ thousand RMB, and divided by China's 2000 VAT revenues of 455.31 billion RMB, is 1.12%.

To obtain the elasticity of firm sales with respect to VAT/Sales (the effective VAT rate), we first compute the treatment effect of computerization on sales and on VAT rate. For sales, we take the average balanced panel coefficient on sales, multiply it by the difference between the average and minimum NDS in the sample, and divide by average pre-period sales. We find that computerization decreased firm sales by $-29,501 \times (0.398 - 0.244)/44,301 = -0.077$, or -7.7% percent. The same computation for effective VAT rate yields $0.0228 \times (0.398 - 0.244)/0.042 = 0.083$, or 8.3%. Dividing the treatment effects, we find that firm sales declined by $-8.3/7.7 = -0.92$ percent for every percent increase in the effective VAT rate.

F 2SLS Estimates

To calculate the Mexican non-deductible shares, we use data from the *2000 World Input-Output Table* reports (Dietzenbacher et al., 2013; Timmer et al., 2016). We use the year 2000 as it is the earliest available year with a richer disaggregation of 56 sectors. (For years prior to 2000, the World Input-Output Tables are reported at an aggregation of 35 sectors). We create a correspondence between the 56 input sectors and whether each sector would provide a non-deductible input type under Chinese tax law in the year 2000.

In practice, we consider inputs from agricultural, mining, and manufacturing industries to be materials, and thus deductible under Chinese VAT rules. We treat inputs from service industries, overhead, labor inputs, and value-added to be non-deductible. To obtain the final measure, we sum the input shares 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. For each Mexican output sector s, we compute:

$$\widetilde{NDS}_s^{MEX} = 1 - \sum_{d \in D} Input\ fraction_{sd}, \tag{4}$$

where $Input\ fraction_{sd}$ is the share of inputs required for one unit of production in industry s from all other industries d, and D is the set of the industries providing VAT-deductible inputs.

For the U.S. non-deductible share, we use a very similar procedure. We use data from the *2007 Detailed Input U.S. Tables* (U.S. Bureau of Economic Analysis, 2007). To construct our measure of U.S. NDS, we again map each sector in the input-output tables into two groups, deductible or non-deductible, according to the same rules as above. We then construct the following object, where D represents the set of deductible industries:

$$\widetilde{NDS}_s^{US} = 1 - \sum_{d \in D} Input\ fraction_{sd}. \tag{5}$$

We also note that the Mexican and U.S. NDS may measure Chinese NDS with error, which if classical, will attenuate the results.

G Simple Model

G.1 Benchmark

We present here a simple model that generates all of the main dynamic effects. In the simple benchmark case, we begin by considering 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 (paid by the buyer) is q, and the tax-exclusive price of the output (received by the producer) 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 the 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 taxes 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 a third that can never be changed. All the key results hold.

G.1.1 Period 0

Consider the firm's cost minimization problem in period 0:

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

The first order conditions are $[k] : r = \eta \alpha k^{\alpha-1} l^{1-\alpha}$ and $[l] : w = \eta(1-\alpha) k^{\alpha} l^{-\alpha}$. These conditions yield the optimal capital-labor ratio $\frac{k_0}{l_0} = \frac{\alpha}{1-\alpha}\frac{w}{r}$. Marginal costs are therefore $C_0'(y) = \eta = \frac{r}{\alpha k^{\alpha-1} l^{1-\alpha}}$, and in equilibrium, we have $C_0'(y_0) = \frac{r}{\alpha\left(\frac{\alpha}{1-\alpha}\frac{w}{r}\right)^{\alpha-1}} \equiv \omega$, where ω does not depend on anything under firm's control.

When firms are perfectly competitive, their tax-exclusive price is equal to their marginal cost, so that $p_0 = C_0'(y_0)$. 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 derive k_0 and p_0 using the above equations.

G.1.2 Short-run equilibrium

Suppose a VAT is introduced. 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

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

which gives $[l] : w = \eta(1-\alpha) k_0^{\alpha} l^{-\alpha}$.Therefore, marginal costs are $C_1'(y) = \eta = \frac{w}{(1-\alpha) k_0^{\alpha} l^{-\alpha}}$.

Perfect competition gives $p_1 = C_1'(y)$, and demand is determined by the pre-tax price $q_1 = (1+\tau) p_1$, so the equilibrium condition is $y_1^{-1/\sigma} = q_1 = (1+\tau) C'(y_1)$.

We wish to derive the effect of taxation on inputs, prices, sales, tax revenues, and TFPR. The sales that we observe in the data are qy; tax revenues are $\tau p y$; 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 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 derive l_1. From the previous equation, we obtain $\left[k_0^{\alpha} l_1^{1-\alpha}\right]^{-1/\sigma} = (1+\tau) \frac{w}{(1-\alpha) k_0^{\alpha} l_1^{-\alpha}}$.

G.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 $\frac{k_2}{l_2} = \frac{\alpha}{1-\alpha} \frac{w}{r} = \frac{k_0}{l_0}$. It follows that $C_2'(y_2) = C_0'(y_0) > C_1'(y_1)$, so $p_2 = p_0 > p_1$.

Since $q_2 = (1+\tau) p_2$, $q_1 = (1+\tau) p_1 > p_0$, and $q_0 = p_0$, we also find that $q_2 > q_1 > q_0$ and $TFPR_2 > TFPR_1 > TFPR_0$.

Remark 2. *Intuitively, 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-exclusive 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 $y_2 = [(1+\tau) p_2]^{-\sigma} < [(1+\tau) p_1]^{-\sigma} < y_1$, so $y_2 < y_1 < y_0$.

Sales are $qy = q^{1-\sigma}$. Therefore, if $\sigma > 1$, $q_2^{1-\sigma} < q_1^{1-\sigma} < q_0^{1-\sigma}$,and $\text{sales}_2 < \text{sales}_1 < \text{sales}_0$.

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 rises, which implies that sales, qy, fall. Since tax revenues are* $\frac{\tau_t}{1+\tau_t} \times sales_t$, *it first increases between periods 0 and 1 (since taxes are increased from 0 to* τ*) and then falls between periods 1 and 2 (since sales fall between periods 1 and 2).*

Finally, we examine how labor responds. We already know $l_0 > l_1$ and $l_0 > l_2$, so 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

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

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

It holds that $k_2 < k_0$ (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, $l_0 > l_1 > l_2$.

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. However, there is an offsetting effect in this setting, as the pre-tax price increase drives higher input purchases. Final demand determines which of these forces dominates: if demand is highly elastic, the first force is stronger, and labor will fall monotonically.*

G.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.

G.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. Firm profits without VAT are $qy - rk - wl - zx$ and profits with VAT tax τ are $(1-\tau)\,[qy - zx] - rk - wl = (1-\tau)\,qy - rk - wl - (1-\tau)\,zx$.

