ONLINE APPENDIX – Not for Publication

A VAT Deductibles

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

B Data

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

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

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

C 2SLS

In this section, we use data from 1998-2000 of the *Annual Survey of Industrial Production* to measure VAT share, and use the measures calculated from the U.S. input output tables as instruments. Specifically, there are three interaction instruments for three endogenous interaction variables. The first stage is shown in Appendix Table A.5, and the instrumented second-stage results are shown in Appendix Table A.6. They are broadly similar to the reduced form estimates that we have focused on so far, although the 2SLS estimates are generally larger in magnitude and more precise.

The 2SLS estimates have advantages and disadvantages. One advantage is that the magnitudes of the coefficients are easier to interpret than the reduced form estimates, and that the instrumented estimates remove bias from measurement error in the OLS estimates (Angrist and Pischke, 2008). The disadvantage is that the first stage is weak (the F-statistic in Appendix Table A.5 is 7.22), which could bias the 2SLS estimates. We know of no way to correct for weak instruments with multiple endogenous variables.

D A Model of VAT Enforcement

D.1 Benchmark

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

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

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

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

D.1.1 Period 0

Consider the cost function in period 0:

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

The first order conditions will be:

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

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

These conditions yield the optimal capital-labor ratio:

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

We can also obtain marginal costs:

$$C_0'(y) = \eta = \frac{r}{\alpha k^{\alpha-1} l^{1-\alpha}}.$$

In equilibrium, we have

$$C_0'(y_0) = \frac{r}{\alpha \left(\frac{\alpha}{1-\alpha} \frac{w}{r}\right)^{\alpha-1}} \equiv \omega,$$

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

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

$$p_0 = C_0'(y_0).$$

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

$$y_0^{-1/\sigma} = C_0'(y_0).$$

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

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

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

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

We can find k_0 and p_0 from the above equations.

D.1.2 Short-run equilibrium

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

Then we have

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

which gives

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

Therefore, marginal costs are

$$C_1'(y) = \eta = \frac{w}{(1-\alpha)\, k_0^{\alpha} l^{-\alpha}}.$$

Competition gives

$$p_1 = C_1'(y).$$

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

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

We are interested in deriving the effect of taxation on inputs, prices, sales, tax revenues, and TFPR. The sales that we observe in the data is qy; tax revenues are τpy; 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 $\sigma > 1$, than $sales_1 < sales_0$.*

Proof. Suppose $y_1 \geq y_0$. Then $l_1 \geq l_0$, and hence $C_1'(y_1) \geq C_0'(y_0)$. This implies that $p_1 \geq p_0$. But $y_1 = [(1+\tau)\, p_1]^{-\sigma}$, so y_1 and p_1 must go in the opposite directions, a contradiction. Therefore, $y_1 < y_0$.

$y_1 < y_0$ implies $l_1 < l_0$, $C_1'(y_1) < C_0'(y_0)$, $p_1 < p_0$. From $y_1 = q_1^{-\sigma}$ we get $q_1 > q_0$.

Tax revenues are $\tau p_1 y_1 = \tau (1+\tau)^{-\sigma} p_1^{1-\sigma} > 0$, so tax revenues increase.

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

Labor goes down $l_1 < l_0$.

Capital does not change $k_1 = k_0$.

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

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

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

D.1.3 Long-run Equilibrium

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

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

This gives us

$$C_2'(y_2) = C_0'(y_0) > C_1'(y_1).$$

Therefore,

$$p_2 = p_0 > p_1.$$

Since

$$\begin{aligned} q_2 &= (1+\tau) p_2, \\ q_1 &= (1+\tau) p_1 > p_{0,} \\ q_0 &= p_0, \end{aligned}$$

this implies that

$$q_2 > q_1 > q_0,$$

$$TFPR_2 > TFPR_1 > TFPR_0.$$

Remark 2. *The intuition behind this result is as follows: since not all factors can be adjusted immediately, the marginal costs fall: there is too much capital relative to labor in the short run, so the marginal cost of labor (the only factor that can be adjusted in period 1) is low. Therefore, the tax-inclusive price falls, although less than one for one* *with the tax rate, so that pre-tax price q increases. Over time, as firms adjust other factors, their marginal costs rise. This implies that p rises, and therefore, q rises even further. Since TFPR is just q, the same is true about TFPR.*

