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Tax Heterogeneity and Misallocation*

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Abstract

Companies face different effective marginal tax rates on their income. This can be detrimental to allocative efficiency unless taxes offset other distortions in the economy. This paper estimates the effect of tax rate heterogeneity on aggregate productivity in distorted economies with multiple frictions. Using firm-level balance-sheet data and estimates of marginal tax rates, we find that tax heterogeneity *reduces* total factor productivity by about 3 percent. Our findings highlight the positive correlation between marginal tax rates and other distortions to capital and especially labor. This implies that tax rate heterogeneity exacerbates the distortionary effects of other frictions in the economy.

Keywords: Business Taxation, Aggregate Productivity, TFP, Misallocation

JEL Classification: D24, H25, O47

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*The views expressed here are those of the authors and do not necessarily reflect the views of the Federal Reserve Bank of Cleveland or the Federal Reserve System.

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1 Introduction

In an efficient economy, marginal products of inputs are equalized across firms. Otherwise, efficiency can be improved by transferring resources from less productive firms to more productive ones. Hsieh and Klenow (2009) document a wide dispersion in productivity across establishments, suggesting a severe misallocation of inputs. Recent estimates suggest that the US could raise its output by as much as 25 percent if inputs were allocated efficiently (Bils et al., 2021). The sources of input misallocation, however, remain largely unknown, preventing policy guidance.

In this paper, we examine corporate income taxation as a potential impediment to the efficient allocation of inputs among firms, and estimate its implications for aggregate productivity in the US. Although the tax code does not distinguish between individual firms *de jure*, the special provisions for deductions and allowances, such as imperfect loss-offsets or the favorable treatment of debt financing, can lead to a dispersion in effective marginal tax rates (EMTR) across firms. Estimates suggest that the resulting dispersion in marginal tax rates is large. In our sample of publicly traded US companies, the EMTR ranges from zero to 51 percent between 1980 and 2021, with a standard deviation of 13 percent to 17 percent depending on the measure and year.

Whether these differences in tax rates necessarily worsen efficiency is nevertheless debatable. While heterogeneity in tax rates would lower efficiency in competitive, otherwise frictionless economies, the same cannot be said of economies with distortions. Efficiency could in fact be *improved* by differential tax rates if tax rates help offset other distortions in the economy. For instance, the tax advantage of debt financing might ease credit constraints, or losses carried over from previous years might alleviate liquidity problems for otherwise healthy firms and prevent premature firm exits. Whether this is the case is an empirical question.

In pursuit of an answer, we link corporate taxation and productivity in a standard model of production under distortions to factor allocation. We derive analytical formulas that help predict the change in output from eliminating differences in marginal tax rates across firms and reallocating total capital and labor accordingly. Our formulas highlight the correlations between the marginal tax rate and factor productivity in the cross-section of firms as key to determining the effect of corporate tax policy on efficiency. These correlations are informative about the interaction between different sources of misallocation.

To apply our formulas, we combine balance-sheet data from Compustat on publicly listed companies in the United States with firm-level estimates of the marginal tax rates on corporate income (Graham and Mills, 2008; Blouin et al., 2010). Our calculations indicate that eliminating tax rate heterogeneity would *raise* aggregate TFP in the US by about 3 percent. This is quantitatively significant, especially given that the primary channel through which corporate taxes affect input allocation is through their impact on equity-financed capital and that the share of *all* capital in total income is about a third.

Our result reflects a positive correlation between tax rates and other distortions, suggesting that corporate tax policy has tended to *exacerbate* distortions to input allocation rather than offsetting them. Indeed, we find that marginal tax rates correlate positively with the marginal cost of capital, amplifying the cross-sectional dispersion in the marginal product of capital. Surprisingly, we also find a strong positive correlation between the EMTR and labor distortions. Because labor expenses can be deducted from net income, corporate taxes are thought to be non-distortionary to employment. However, the empirical correlations suggest that a tax rate equalization would lower tax rates for firms where the marginal products of capital and labor are higher on average, thus putting the available inputs to a more productive use. Our calculations suggest that if tax rates were not correlated with other distortions, then potential losses in productivity would be much smaller, less than 1 percent for most years, with the exception of the period prior to the 1986 tax reform.