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

G.2.1 Period 0

Consider the cost function in period 0:

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

The first order conditions are $[k] : r = \omega\alpha k^{\alpha-1} l^{1-\alpha-\beta} x^{\beta}$, $[l] : w = \omega(1-\alpha-\beta) k^{\alpha} l^{-\alpha-\beta} x^{\beta}$, and $[x] : z = \omega\beta k^{\alpha} l^{1-\alpha-\beta} x^{\beta-1}$. The optimal input ratios and therefore $\frac{k_0}{l_0} = \frac{\alpha}{1-\alpha-\beta}\frac{w}{r}$ and $\frac{x_0}{l_0} = \frac{\beta}{1-\alpha-\beta}\frac{w}{z}$.

Marginal costs are $C_0'(y_0) = \omega_0 = \frac{w}{(1-\alpha-\beta) k_0^{\alpha} l_0^{-\alpha-\beta} x_0^{\beta}} = \frac{w}{(1-\alpha-\beta)\left(\frac{k_0}{l_0}\right)^{\alpha}\left(\frac{x_0}{l_0}\right)^{\beta}} = \frac{w}{(1-\alpha-\beta)\left(\frac{\alpha}{1-\alpha-\beta}\frac{w}{r}\right)^{\alpha}\left(\frac{\beta}{1-\alpha-\beta}\frac{w}{z}\right)^{\beta}}$.

Competitive firms set the tax-exclusive 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 $rk_0 = \alpha q_0 y_0$, $zx_0 = \beta q_0 y_0$, and $wl_0 = (1-\alpha-\beta) q_0 y_0$. Finally, quantities are determined by the downward sloping demand curve, $y_0 = q_0^{-\sigma}$.

This equation gives $\left(\frac{k_0}{l_0}\right)^{\alpha}\left(\frac{x_0}{l_0}\right)^{\beta} l_0 = \left[\frac{w}{(1-\alpha-\beta)\left(\frac{k_0}{l_0}\right)^{\alpha}\left(\frac{x_0}{l_0}\right)^{\beta}}\right]^{-\sigma}$, which simplifies to $l_0 = \left(\frac{w}{1-\alpha-\beta}\right)^{-\sigma}\left(\frac{k_0}{l_0}\right)^{\alpha(\sigma}$

Substitution yields:

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

It then follows that

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

G.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 $(1-\tau)[qy - zx] - rk - wl = (1-\tau) qy - rk - wl - (1-\tau) zx$, so the cost minimization problem is:

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

The tax-exclusive price is equal to the marginal cost, so that $(1-\tau)q_2 = C_2'(y_2) = \omega_2 \Longrightarrow q_2 = \frac{C_2'(y_2)}{1-\tau} = \frac{\omega_2}{1-\tau}$. The optimal input ratios are therefore $\frac{k_2}{l_2} = \frac{\alpha}{1-\alpha-\beta}\frac{w}{r}$ and $\frac{x_2}{l_2} = \frac{\beta}{1-\alpha-\beta}\frac{w}{(1-\tau)z}$. Solving for wage, we obtain $\omega_2 = \frac{w}{(1-\alpha-\beta)\left(\frac{k_2}{l_2}\right)^{\alpha}\left(\frac{x_2}{l_2}\right)^{\beta}} = \frac{w}{(1-\alpha-\beta)\left(\frac{\alpha}{1-\alpha-\beta}\frac{w}{r}\right)^{\alpha}\left(\frac{\beta}{1-\alpha-\beta}\frac{w}{(1-\tau)z}\right)^{\beta}}$ and

$$\omega_2 = (1-\tau)^{\beta}\,\omega_0.$$

Finally, $y_2 = q_2^{-\sigma} = \left(\frac{\omega_2}{1-\tau}\right)^{-\sigma}$ gives $\left(\frac{k_2}{l_2}\right)^{\alpha}\left(\frac{x_2}{l_2}\right)^{\beta} l_2 = (1-\tau)^{\sigma}\left[\frac{w}{(1-\alpha-\beta)\left(\frac{k_2}{l_2}\right)^{\alpha}\left(\frac{x_2}{l_2}\right)^{\beta}}\right]^{-\sigma} \Longrightarrow$ $l_2 = (1-\tau)\left(\frac{w}{1-\alpha-\beta}\right)^{-\sigma}\left(\frac{k_2}{l_2}\right)^{\alpha(\sigma-1)}\left(\frac{x_2}{l_2}\right)^{\beta(\sigma-1)}$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 ω earlier.

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

$$taxes_2 = \tau[q_2y_2 - zx_2] = \tau[q_2y_2 - \beta q_2y_2] = \tau(1-\beta)q_2y_2 > 0 = taxes_0.$$

■

G.2.3 Period 1

Now consider the period 1 problem. We assume that intermediate goods can be adjusted in period 1, which simplifies the analysis.[53]

We have

$$\begin{aligned} C_1(y) &= \min_{l,x} rk_0 + wl + (1-\tau)zx, \\ s.t.\ y &= k_0^{\alpha} l^{1-\alpha-\beta} x^{\beta}. \end{aligned}$$

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

$$q_1 = \frac{C_1'(y_1)}{1-\tau} = \frac{\omega_1}{1-\tau}.$$

Hence, we have

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

[53] If they cannot, there is a lot more algebra involved although the result about taxes will hold under additional assumptions about the parameters.

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

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

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

Similarly, the anaous 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

$$\frac{zx_1}{q_1 y_1} = \frac{zx_2}{q_2 y_2} = \beta,$$

it becomes

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

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

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

■

G.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 and each firm produces a differentiated good.[54] 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.

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 $w = 1$.

[54] We assume that the variety set is [0,1] because we assume that $y = Y$ and $q = Q$.

G.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 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

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

Note that ω_0 has the same meaning as before: the marginal cost of producing an extra unit of a good.

In equilibrium, since all firms are identical, we have

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

Therefore, the last two optimality conditions become

$$\begin{aligned} q_0 &= \lambda_0 + \omega_0, \\ q_0 &= \lambda_0 \varepsilon. \end{aligned}$$

This gives us

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

This equation is the standard condition that the optimal price is equal to a markup $\frac{\varepsilon}{\varepsilon-1} > 1$ times the marginal cost, ω_0. As $\varepsilon \to \infty$, 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

$[l] : w = \omega(1-\alpha)k^{\alpha}l^{-\alpha}$, $[k] : r = \omega\alpha k^{\alpha-1}l^{1-\alpha}$, $[y] : (1-\tau)q = \lambda + \omega$, $[q] : (1-\tau)qy = \lambda\varepsilon\left(\frac{q}{Q}\right)^{-\varepsilon} Y$.

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

$$\omega_2 = \omega_0.$$

The last two give us

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

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

Finally, the period 1 problem is

$$\max_{q,y,l}\left(1-\tau\right)qy-wl-rk_0.$$

with $[l]: w=\omega\left(1-\alpha\right)k_0^{\alpha}l^{-\alpha}$, $[y]:\left(1-\tau\right)q=\lambda+\omega$, and $[q]:\left(1-\tau\right)qy=\lambda\varepsilon\left(\frac{q}{Q}\right)^{-\varepsilon}Y$.

Note that again we have, $q_1=\frac{\varepsilon}{\varepsilon-1}\frac{\omega_1}{1-\tau}$.