Demand is

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

Therefore,

$$y_2 < y_1 < y_0.$$

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

$$\begin{aligned} q_2^{1-\sigma} &< q_1^{1-\sigma} < q_0^{1-\sigma}, \\ \text{sales}_2 &< \text{sales}_1 < \text{sales}_0. \end{aligned}$$

Tax revenues are $\tau py = \tau \frac{p}{q} qy = \frac{\tau}{1+\tau} \times$sales. Since $\tau_0 = 0$, $\tau_1 = \tau_2 > 0$, this gives us, if $\sigma > 1$, that

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

Remark 3. *The intuition behind these results comes from the previous remark and the assumption that $\sigma > 1$. As q increases in each period, y must fall in each period. If demand is elastic, y falls faster than q raises, which implies that sales, qy, fall. Since tax revenues are $\frac{\tau_t}{1+\tau_t} \times sales_t$, 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 what happens to labor. We have

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

The remaining comparison of interest is between l_1 and l_2.

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

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

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

We must have $k_2 < k_0$ (since $k_2/l_2 = k_0/l_0$ and $k_2\,(k_2/l_2)^{\alpha-1} = y_2 < y_0 = k_0\,(k_0/l_0)^{\alpha-1}$). Therefore, if $\sigma > 1$, we have $k_2^{\alpha/\sigma-\alpha} > k_0^{\alpha/\sigma-\alpha}$ and therefore $l_2^{(\alpha-1)/\sigma-\alpha} > l_1^{(\alpha-1)/\sigma-\alpha}$. Since $\alpha < 1$, this implies that $l_2 < l_1$. Therefore we have

$$l_0 > l_1 > l_2.$$

Remark 4. *The intuition for this result comes from the following observation. We know from the Le Chatelier Principle (Samuelson, 1949) that the short-run elasticity of labor should be smaller than the long-run elasticity of labor (because capital can also be adjusted in the long run)* holding pre-tax prices fixed*. This effect implies that labor should react even more in the long run to the tax change than in the short run. In our settings, there is an offsetting effect, since the pre-tax price increases which, all things being equal, call for more inputs. If demand is elastic, prices react little to changes in output, and the first effect dominates.*

D.1.4 Empirical Implications

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

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

D.2 Intermediate goods

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

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

and profits with VAT tax τ are

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

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

D.2.1 Period 0

Consider the cost function in period 0:

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

It obviously gives

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

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

$[x] : z = \omega\beta k^{\alpha}l^{1-\alpha-\beta}x^{\beta-1}$.

This gives optimal capital-labor ratio

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

We also have marginal costs

$$\begin{aligned}C_0'\left(y_0\right) &= \omega_0 = \frac{w}{\left(1-\alpha-\beta\right)k_0^{\alpha}l_0^{-\alpha-\beta}x_0^{\beta}} \\ &= \frac{w}{\left(1-\alpha-\beta\right)\left(\frac{k_0}{l_0}\right)^{\alpha}\left(\frac{x_0}{l_0}\right)^{\beta}} \\ &= \frac{w}{\left(1-\alpha-\beta\right)\left(\frac{\alpha}{1-\alpha-\beta}\frac{w}{r}\right)^{\alpha}\left(\frac{\beta}{1-\alpha-\beta}\frac{w}{z}\right)^{\beta}}.\end{aligned}$$

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

$$q_0 = \omega_0.$$

Then, the first order conditions immediately imply

$$\begin{aligned}rk_0 &= \alpha q_0 y_0, \\ zx_0 &= \beta q_0 y_0, \\ wl_0 &= \left(1-\alpha-\beta\right)q_0 y_0.\end{aligned}$$

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

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

This equation gives

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

or

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

It then follows that

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

D.2.2 Period 2

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

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

So the cost function is

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

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

$$\begin{aligned}(1-\tau)\,q_2 &= C_2'(y_2) = \omega_2,\\ q_2 &= \frac{C_2'(y_2)}{1-\tau} = \frac{\omega_2}{1-\tau}.\end{aligned}$$

So we have

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

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

Finally,

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

gives

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

or

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

Similarly, we have

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

This result generates clear predictions about the long run.