This paper connects two strands of the literature on the macroeconomic effects of factor misallocation (Restuccia and Rogerson, 2008; Hsieh and Klenow, 2009). Papers in this literature typically adopt one of two approaches. The first approach aims to measure the dispersion in marginal products directly using micro-level data on firms or establishments. These papers often find large potential gains from removing frictions to the optimal allocation of factors, but do not specify what types of distortions are behind misallocation. The primary challenge for this literature has been to distinguish between differences in marginal products and differences in production technologies and measurement error (Bils et al., 2021).[1]

Papers that adopt the second approach study specific frictions and use calibrated models to quantify the associated output losses, typically by comparing the distorted economy with a frictionless counterfactual (Midrigan and Xu, 2014; David and Venkateswaran, 2019; Kaymak and Schott, 2019). Because of computational and theoretical complexities, this approach is limited in its ability to model and compute a diverse set of distortions, and, therefore, to study the interactions between them. As a result, eliminating specific frictions leads to productivity gains by methodological design. Furthermore, because the change in productivity from reallocating inputs is a second-order concept – one firm's gain is another firm's loss – by and large, these studies find the productivity gains from reallocation to be much smaller than what is suggested by the empirical dispersion in marginal productivity.

This paper combines elements from both approaches by focusing on a specific friction – corporate income taxes – while allowing for other distortions more generally. Because our findings rely on the covariance between tax wedges and productivity, errors in specification or measurement of marginal products are less of a concern, and none at all if the errors are orthogonal to tax rates.[2]

[1] Hsieh and Klenow (2009) address these issues by benchmarking their misallocation measure to the US when assessing the extent of resource misallocation in India. Bils et al. (2021) exploit panel data to purge the firm-level dispersion in productivity of measurement error.

[2] We also show that (classical) measurement error in tax rates biases the estimated change in productivity associated with eliminating tax differentials downward, and it affects the interpretation of how taxes interact with other distortions in the economy. We address such measurement error by using multiple measures of marginal tax rates.

Our paper is also related to the large body of literature that is concerned with measuring the effects of corporate taxes on economic outcomes, such as investment and employment (see, for instance, Cummins et al. (1994), Djankov et al. (2010), or Slattery and Zidar (2020), among others). Whereas the papers in this literature focus on the effects of changes in the *level* of corporate taxes, this paper studies the effects of the *dispersion* in marginal tax rates.

The rest of the paper is organized as follows. Section 2 derives our theoretical results. Section 3 describes how we connect the theory to the data, presents the degree of tax heterogeneity, and shows how tax distortions can be measured. We present our findings in Section 4 and conclude in Section 5.

2 Model

In this section we derive a general formula for quantifying the changes in aggregate TFP from eliminating the heterogeneity in firm-level tax rates in the spirit of Hsieh and Klenow (2009). To fix ideas, we first develop an investment problem with multiple distortions and show how the resulting optimality conditions can be generalized.

Consider the investment problem of a firm that is facing an effective marginal tax rate on its income, τ, as well as other frictions, such as capital adjustment costs and credit constraints. Each period, the firm chooses labor, future capital, and investment to maximize the payout to shareholders, which depends on current and expected after-tax profits. For simplicity, assume that the firm knows the realization of the next period's productivity z and taxes τ at the time of the investment decision. The firm's problem is given by

$$V(z,k) = \max_{n,k',i} \; -i - \Phi\left(\frac{i}{k}\right)k + \beta\left[(1-\tau)\left[zF(k',n) - \omega_n n\right] + E_{z'|z}V(z',k')\right] \tag{1}$$

subject to the law of motion for capital and a collateral constraint

$$
\begin{aligned}
k' &= i + (1-\delta)k && (2)\\
i &\leq \zeta q k, && (3)
\end{aligned}
$$

with associated multipliers q and μ.