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

G.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

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

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, $\mu\in\left(0,1\right)$. The case $\mu=0$ corresponds to what we have done before: sector 1 is small, so nothing there affects taxes. Here, Π denotes firm profits. 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 normalization, demand is again given by $y=\mu q^{-\sigma},Y=\left(1-\mu\right)Q^{-\sigma}$.

G.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

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

and

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

Demand in the other sector is

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

This allows us to find the rental rate r_0 from

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

G.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 setup 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

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

G.4.3 Period 2

We have, following the same steps as before, $l_2 = \mu\left(1-\tau\right)^{\sigma}\left(\frac{w}{1-\alpha}\right)^{-\sigma}\left(\frac{\alpha}{1-\alpha}\frac{w}{r_2}\right)^{\alpha(\sigma-1)} = \left(1-\tau\right)^{\sigma}\left(\frac{r_2}{r_0}\right)^{\alpha(\sigma-1)} l_0$ and $k_2 = \frac{\alpha}{1-\alpha}\frac{w}{r_2}l_2 = \mu\left(1-\tau\right)^{\sigma}\left(\frac{w}{1-\alpha}\right)^{-\sigma}\left(\frac{\alpha}{1-\alpha}\frac{w}{r_2}\right)^{\alpha(\sigma-1)+1} = \left[\left(1-\tau\right)^{\sigma}\left(\frac{r_0}{r_2}\right)^{\alpha(\sigma-1)+1}\right]\mu\left(\frac{w}{1-\alpha}\right)^{-\sigma}\left(\frac{\alpha}{1-\alpha}\frac{w}{r_0}\right)^{\alpha(\sigma-}$ $\left[\left(1-\tau\right)^{\sigma}\left(\frac{r_0}{r_2}\right)^{\alpha(\sigma-1)+1}\right] k_0$.

Capital in the other sector is $K_2 = \left(1-\mu\right)\left(\frac{w}{1-\alpha}\right)^{-\sigma}\left(\frac{\alpha}{1-\alpha}\frac{w}{r_2}\right)^{\alpha(\sigma-1)+1}$, so the market clearing condition is $\left[\mu\left(1-\tau\right)^{\sigma}+\left(1-\mu\right)\right]\left(\frac{w}{1-\alpha}\right)^{-\sigma}\left(\frac{\alpha}{1-\alpha}\frac{w}{r_2}\right)^{\alpha(\sigma-1)+1} = \bar{k}$. Equivalently,

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

or

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

Lemma 8. *Therefore,* $\left(1-\tau\right)^{\sigma}\left(\frac{r_0}{r_2}\right)^{\alpha(\sigma-1)+1}$ *is strictly increasing in* μ*, and* $\left(1-\tau\right)^{\sigma} \leq \left(1-\tau\right)^{\sigma}\left(\frac{r_0}{r_2}\right)^{\alpha(\sigma-1)+1} \leq 1$*. The left and right relations hold with equality when* $\mu = 0$ *and* $\mu = 1$*, respectively.*

Lemma 9. *Additionally, 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

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

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 this if we redefine all variables as ratios to μ and look at the limit as $\mu \to 0$). In this case, sector 1 is 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.

Table A.1: Sectors with Highest and Lowest Non-Deductible Shares

Lowest Non-Deductible Share		Highest Non-Deductible Share	
(1)	(2)	(3)	(4)
Sector Name	**Non-Deductible Share**	**Sector Name**	**Non-Deductible Share**
Beet Sugar	0.24	Tobacco Leaf Re - Baking	0.60
Cane Sugar	0.24	Other Tobacco Processing	0.60
Frozen Aquatic Products Processing	0.25	Cigarette Manufacturing	0.60
Dry Processing Of Aquatic Products	0.25	Caustic Soda Manufacturing	0.56
Electric Light Source Manufacturing	0.27	Inorganic Acid Manufacturing	0.56
Lamp Holder, Lampholders Manufacturing	0.27	Industrial Ceramics	0.53
Wire And Cable Manufacturing	0.30	Other Ceramics	0.53
Postal Machinery And Equipment Manufacturing	0.30	Other Stationery Manufacturing	0.51
Construction Machinery Manufacturing	0.30	Notebook Manufacturing	0.51
Sewing Machine Manufacturing	0.30	Stationery Manufacturing	0.51
Manufacture Of Special Equipment Not Included In Other Categories	0.30	Lime	0.51
Geological Special Equipment Manufacturing	0.30	Special Chemical Products Manufacturing	0.50
Commercial, Catering, Service Machinery Manufacturing	0.30	Manufacture Of Chemical Products In Forest Products	0.50
Petroleum Products	0.31	Explosives And Pyrotechnic Products Manufacturing	0.50
Viscose Fiber Manufacturing	0.33	Chemical Reagents, Additives Manufacturing	0.50
Acrylic Fiber Manufacturing	0.33	Chinese Herbal Medicine And Chinese Medicine Processing	0.50
Nylon Fiber Manufacturing	0.33	Biological Products	0.50
Polyester Fiber Manufacturing	0.33	Chemical Drug Manufacturing	0.50
Chemical Fiber Pulp Manufacturing	0.33	Manufacture Of Chemical Preparations	0.50
Other Synthetic Fiber Manufacturing	0.33	Books, Newspapers And Periodicals	0.49
Vinylon Fiber Manufacturing	0.33	Packaging And Decoration Printing	0.49
Motorcycle Manufacturing	0.33	Other Printing	0.49
Manufacturing Of Inland Waterways	0.33	Copying Of Recording Medium	0.49
Diving Equipment Manufacturing	0.33	Crude Oil Processing	0.48
Manufacture Of Aids To Navigation	0.33	Bearing Manufacturing	0.48
Motorcycle Parts And Accessories Manufacturing	0.33	Valve Manufacturing	0.48
Manufacture Of Marine Transport Ships	0.33	Casting Manufacturing	0.48
Luggage Manufacturing	0.33	Communication Terminal Equipment Manufacturing	0.48
Leather Leather Garment Manufacturing	0.33	Switching Equipment Manufacturing	0.48
Other Fur Products	0.33	Electronic Computer Manufacturing	0.48
Leather Shoes Manufacturing	0.33	Radar Special Equipment And Components	0.48
Fur Tanning	0.33	Other Electronic Equipment	0.48
Fur Clothing	0.33	Transmission Equipment Manufacturing	0.48
Wool Spinning	0.34	Radar Complete Machine Manufacturing	0.48
Top Processing	0.34	Other Communication Equipment Manufacturing	0.48
Wool Knitting	0.34	Radio And Television Equipment Manufacturing	0.48
Automotive Body Manufacturing	0.34	Asbestos Products	0.48
Special Vehicles And Modified Car Manufacturing	0.34	Other Refractory Products	0.48
Small Car Manufacturing	0.34	Concrete Structural Component Manufacturing	0.48
Passenger Car Manufacturing	0.34	Manufacture Of Waterproof Seal Building Materials	0.48
Heavy Truck Manufacturing	0.34	Building Stone Processing	0.48
Micro - Car	0.34	Asbestos Cement Products	0.48
Ink Manufacturing	0.34	Brick And Tile Manufacturing	0.48
Paint Manufacturing	0.34	Manufacture Of Lightweight Building Materials	0.48
Manufacture Of Organic Chemical Materials	0.34	Cement Products	0.48
Other Organic Chemical Products	0.34	Other Brick, Lime And Light Construction Materials	0.48
Foam And Synthetic Leather, Synthetic Leather Manufacturing	0.34	Other Cement Products	0.48
Other Plastic Products	0.34	Manufacture Of Other Basic Chemical Raw Materials	0.48
Manufacture Of Daily Plastic Sundry Goods	0.34	Optical Glass Manufacturing	0.47
Plastic Shoe Manufacturing	0.34	Other Glass And Glass Products	0.47

Notes: Manufacturing sectors are defined by four-digit Chinese Industrial Codes. Non-deductible share is calculated from 1997 Chinese Input Output Tables. See the text for a detailed description.