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

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

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

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

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

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

3. We have

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

and

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

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

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

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

■

D.2.3 Period 1

Now consider period 1 problem. We assume that intermediate goods can be adjusted in period 1, which simplifies the analysis.[38]

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

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

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

We have

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

As before, we have

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

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

Hence, we have

$$\begin{aligned} wl_1 &= (1-\alpha-\beta)(1-\tau) q_1 y_1, \\ (1-\tau) z x_1 &= \beta (1-\tau) q_1 y_1. \end{aligned}$$

The marginal costs are

$$\begin{aligned} \omega_1 &= C_1'(y_1) = \frac{1}{1-\alpha-\beta} \frac{w}{k_0^\alpha l_1^{-\alpha-\beta} x_1^\beta} \\ &= \frac{1}{1-\alpha-\beta} \frac{w}{k_0^\alpha l_1^{-\alpha} \left(\frac{x_1}{l_1}\right)^\beta}. \end{aligned}$$

We find l_1 as before, using the demand curve:

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

Therefore,

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

This equation gives the following useful intermediate result.

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

1. $l_0 > l_1 > l_2$,

2. $y_0 > y_1 > y_2$,

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

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

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

which implies

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

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

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

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

Therefore $l_1 < l_0$.

2. For output, we have

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

Therefore, $y_1 < y_0$.

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

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

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

3. For marginal costs, we have

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

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

Moreover,

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

or

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

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

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

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

1. $TFPR_2 > TFPR_1 > TFPR_0$,

2. $sales_0 > sales_1 > sales_2$,

3. $0 = taxes_0 < taxes_2 < taxes_1$.

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

$$q_0 < q_1 < q_2.$$

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

$$sales_0 > sales_1 > sales_2.$$

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

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

it becomes

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

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

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

■

D.3 Monopolistic competition

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

Firms will be monopolistically-competitive, as in the Dixit-Stiglitz model. There is a continuum of firms, each firm produces a differentiated good.[39] 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.

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

Consumer preferences in each period are given by

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

where

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

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

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

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

where the aggregate price satisfies

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

The aggregate demand can be found from

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

$$YQ = wl + m$$

which gives

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

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

D.3.1 Firm's problem

We will do things in "partial" equilibrium so that the interest rate r is fixed (equivalent to a GE model in which there are international capital markets with a rental rate of capital given by r). We will relax this assumption in another extension. In equilibrium, firm i will take for now Q, Y, and r as given ($w = 1$ always) and chooses $q(i)$ to maximize its profits, taking into account consumer's demand. So the firm in period 0 solves

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

s.t.

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

We have

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

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

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

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

The first two equations give us the usual conditions

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

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

In equilibrium, since all firms are identical, we have

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

Therefore, the last two optimality conditions become

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

This gives us

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

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

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

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

Finally, period 1 problem is

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

with

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

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

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

Note that again we have

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

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

D.4 Multiple sectors, fixed capital

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

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

s.t.

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

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

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

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

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

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

Given our normalizations, demand is again given by

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

D.4.1 Period 0

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

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

or

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

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

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

This equation gives us r_0.

D.4.2 Period 1

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

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

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

D.4.3 Period 2

We have, following the same steps as before

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

and

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

Capital in the other sector is

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

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

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

Therefore we have

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

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

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

Therefore, we have

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

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

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

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

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

This step completes the proof, since we already know what happens in period 1. Note that $\mu = 0$ is the same case as our baseline model (it is easier to see it, if we redefine all variables as ratios to μ and look at the limit as $\mu \to 0$). In this case, sector 1 is so small, so that any reallocation of capital from sector 1 to sector 2 has no effect on price r. The lemma above shows that all the insights continue to generalize in the 2 sector GE model where interest rate r is endogenously determined and is affected by the reallocation. The mechanism is the same as in the benchmark case: as long as there is some reallocation in period 2 of capital due to re-optimization, capital k_2 will decrease in period 2, further depressing labor demand l_2 and output y_2, leading to lower sales and tax revenues in sector 1. In the limit case, $\mu = 1$, sector 2 is negligibly small and cannot absorb any capital. As a result, with fixed capital stock, rental rates r_2 must fall sufficiently to prevent any re-allocation of capital from sector 1, in which case, period 1 and period 2 become identical.