The labor decision is not affected by the level of τ because wage payments are tax-deductible.[3] The first-order condition with respect to labor is given by

$$zF_n(k,n) = \omega_n, \tag{4}$$

where ω_n denotes the effective user cost of labor. The optimality condition for the choice of capital is given by

$$q = \beta\left[(1-\tau)zF_k(k',n) - \Phi\left(\frac{i'}{k'}\right) + \Phi'\left(\frac{i'}{k'}\right)\frac{i'}{k'} + q'(1-\delta) + \mu'\zeta' q'\right], \tag{5}$$

with the familiar interpretation that at the optimal choice, the marginal cost of capital, q, equals the future benefit of an additional unit of capital.[4] This benefit consists of the marginal product of capital (net of expected future taxes), the value of non-depreciated capital, and the effects on the marginal costs of investment as well as on the financial constraint.

We define the following two terms that will be used to simplify (5). First, the tax wedge ω_τ is defined as

$$\omega_\tau \equiv \frac{1}{1-\tau}. \tag{6}$$

A higher effective marginal tax rate τ implies a higher value of ω_τ. Second, the

[3] The same is true for capital depreciation and eventual interest payments. Note, however, that we are using *effective* marginal tax rates in our estimations below. These already take into account the tax provisions for depreciation and debt-financing.

[4] The full derivations are relegated to the Appendix.

“residual” wedge ω_R is defined as

$$\omega_R \equiv \frac{q}{\beta} - q'(1-\delta) - \mu'\zeta'q' + E_{z'|z}\left[\Phi\left(\frac{i'}{k'}\right) + \Phi'\left(\frac{i'}{k'}\right)\frac{i'}{k'}\right]. \tag{7}$$

Any additional frictions a firm might be facing would be included in the residual wedge ω_R. In that sense, the particular distortions firms face other than differential tax rates, be it adjustment costs or credit constraints, do not matter for our results below.[5]

Using the expression for ω_τ and ω_R, we can write (5) as

$$zF_k(k', n) \quad = \quad \omega_k \quad \equiv \quad \omega_\tau \cdot \omega_R, \tag{8}$$

where ω_k denotes the effective user cost of capital, including all distortions such as capital adjustment costs, financial constraints, and taxes. We decompose ω_k into two parts, the first part, ω_τ stemming from a directly observable distortion (effective marginal tax rates), the second being a residual term, ω_R, that captures all other factors that affect the user-cost of capital.

This formulation allows us to rewrite the firm's problem in (1) as a static allocation problem:

$$\max_{n,k'} -\omega_k k' + zF(k', n) - \omega_n n \tag{9}$$

The first-order conditions of (9) are consistent with the optimality conditions derived in (4) and (8).

2.1 Tax heterogeneity and misallocation

We now derive a general formula to measure the effect on aggregate total factor productivity (TFP) stemming from heterogeneity in firm-specific effective costs of capital, ω_K, and labor, ω_N. To do so, we assume a Cobb-Douglas production

[5] Below, we interpret any correlation between the residual wedge and the tax wedge as non-causal. If there is a causal link, eliminating tax rates would also reduce the dispersion in ω_R, given the empirical patterns in the data. In that sense, our findings should be taken to be conservative.

function $F(k,n) = zk^\alpha n^\beta$. Let $G(\omega_k, \omega_n)$ denote the joint distribution of distortions to capital and labor across firms.

Our aim is to compare total output in the distorted economy with the allocation that a social planner would choose - using the same aggregate inputs as the competitive equilibrium of the distorted economy. These aggregates are denoted as $K = \int k\, dG$ and $N = \int n\, dG$ for capital and labor, and $Y = \int y\, dG$ for total output. Because total inputs are held constant between the two economies, any change in output is equivalent to a change in aggregate TFP.

The following proposition derives TFP in the distorted competitive equilibrium of this economy:

Proposition 1. *Total factor productivity in the distorted economy is*

$$Z = \frac{Y}{K^\alpha N^\beta} = \frac{\int z^{\frac{1}{1-\gamma}} \omega_n^{-\frac{\beta}{1-\gamma}} \omega_k^{-\frac{\alpha}{1-\gamma}} dG}{\left[\int z^{\frac{1}{1-\gamma}} \omega_n^{-\frac{\beta}{1-\gamma}} \omega_k^{-\frac{1-\beta}{1-\gamma}} dG\right]^\alpha \left[\int z^{\frac{1}{1-\gamma}} \omega_n^{-\frac{1-\alpha}{1-\gamma}} \omega_k^{-\frac{\alpha}{1-\gamma}} dG\right]^\beta}. \tag{10}$$