Table A.2: The Effects of Computerization on VAT - NDS Quartiles

	Dependent Variable			
	(1)	(2)	(3)	(4)
	VAT Gross (1,000 RMB)	VAT Deductions (1,000 RMB)	VAT (1,000 RMB)	VAT/Sales
Dep Var Mean	**7,758**	**6,194**	**2,043**	**0.0418**
I(NDS 25th - 50th percentile) × Post-2002	-230.9	-199.3	4.119	0.00104*
	(453.2)	(417.9)	(85.59)	(0.000571)
I(NDS 50th -75th percentile) × Post-2002	-797.7*	-1,025***	152.3	0.00348***
	(466.3)	(330.3)	(133.1)	(0.000989)
I(NDS 75th -100th percentile) × Post-2002	-466.0	-836.2**	318.0***	0.00356***
	(423.3)	(361.7)	(107.1)	(0.000921)
Observations	180,103	180,103	180,103	180,103
R-squared	0.628	0.503	0.702	0.570

Notes: The sample is a balanced panel of firms covering 1998-2007. All regressions include firm fixed effects, year fixed effects and the interactions of year fixed effects with average pre-reform firm sales and average pre-reform firm VAT. Standard errors are clustered at the sector level. *** p<0.01, ** p<0.05, * p<0.1 In Panels B (D), the instrument is U.S. (Mexico) non-deductible share x post-2002.

Table A.3: The Average 2SLS Effect of Computerization on VAT – Robustness to Dropping Sectors Highly Exposed to Chinese Trade

	Dependent Variable: VAT	
	(1)	(2)
	Drop Sectors with top 25% (Total Mexico to China Trade Flows) /(Total Mexico Production)	
	2SLS	Reduced Form
Dep Var Mean	**2,037**	**2037**
Non-deductible share × Post-2002	6,221**	1111.7***
	-3,128	-422.9
Observations	148,242	148,242
	Drop Sectors with top 25% (Total U.S. to China Trade Flows) /(Total U.S. Production)	
	2SLS	Reduced Form
Dep Var Mean	**2074**	**2074**
Non-deductible share × Post-2002	3,607**	873.4**
	(1,767)	(374.0)
Observations	137,593	137,593

Notes: The sample is a balanced panel of firms covering 1998-2007. All regressions include firm fixed effects, year fixed effects and the interactions of year fixed effects with average pre-reform firm sales and average pre-reform firm VAT. The instrument is U.S. non-deductible share x Post-2002. Standard errors are clustered at the sector level. *** p<0.01, ** p<0.05, * p<0.1

Table A.4: The Year by Year Effects of Computerization on VAT

	Dependent Variables					
	VAT (1)	Sales (2)	Ineligible Sales (3)	Employees (4)	Intermediate Inputs (5)	TFPR DLW (6)
Non-deductible Share × 1998	141.5	4,621	1,211	-29.48	4,374	0.0114
	(296.4)	(5,464)	(5,303)	(50.71)	(4,759)	(0.287)
Non-deductible Share × 1999	157.5	4,072	2,755	-11.60	3,073	-0.0506
	(258.3)	(4,685)	(4,804)	(36.35)	(3,726)	(0.218)
Non-deductible Share × 2000	-4.821	-1,302	1,074	-14.45	-497.5	0.284*
	(255.3)	(3,211)	(4,357)	(51.91)	(2,361)	(0.157)
Non-deductible Share × 2001	-	-	-	-	-	-
Non-deductible Share × 2002	1,031**	-4,431	-1,882	-45.23	-2,411	-0.104
	(417.0)	(5,061)	(4,186)	(28.94)	(3,760)	(0.187)
Non-deductible Share × 2003	1,520***	-13,922*	-1,800	-31.86	-10,592*	0.0413
	(580.6)	(8,275)	(5,599)	(33.89)	(5,909)	(0.292)
Non-deductible Share × 2004	2,247***	-29,191**	-935.4	-62.86	-22,411***	2.113***
	(592.4)	(11,344)	(7,078)	(48.56)	(8,557)	(0.541)
Non-deductible Share × 2005	2,431***	-21,249	-4,571	-44.91	-14,139	2.863***
	(517.2)	(13,726)	(5,948)	(59.09)	(9,498)	(0.758)
Non-deductible Share × 2006	2,158***	-48,902**	-16,216*	-51.52	-31,018**	4.302***
	(641.8)	(21,652)	(8,656)	(73.21)	(13,668)	(1.176)
Non-deductible Share × 2007	2,084***	-47,468*	-15,217*	-58.15	-27,941**	5.686***
	(695.9)	(24,754)	(8,222)	(81.35)	(13,439)	(1.202)
Observations	180,103	180,103	180,103	180,103	180,103	180,103
R-squared	0.702	0.769	0.306	0.817	0.788	0.660
2002-2007 Joint p-value	<0.001	0.0513	0.401	0.400	0.0383	<0.001

Notes: This sample comprises of a balanced panel of firms during 1998-2007. All regressions include firm fixed effects, year fixed effects and the interactions of year fixed effects with average pre-reform firm sales and average pre-reform firm VAT. Standard errors are clustered at the sector level. *** p<0.01, ** p<0.05, * p<0.1

Table A.5: The Average Effect of Computerization on Firm Behavior

	Dependent Variable						
	Sales (1,000 RMB)	Ineligible Sales (1,000 RMB)	Employees	Intermediate Inputs (1,000 RMB)	Intermediate Inputs as a Share of Total Input		TFPR DLW
					All	Deductible	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dep Var Mean	**58545**	**6776**	**355.2**	**40590**	**0.835**	**0.764**	**6.329**
Non-deductible share × Post-200	-29,501	-8,114**	-35.17	-19,871**	-0.0333	-0.256***	2.445***
	(14,030)	(3,958)	(68.93)	(9,247)	(0.0310)	(0.0930)	(0.658)
Observations	180,103	180,103	180,103	180,103	180,103	180,103	180,103
R-squared	0.769	0.306	0.817	0.788	0.639	0.145	0.653

Notes: The sample is a balanced panel of firms covering 1998-2007. All regressions include firm fixed effects, year fixed effects and the interactions of year fixed effects with average pre-reform firm sales and average pre-reform firm VAT. Standard errors are clustered at the sector level. *** p<0.01, ** p<0.05, * p<0.1

Table A.6: The Dynamic Effects of Computerization – Robustness to Additional Controls