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

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

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

Table A.2: Descriptive Statistics

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

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

Table A.3: The Effect of Computerization by Year

	Dependent Variable	
	VAT	VAT/Sales
	(1)	(2)
VAT Share x 1999	52.38	0.00307
	(282.3)	(0.00469)
VAT Share x 2000	212.9	0.00679
	(348.1)	(0.00432)
VAT Share x 2001	196.3	0.00631
	(418.6)	(0.00555)
VAT Share x 2002	300.0	0.00900*
	(485.1)	(0.00522)
VAT Share x 2003	895.2	0.0139***
	(622.7)	(0.00442)
VAT Share x 2004	1,172*	0.0232***
	(608.5)	(0.00519)
VAT Share x 2005	513.5	0.0114*
	(612.0)	(0.00617)
VAT Share x 2006	336.0	0.0119*
	(605.3)	(0.00643)
VAT Share x 2007	433.1	0.0142*
	(640.5)	(0.00786)
Observations	61,308	61,308
R-squared	0.780	0.658
2001-2007 Joint p-value	0.0256	2.54e-05

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

Table A.4: The Heterogeneous Effects of Computerization by Ownership

	Dependent Variables				
	(1)	(2)	(3)	(4)	(5)
	VAT	VAT/Sales	TFPR (DLW)	Sales	Intermediate Input
	A. State Owned				
Dep Var Mean	**1668**	**0.0507**	**1.376**	**37446**	**27094**
VAT share x 2001-2002 (β1)	335.1	0.00119	0.0135	-2,155	-2,158
	(249.7)	(0.00306)	(0.0425)	(3,491)	(2,780)
Beta Coef.	*0.0251*	*0.00821*	*0.00580*	*-0.00779*	*-0.0114*
VAT share x 2003-2005 (β2)	963.6**	0.0149***	0.218**	-3,271	-1,051
	(424.8)	(0.00444)	(0.0853)	(7,487)	(5,640)
Beta Coef.	*0.0806*	*0.115*	*0.104*	*-0.0132*	*-0.00619*
VAT share x 2006-2007 (β3)	183.8	0.0169***	0.419***	-21,565	-4,617
	(597.3)	(0.00562)	(0.140)	(20,921)	(11,355)
Beta Coef.	*0.0133*	*0.113*	*0.174*	*-0.0755*	*-0.0236*
Observations	25,181	25,181	25,181	25,181	25,181
R-squared	0.805	0.683	0.842	0.798	0.814
H0: β1=β2 (p-value)	0.0190	0.00400	0.00600	0.840	0.788
H0: β2=β3 (p-value)	0.128	0.639	0.0210	0.298	0.691
	B. Privately Owned				
Dep Var Mean	**2099**	**0.0471**	**13.09**	**48870**	**33093**
VAT share x 2001-2002 (β1)	-173.3	-0.000305	0.0683	-15,041**	-13,577**
	(327.9)	(0.00444)	(0.0509)	(7,258)	(5,248)
Beta Coef.	*-0.0130*	*-0.00211*	*0.0293*	*-0.0544*	*-0.0717*
VAT share x 2003-2005 (β2)	608.5	0.00395	0.169*	-24,788**	-18,997***
	(516.5)	(0.00569)	(0.0922)	(11,232)	(7,172)
Beta Coef.	*0.0509*	*0.0305*	*0.0808*	*-0.100*	*-0.112*
VAT share x 2006-2007 (β3)	113.0	-0.00151	0.419***	-40,489***	-20,161**
	(580.3)	(0.00687)	(0.128)	(15,366)	(9,152)
Beta Coef.	*0.00820*	*-0.0101*	*0.174*	*-0.142*	*-0.103*
Observations	25,733	25,733	25,733	25,733	25,733
R-squared	0.806	0.695	0.820	0.811	0.822
H0: β1=β2 (p-value)	0.0290	0.280	0.107	0.126	0.181
H0: β2=β3 (p-value)	0.137	0.301	0	0.100	0.844
H0: State = Private (SUR p-value)	0.765	0.0724	0.395	0.0792	0.196
	C. Foreign Owned				
Dep Var Mean	**3021**	**0.0531**	**1.477**	**62621**	**42863**
VAT share x 2001-2002 (β1)	32.63	0.0115**	-0.0253	-3,331	-2,819
	(507.5)	(0.00583)	(0.0686)	(7,692)	(6,235)
Beta Coef.	*0.00245*	*0.0798*	*-0.0108*	*-0.0120*	*-0.0149*
VAT share x 2003-2005 (β2)	334.1	0.0165*	0.0447	-25,945**	-18,828*
	(755.4)	(0.00856)	(0.117)	(13,035)	(10,247)
Beta Coef.	*0.0280*	*0.128*	*0.0214*	*-0.105*	*-0.111*
VAT share x 2006-2007 (β3)	123.7	0.0158	0.218	-38,032*	-17,122
	(769.1)	(0.0105)	(0.173)	(20,017)	(14,847)
Beta Coef.	*0.00898*	*0.106*	*0.0903*	*-0.133*	*-0.0875*
Observations	9,383	9,383	9,383	9,383	9,383
R-squared	0.806	0.682	0.798	0.802	0.809
H0: β1=β2 (p-value)	0.564	0.332	0.440	0.0100	0.0390
H0: β2=β3 (p-value)	0.745	0.891	0.0680	0.263	0.812
H0: State = Foreign (SUR p-value)	0.772	0.103	0.531	0.100	0.313