We are interested in the effect of eliminating tax heterogeneity alone. Therefore we assume that the planner does not (or cannot) alter ω_R and ω_n. Eliminating tax differentials will generally alter the aggregate demand for capital and labor. We therefore introduce common tax rates (or subsidies) on capital and labor in order to keep the aggregate quantities unchanged. Therefore, the marginal products of labor and capital in the planner's allocations are proportional to ω_R and ω_n, but not equalized across production sites. The optimality conditions in this counterfactual scenario are given by:

$$zF_n(k,n) = \omega_n' = \bar{\omega}_n \cdot \omega_n \quad \text{and} \quad zF_n(k,n) = \omega_k' = \bar{\omega}_k \cdot \omega_R, \tag{11}$$

where $\bar{\omega}_n > 0$ and $\bar{\omega}_k > 0$ represent the planner's tax or subsidy policy that is common across firms. The resulting optimality conditions for k and n coincide with those of a profit-maximizing firm that takes the distortions and the common tax wedges $\bar{\omega}_k$ and $\bar{\omega}_n$ as given. Those wedges are chosen to satisfy the inputneutrality constraints on the allocation problem:

$$\int k(\omega_n', \omega_k') dG' = K \text{ and } \int n(\omega_n', \omega_k') dG' = N$$

where $G'(\omega_k', \omega_n')$ denotes the distribution associated with the new distortions. Because wedges that are common to all firms do not distort relative marginal products, they do not cause misallocation of inputs. Consequently, $G'(\omega_k', \omega_n')$ is equivalent to $G'(\omega_R, \omega_n)$ in terms of its implications for TFP distortions.

The effect of eliminating tax heterogeneity on TFP can be obtained by setting $\omega_\tau = 1$ (or to any positive scalar), and replacing ω_k by ω_R in equation (10). This implies that from (8) the marginal cost of capital, ω_k, is only determined by the residual distortions ω_R, but not by heterogeneous tax rates. The following proposition summarizes the change in the economy's TFP in response to equalizing tax rates across firms.

Proposition 2. *The total change in TFP from eliminating tax differentials across firms is:*

$$\frac{Z^*}{Z} = \frac{\int_\tau \frac{y(\tau)}{Y} \omega_\tau^{\frac{\alpha}{1-\gamma}} dG}{\left(\int_\tau \frac{k(\tau)}{K} \omega_\tau^{\frac{1-\beta}{1-\gamma}} dG\right)^\alpha \left(\int_\tau \frac{n(\tau)}{N} \omega_\tau^{\frac{\alpha}{1-\gamma}} dG\right)^\beta}, \tag{12}$$

where $y(\tau)/Y, k(\tau)/K$, and $n(\tau)/N$ denote the output, capital and employment shares of firms that are subject to the same tax rate τ.

The formula expresses weighted moments of distortions stemming from the tax rates. The different components respectively weigh tax wedges by capital, labor or output. In a frictionless economy, capital, labor and output are proportional to each other with a fixed rate of proportionality. In that world, a firm's output share is the same as its capital and employment shares. More generally, with distortions ω_R and ω_n, that proportionality breaks down, leading to different values based on which weight is used. For instance, higher values of ω_n are associated with lower employment weights. If there is a negative correlation between labor distortions and tax distortions, then the employment share, n/N, would correlate positively with ω_τ, raising the denominator in (12) and giving lower TFP gains from eliminating tax distortions.