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
	Baseline	Pre-Reform Firm Correlates x Year FE	Export Rebates, Import and Export Duties	Export Growth 1998-2000 x Year FE	HHI 1998-2000 x Year FE	Province FE x Year FE	Sector-Year Imports and Exports	Omit Liaoning, Jiling and Heilongjiang 2004-2007	Ownership Category x Year FE	Firm Distance from County Seat x Year FE	2001 Share of County Revenues from VAT	Sectoral SD of Firm NDS x Year FE	SE Clustered at 2-digit Sector Level, Wildbootstraps
	Panel A: Dependent Variable - VAT												
Non-deductible share × 2002-2003	1,203**	1,266**	1,113**	1,221**	1,217**	1,215**	1,193**	1,202**	1,210**	1,291**	1,138**	1,013*	1,203
	(551.9)	(577.1)	(536.9)	(541.8)	(546.9)	(551.3)	(542.4)	(550.6)	(547.9)	(566.3)	(555.5)	(592.3)	[0.08]
Non-deductible share × 2004-2005	2,267***	2,281***	2,154***	2,287***	2,279***	2,181***	2,236***	2,290***	2,270***	2,424***	2,248***	2,042***	2,267
	(594.4)	(590.7)	(560.4)	(594.1)	(593.7)	(588.3)	(575.4)	(610.8)	(577.4)	(593.8)	(596.7)	(589.8)	[0.004]
Non-deductible share × 2006-2007	2,047***	2,084***	1,905***	2,066***	2,048***	1,905***	1,955***	2,057***	2,053***	2,247***	2,141***	1,811**	2,047
	(720.8)	(714.1)	(697.5)	(713.5)	(722.3)	(701.3)	(697.4)	(734.3)	(699.1)	(724.4)	(735.3)	(727.5)	[0.036]
Observations	180,103	180,148	180,012	180,103	180,103	180,075	180,103	177,026	180,102	158,820	145,036	158,812	180,103
R-squared	0.702	0.703	0.702	0.702	0.702	0.706	0.702	0.703	0.702	0.710	0.711	0.710	0.702
	Panel B: Dependent Variable - Sales												
Non-deductible share × 2002-2003	-11,020	-13,808*	-14,301*	-10,547	-11,020	-7,844	-10,016	-11,231	-10,507	-7,437	-9,588	-7,173	-11,020
	(7,901)	(7,988)	(8,581)	(7,303)	(7,883)	(7,449)	(7,103)	(7,872)	(7,932)	(8,556)	(8,429)	(9,373)	[0.238]
Non-deductible share × 2004-2005	-26,978**	-31,426**	-31,322***	-26,063**	-27,087**	-24,219*	-25,400**	-25,444*	-25,962*	-22,423	-26,884**	-21,938	-26,978
	(13,228)	(12,740)	(11,092)	(12,113)	(13,257)	(12,609)	(11,331)	(13,283)	(13,497)	(14,041)	(14,120)	(15,013)	[0.204]
Non-deductible share × 2006-2007	-50,019**	-54,417**	-55,247**	-48,720**	-50,440**	-48,600**	-47,848**	-48,391**	-49,041**	-44,970*	-50,134***	-45,400*	-50,019
	(24,328)	(23,524)	(21,476)	(22,652)	(24,395)	(23,300)	(21,964)	(24,142)	(24,362)	(25,174)	(25,756)	(26,293)	[0.246]
Observations	180,103	180,148	180,012	180,103	180,103	180,075	180,103	177,026	180,102	158,820	145,036	158,812	180,103
R-squared	0.769	0.766	0.770	0.769	0.769	0.774	0.769	0.771	0.770	0.783	0.777	0.783	0.769

Notes: The sample is a balanced panel of firms covering 1998-2007. All regressions include firm fixed effects, year fixed effects, and the interactions of year fixed effects with average pre-reform firm sales and average pre-reform firm VAT. Additional controls are stated in the column headings. Standard errors are clustered at the sector level. Standard errors are reported in parentheses, while p-values are reported in brackets. *** p<0.01, ** p<0.05, * p<0.1

Table A.7: The Dynamic Effects of Computerization – Robustness to Additional Controls (Cont.)

	(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Baseline	Pre-Reform Firm Correlates x Year FE	Export Rebates, Import and Export Duties	Export Growth 1998-2000 x Year FE	HHI 1998-2000 x Year FE	Province FE x Year FE	Sector-Year Imports and Exports	Omit Liaoning, Jiling and Heilongjiang 2004-2007	Ownership Category x Year FE	Firm Distance from County Seat x Year FE	2001 Share of County Revenues from VAT	Sectoral SD of Firm NDS x Year FE	SE Clustered at 2-digit Sector Level, Wildbootstraps
	Panel C. Dependent Variable - Intermediate Inputs												
Non-deductible share × 2002-2003	-8,237	-12,139**	-10,393*	-7,893	-8,206	-5,831	-7,579	-8,377	-7,955	-6,831	-8,291	-7,992	-8,237
	(5,761)	(5,691)	(6,159)	(5,321)	(5,750)	(5,355)	(5,213)	(5,740)	(5,780)	(6,042)	(6,081)	(6,309)	[0.200]
Non-deductible share × 2004-2005	-19,923**	-25,182***	-22,870***	-19,283**	-19,927**	-17,793*	-18,880**	-19,120*	-19,275*	-18,268*	-20,523**	-19,054*	-19,923
	(9,702)	(9,533)	(8,419)	(8,878)	(9,721)	(9,340)	(8,282)	(9,863)	(9,872)	(9,996)	(10,114)	(10,328)	[0.238]
Non-deductible share × 2006-2007	-31,200**	-35,969**	-34,765***	-30,426**	-31,390**	-29,882**	-29,745**	-30,278**	-30,704**	-29,296**	-32,304**	-31,206**	-31,200
	(14,406)	(14,096)	(12,723)	(13,361)	(14,434)	(13,903)	(12,983)	(14,359)	(14,420)	(14,799)	(14,890)	(14,892)	[0.202]
Observations	180,103	180,148	180,012	180,103	180,103	180,075	180,103	177,026	180,102	158,820	145,036	180,103	180,103
R-squared	0.788	0.788	0.789	0.788	0.788	0.792	0.789	0.790	0.789	0.802	0.798	0.788	0.788
	Panel D. Dependent Variable - TFPR (DLW)												
Non-deductible share × 2002-2003	-0.0778	-0.290	-0.103*	-0.0795	-0.0772	-0.0636	-0.0832	-0.0771	-0.0752	-0.0594	-0.0844	-0.128	-0.0778
	(0.0601)	(0.303)	(0.0620)	(0.0591)	(0.0602)	(0.0591)	(0.0602)	(0.0601)	(0.0600)	(0.0566)	(0.280)	(0.285)	[0.552]
Non-deductible share × 2004-2005	0.387***	2.036***	0.354***	0.384***	0.388***	0.395***	0.378***	0.389***	0.391***	0.413***	2.452***	2.348***	0.387
	(0.136)	(0.592)	(0.128)	(0.132)	(0.136)	(0.133)	(0.127)	(0.137)	(0.135)	(0.131)	(0.633)	(0.707)	[0.210]
Non-deductible share × 2006-2007	0.863***	4.466***	0.831***	0.858***	0.864***	0.855***	0.847***	0.857***	0.866***	0.891***	4.953***	4.827***	0.863*
	(0.216)	(1.059)	(0.211)	(0.210)	(0.217)	(0.214)	(0.203)	(0.216)	(0.215)	(0.208)	(1.151)	(1.225)	[0.098]
Observations	180,103	180,148	180,012	180,103	180,103	180,075	180,103	177,026	180,102	158,820	145,036	180,103	180,103
R-squared	0.978	0.678	0.978	0.978	0.978	0.979	0.978	0.979	0.978	0.979	0.671	0.660	0.978