Notes: The sample is a balanced panel of firms covering 1998-2007. A firm's ownership is defined its legal registration. All regressions include year and firm fixed effects. Standard errors are clustered at the sector level. *** p<0.01, ** p<0.05, * p<0.1

Table A.5: First Stage Estimates – Chinese VAT Share (pre-computerization, 1998-2000) instrumented by U.S. VAT Share

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

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

Table A.6: The 2SLS Effects of Computerization on VAT

	Dependent Variables					
	VAT (1000 RMB) (1)	VAT/Sales (Fraction) (2)	TFPR (DLW) (3)	Sales (1000 RMB) (4)	Employees (#) (5)	Deductible Inputs as a Share of Total Inputs (6)
VAT share x 2001-2002 ($\beta 1$)	305.7	0.00810	0.00410	-15,034*	16.97	0.0422
	(548.1)	(0.00728)	(0.0784)	(8,836)	(63.49)	(0.102)
VAT share x 2003-2005 ($\beta 2$)	1,804**	0.0289***	0.345*	-40,238**	-40.17	-0.390***
	(915.9)	(0.0104)	(0.176)	(17,520)	(99.78)	(0.120)
VAT share x 2006-2007 ($\beta 3$)	654.7	0.0216	0.921***	-78,011**	-79.89	-0.739***
	(1,102)	(0.0153)	(0.308)	(35,536)	(161.4)	(0.246)
Observations	61,308	61,308	61,308	61,308	61,308	61,308
H0: $\beta 1 = \beta 2$ (p-value)	0.00400	0.00800	0.0240	0.0410	0.376	0.00400
H0: $\beta 2 = \beta 3$ (p-value)	0.116	0.372	0.00200	0.133	0.592	0.0350