Notes: The sample is a balanced panel of firms covering 1998-2007. All regressions include firm fixed effects, year fixed effects, and the interactions of year fixed effects with average pre-reform firm sales and average pre-reform firm VAT. Additional controls are stated in the column headings. Standard errors are clustered at the sector level. Standard errors are reported in parentheses, while p-values are reported in brackets. *** p<0.01, ** p<0.05, * p<0.1

Table A.8: The Dynamic Effects of Computerization on VAT and Firm Behavior – 2SLS with Mexican Non-Deductible Share × Post Periods as Instruments

	Dependent Variables							
	VAT	Sales	Ineligible Sales	Employees	Intermediate Inputs	Intermediate Inputs as a Share of Total Input		TFPR DLW
						All	Deductible	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	A. Mexico: 2SLS							
Non-deductible share x 2002-2003	3,897**	-13,624	7,805	-330.1*	-6,918	0.0728	-42,711*	1.570
	(1,856)	(23,186)	(12,822)	(186.6)	(16,687)	(0.0832)	(21,772)	(0.988)
Non-deductible share x 2004-2005	5,951**	-40,106	3,551	-448.2	-28,726	0.0371	-76,245**	8.863***
	(2,457)	(40,661)	(18,860)	(288.2)	(27,429)	(0.127)	(37,198)	(3.060)
Non-deductible share x 2006-2007	4,972*	-92,153	-43,549*	-626.5	-48,398	-0.0138	-115,524**	11.32***
	(2,831)	(71,783)	(23,913)	(382.2)	(40,201)	(0.185)	(55,667)	(3.550)
Observations	180,026	180,026	180,026	180,026	180,026	180,026	180,026	180,026
Weak-ID F-statistic	0.053	0.127	0.004	0.019	0.073	0.042	0.040	0.079
H0: $\beta1=\beta2$ (p-value)	0.104	0.322	0.766	0.379	0.220	0.529	0.156	0.00300
H0: $\beta2=\beta3$ (p-value)	0.422	0.168	0.0420	0.111	0.289	0.468	0.149	0.0100
H0: $\beta1=\beta3$ (p-value)	0.600	0.188	0.0460	0.189	0.189	0.451	0.103	0.00100
	B. Mexico: Reduced Form							
Non-deductible share x 2002-2003	800.1**	-2,775	1,617	-67.75*	-1,407	0.0150	-8,753**	0.319*
	(320.0)	(4,741)	(2,573)	(37.21)	(3,418)	(0.0172)	(3,610)	(0.171)
Non-deductible share x 2004-2005	1,222***	-8,226	734.1	-91.97	-5,894	0.00761	-15,644**	1.819***
	(418.1)	(8,239)	(3,861)	(59.79)	(5,454)	(0.0261)	(6,582)	(0.307)
Non-deductible share x 2006-2007	1,018**	-18,862	-8,910**	-128.3	-9,906	-0.00281	-23,650**	2.317***
	(517.3)	(14,220)	(4,363)	(78.07)	(8,018)	(0.0378)	(10,573)	(0.465)
Observations	180,026	180,026	180,026	180,026	180,026	180,026	180,026	180,026
R-squared	0.702	0.769	0.306	0.818	0.788	0.638	0.503	0.655
H0: $\beta1=\beta2$ (p-value)	0.0930	0.315	0.764	0.395	0.197	0.523	0.146	<0.001
H0: $\beta2=\beta3$ (p-value)	0.416	0.147	0.0160	0.0980	0.289	0.438	0.160	0.0320
H0: $\beta1=\beta3$ (p-value)	0.601	0.172	0.0180	0.196	0.175	0.429	0.105	<0.001

Notes: The sample is a balanced panel of firms covering 1998-2007. All regressions include firm fixed effects, year fixed effects and the interactions of year fixed effects with average pre-reform firm sales and average pre-reform firm VAT. Standard errors are clustered at the sector level. *** p<0.01, ** p<0.05, * p<0.1

Table A.9: The Dynamic Effects of Computerization on VAT and Firm Behavior – 2SLS with U.S. Non-Deductible Share × Post Periods as Instruments

	Dependent Variables							
	VAT	Sales	Ineligible Sales	Employees	Intermediate Inputs	Intermediate Inputs as a Share of Total Input		TFPR DLW
						All	Deductible	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	A. United States: 2SLS							
Non-deductible share × 2002-2003 ($\beta 1$)	1,995	-29,938	7,015	45.26	-26,755**	-0.0265	-0.558**	0.320
	(1,471)	(18,265)	(10,201)	(130.2)	(13,209)	(0.0508)	(0.242)	(0.694)
Non-deductible share × 2004-2005 ($\beta 2$)	2,709*	-68,169**	27,723	199.9	-54,854***	-0.149*	-1.068***	4.552***
	(1,623)	(28,928)	(18,241)	(214.7)	(20,538)	(0.0865)	(0.314)	(1.354)
Non-deductible share × 2006-2007 ($\beta 3$)	1,963	-105,635**	-10,076	267.0	-66,124**	-0.265**	-1.290***	7.262***
	(1,865)	(51,421)	(21,958)	(289.9)	(29,397)	(0.126)	(0.386)	(1.977)
Observations	180,103	180,103	180,103	180,103	180,103	180,103	180,103	180,103
Weak-ID F-statistic	10.84	10.84	0.009	10.84	10.84	10.84	10.84	10.84
H0: $\beta 1=\beta 2$ (p-value)	0.406	0.0680	0.101	0.202	0.0560	0.00700	0.00400	<0.001
H0: $\beta 2=\beta 3$ (p-value)	0.328	0.202	0.00500	0.478	0.462	0.0120	0.262	0.005
H0: $\beta 1=\beta 3$ (p-value)	0.980	0.104	0.339	0.253	0.131	0.00500	0.00900	<0.001
	B. United States: Reduced Form							
Non-deductible share × 2002-2003 ($\beta 1$)	504.9	-7,574*	1,777	11.45	-6,770**	-0.00670	-0.141**	0.0809
	(361.5)	(4,586)	(2,561)	(32.77)	(3,285)	(0.0128)	(0.0557)	(0.173)
Non-deductible share × 2004-2005 ($\beta 2$)	685.1*	-17,240**	7,007	50.54	-13,872***	-0.0376*	-0.270***	1.151***
	(404.5)	(7,522)	(4,450)	(52.37)	(5,255)	(0.0214)	(0.0709)	(0.304)
Non-deductible share × 2006-2007 ($\beta 3$)	497.1	-26,757*	-2,555	67.63	-16,747**	-0.0672**	-0.327***	1.840***
	(460.4)	(13,873)	(5,600)	(70.87)	(7,966)	(0.0307)	(0.0915)	(0.500)
Observations	180,103	180,103	180,103	180,103	180,103	180,103	180,103	180,103
R-squared	0.701	0.769	0.431	0.817	0.788	0.639	0.145	0.654
H0: $\beta 1=\beta 2$ (p-value)	0.415	0.0790	0.0880	0.172	0.0630	0.00500	0.00400	<0.001
H0: $\beta 2=\beta 3$ (p-value)	0.349	0.226	0.00400	0.467	0.476	0.00700	0.264	0.0110
H0: $\beta 1=\beta 3$ (p-value)	0.980	0.125	0.344	0.227	0.154	0.00200	0.0100	<0.001

Notes: The sample is a balanced panel of firms covering 1998-2007. All regressions include firm fixed effects, year fixed effects and the interactions of year fixed effects with average pre-reform firm sales and average pre-reform firm VAT. Standard errors are clustered at the sector level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table A.10: The Dynamic Effect of Computerization on Firm Behavior – Full Sample

	Dependent Variables							
	VAT	Sales	Ineligible Sales	Employees	Intermediate Inputs	Intermediate Inputs as a Share of Total Input		TFPR DLW
						All	Deductible	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dep Var Mean	**1538**	**47339**	**6719**	**311.9**	**33861**	**0.847**	**0.715**	**6.264**
Non-deductible share × 2002-2003	1,226***	-11,220*	-639.6	-12.72	-7,319*	-0.00461	-0.212***	-0.203
	(353.0)	(5,850)	(2,217)	(45.04)	(4,398)	(0.0141)	(0.0566)	(0.264)
Non-deductible share × 2004-2005	2,097***	-30,582***	-8,518**	-66.07	-19,831**	-0.0290	-0.285***	1.552***
	(478.7)	(11,474)	(3,621)	(79.07)	(7,721)	(0.0309)	(0.0845)	(0.446)
Non-deductible share × 2006-2007	1,810***	-45,593***	-15,501***	-117.2	-24,205***	-0.0315	-0.298**	2.433***
	(568.4)	(16,717)	(4,621)	(102.5)	(9,170)	(0.0449)	(0.118)	(0.577)
Observations	711,643	711,643	711,643	711,643	711,643	711,643	711,643	711,643
R-squared	0.612	0.668	0.087	0.370	0.693	0.129	0.033	0.343
H0: $\beta1=\beta2$ (p-value)	0.00200	0.0150	0.00700	0.176	0.0170	0.224	0.216	<0.001
H0: $\beta2=\beta3$ (p-value)	0.289	0.0630	0.0870	0.0970	0.248	0.876	0.864	<0.001
H0: $\beta1=\beta3$ (p-value)	0.188	0.0130	<0.001	0.104	0.0170	0.424	0.378	<0.001

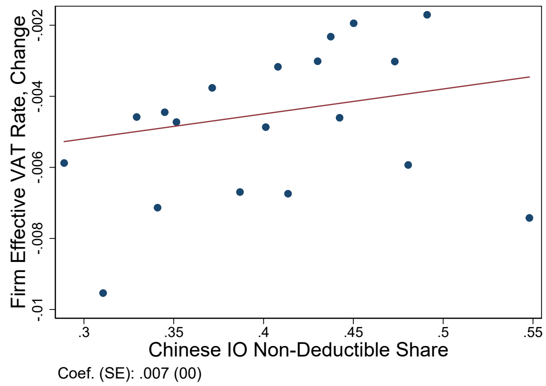
Notes: The sample includes all firms covering 1998-2007. All regressions include firm fixed effects, year fixed effects and the interactions of year fixed effects with average pre-reform sector sales and average pre-reform sector VAT. Standard errors are clustered at the sector level. *** p<0.01, ** p<0.05, * p<0.1

Table A.11: Correlates of Tax Officials Before and After 2002

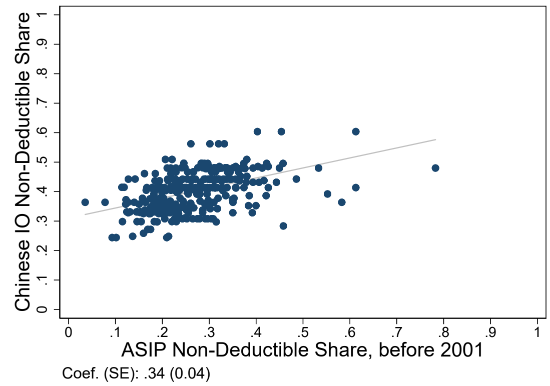
	Dependent Variable: Ln # of Tax Officials	
	1998-2000	2001-2007
	(1)	(2)
Non-Deductible Share	-30.86***	-8.550**
	(6.134)	(4.122)
Beta Coef.	-0.278	-0.0726
Ruggedness	-0.0317	-0.0193
	(0.0591)	(0.0300)
Beta Coef.	-0.0279	-0.0178
Ln Area (Square km)	0.111***	0.0898***
	(0.0401)	(0.0243)
Beta Coef.	0.160	0.135
Ln Population	0.558***	0.636***
	(0.0768)	(0.0435)
Beta Coef.	0.584	0.685
Ln # Firms	0.120**	0.152***
	(0.0588)	(0.0218)
Beta Coef.	0.202	0.284
Observations	121	186
R-squared	0.875	0.923

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

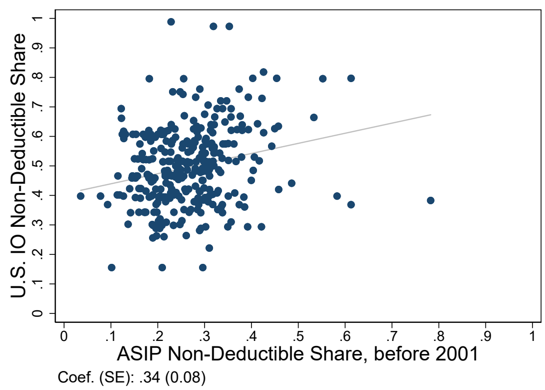
Figure A.1: Scatterplot of Firm NDS Measure and I-O Table NDS Measures



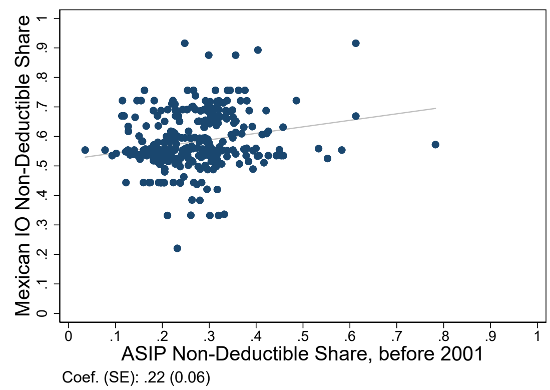
(a) Change in VAT/Sales, Before and After 2001