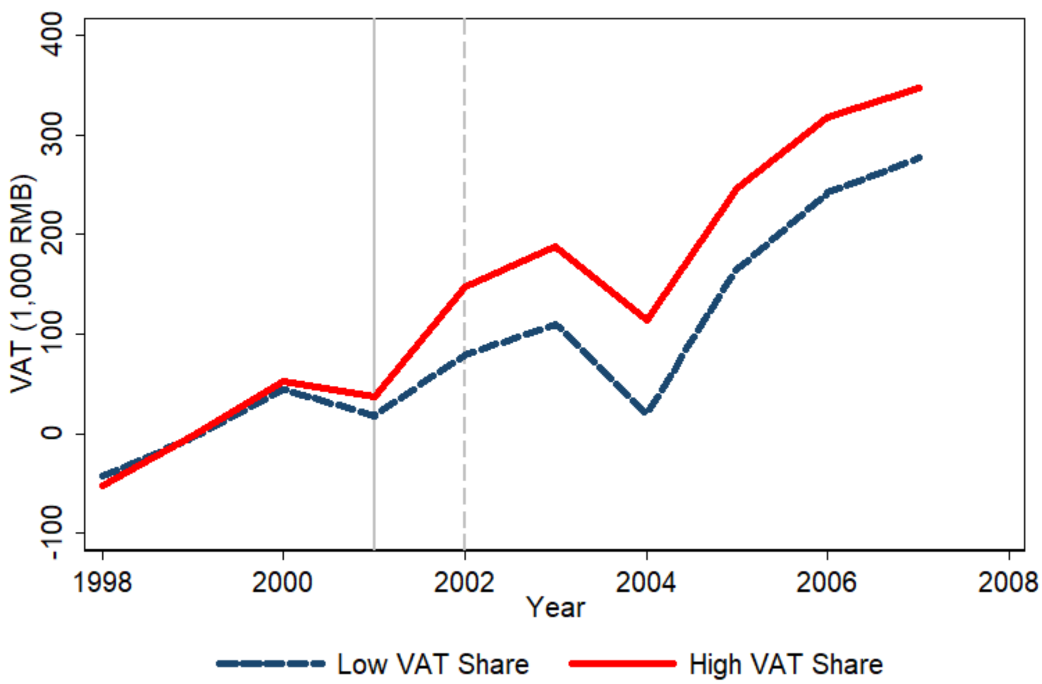
Notes: The sample is a balanced panel of firms, 1998-2007. All regressions include year and firm fixed effects. Standard errors are clustered at the sector level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$ The endogenous explanatory variables are the three post-reform indicators interacted with Chinese 1998-2000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

Table A.7: The Effect of Computerization on Firm Outcomes – All Firms

	Dependent Variables				
	(1)	(2)	(3)	(4)	(5)
	VAT (1000 RMB)	VAT/Sales (Fraction)	TFPR (DLW)	Sales (1000 RMB)	Deductible Inputs as a Share of Total Input
Dep Var Mean	**1419**	**0.0415**	**0.106**	**38366**	**0.865**
VAT share x 2001-2002 ($\beta 1$)	229.2	0.00383*	-0.00896	-2,205	-0.0749*
	(156.1)	(0.00214)	(0.0337)	(2,811)	(0.0383)
Beta Coef.	*0.0575*	*0.0674*	*-0.00456*	*-0.0237*	*-0.0719*
VAT share x 2003-2005 ($\beta 2$)	519.2	0.00642	0.162**	-142.8	-0.159***
	(331.7)	(0.00411)	(0.0703)	(6,037)	(0.0462)
Beta Coef.	*0.150*	*0.130*	*0.0948*	*-0.00177*	*-0.176*
VAT share x 2006-2007 ($\beta 3$)	418.2	0.000962	0.373***	-526.7	-0.202***
	(405.6)	(0.00563)	(0.111)	(8,626)	(0.0562)
Beta Coef.	*0.105*	*0.0169*	*0.190*	*-0.00567*	*-0.194*
Observations	2,990	2,990	2,990	2,990	2,990
R-squared	0.877	0.919	0.960	0.880	0.938
H0: $\beta 1$=$\beta 2$ (p-value)	0.263	0.412	0.00100	0.656	0.00900
H0: $\beta 2$=$\beta 3$ (p-value)	0.429	0.0130	0	0.910	0.188

Notes: The sample is a balanced panel of sectors, 1998-2007. The regression is weighted by the number of firms in each sector-year cell. All regressions include year and sector fixed effects. Standard errors are clustered at the sector level. *** p<0.01, ** p<0.05, * p<0.1

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



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