(b) Pre-2001 Firm and Chinese I-O Non-Deductible Shares



(c) Pre-2001 Firm and U.S. I-O Non-Deductible Shares



(d) Pre-2001 Firm and Mexican I-O Non-Deductible Shares

Figure A.2: The Effect of VAT and Firm Outcomes with Random Permutations of Non-Deductible Share

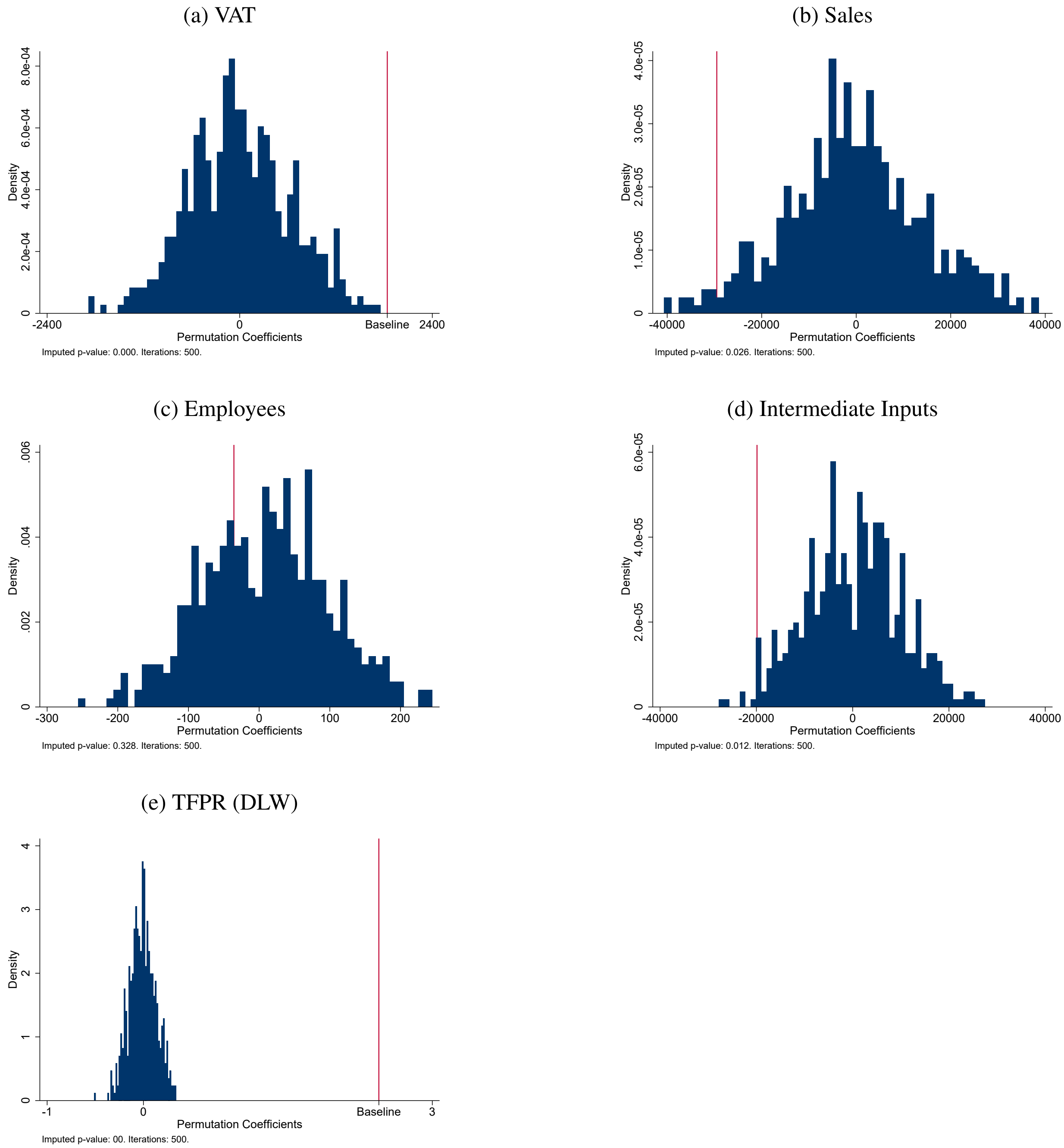
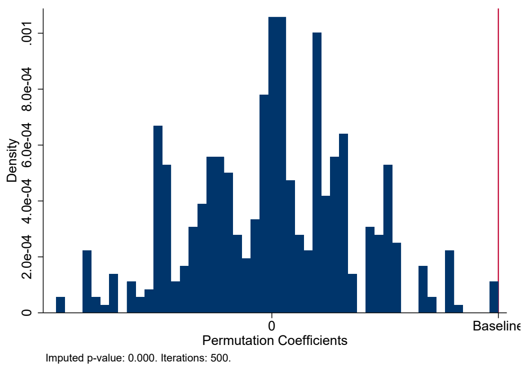
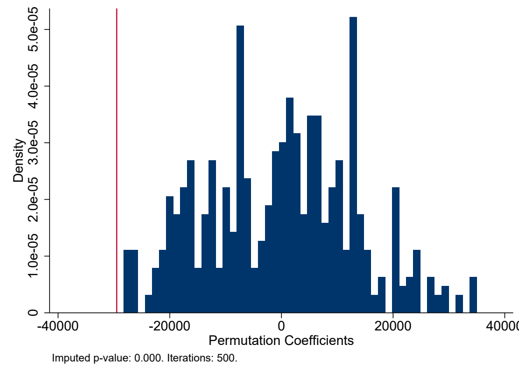


Figure A.3: The Effect of VAT and Firm Outcomes with Random Permutations of Treated Years

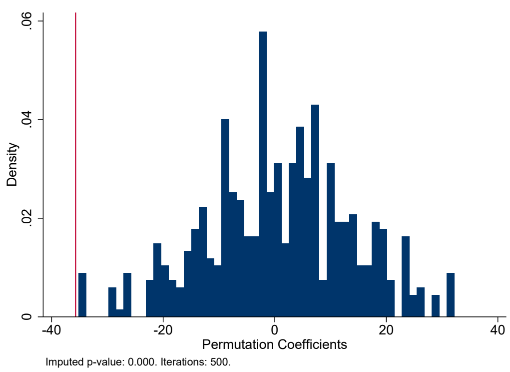
(a) VAT



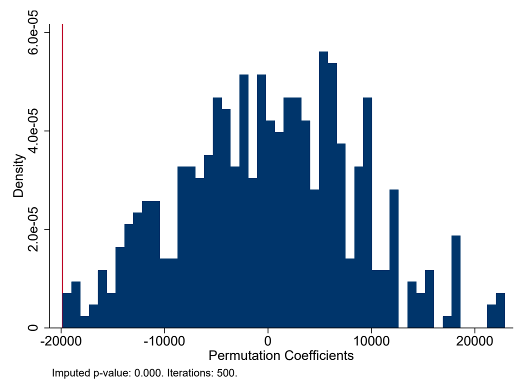
(b) Sales



(c) Employees



(d) Intermediate Inputs



(e) TFPR (DLW)