It is generally hard to interpret the marginal effect of tax heterogeneity on aggregate TFP based on equation (12) due to its complex and non-linear nature. To obtain deeper insights, we therefore impose further restrictions on the distribution of distortions. The resulting formulas provide a better way to form an intuition about the sources of misallocation from tax heterogeneity and how interactions between tax rates and other distortions can play an important role in assessing the allocative effects of tax distortions. To illustrate this point more clearly, let us now consider an economy where the distortions are distributed jointly according to a log-normal density. Under that assumption, TFP in the distorted economy is equivalent to:

$$\ln Z = \ln \int z^{\frac{1}{1-\gamma}} - \frac{1}{2}\frac{1}{1-\gamma}\left[\alpha(1-\beta)\sigma_k^2 + \beta(1-\alpha)\sigma_n^2 + 2\alpha\beta\sigma_{kn}\right], \tag{13}$$

where σ_k^2 and σ_n^2 denote the variances of $\ln\omega_k$ and $\ln\omega_n$ respectively, and σ_{kn} is the covariance between them. Aggregate TFP reflects the underlying distribution of micro-level productivity levels, z, adjusted for efficiency losses caused by input distortions. We are interested in the change in TFP from eliminating the variation in tax rates, i.e., from setting $\sigma_\tau = 0$. This can be obtained by substituting $\omega_k = \omega_R$ into (10) and taking differences, which gives the formula shown in the following proposition.

Proposition 3. *Eliminating the heterogeneity in the marginal tax rates ($\sigma_\tau = 0$) yields the following change in aggregate TFP:*

$$\ln\frac{Z^*}{Z} = \frac{\alpha(1-\beta)}{1-\gamma}\frac{\sigma_\tau^2}{2} + \frac{\alpha(1-\beta)}{1-\gamma}\sigma_\tau^2(L_{k\tau}-1) + \frac{\alpha\beta}{1-\gamma}\sigma_\tau^2 L_{n\tau}, \tag{14}$$

where $L_{k\tau} = \sigma_{k\tau}/\sigma_\tau^2$ and $L_{n\tau} = \sigma_{n\tau}/\sigma_\tau^2$ denote the slope coefficients from a linear projection of ω_k and ω_n on ω_τ.

Equation (14) captures the total change in TFP from eliminating tax heterogeneity in much simpler terms relative to equation (12). It has three distinct components. The first one is a pure misallocation component, representing the reduction in aggregate output caused by a dispersion in the marginal products of capital across firms. In the absence of other distortions to the efficiency of the allocation, or if other distortions were orthogonal to tax rates, this would be the total improvement in TFP that can be expected from equalizing marginal tax rates. The magnitude of the TFP gains is increasing in the variance of the tax rates, σ_τ^2, the span of control parameter, γ, and capital's share of income, α.[6]

The second term in (14) captures the correlation of marginal tax rates with other distortions to capital. The coefficient $L_{k\tau}$ is less than one if $\ln \omega_R$ and $\ln \omega_\tau$ are negatively correlated. This can arise if tax rates act to alleviate other distortions. Eliminating tax differentials in this case need not lead to TFP gains. In fact, in the extreme case where tax rates fully offset other distortions, $\omega_\tau = \omega_R^{-1}$, $L_{k\tau} = 0$, which implies that the first two terms cancel each other.

Of course, taxes could also exacerbate the existing distortions. If firms that have higher marginal costs of borrowing also have higher marginal tax rates, this would manifest as $L_{k\tau} > 1$, and raise the potential gains from eliminating tax differentials.

The last term in (14) captures the correlation of marginal tax rates with distortions to labor. If tax rates are higher among firms that face higher marginal costs of labor, i.e., $L_{n\tau} > 0$, then eliminating tax differentials also improves the allocation of labor, leading to higher TFP gains. This might seem counter-intuitive because labor costs are deducted from the tax base, which implies that the corporate tax rate should not in principle distort employment decisions. However, the correlation between distortions to labor and the tax rates need not be causal in order to realize the additional TFP gains from equalizing tax rates. Equalization of tax rates lowers the tax rates for some firms and raises their input demand resulting in a reallocation of labor toward those firms. This improves efficiency

[6]To see this, note that $\frac{\alpha(1-\beta)}{1-\gamma} = \alpha + \frac{\alpha^2}{1-\gamma}$.

only if the marginal product of labor, ω_n, is higher at those firms on average.

3 Data and methodology

In this section we apply the expressions for TFP gains derived in the previous section to US data. Although corporations all face the same statutory corporate income tax schedule, a wide array of special provisions for deductions and allowances leads to a significant amount of dispersion in *effective* marginal tax rates, potentially distorting investment decisions. We use firm-level estimates of the effective marginal corporate income tax rate in combination with information on the balance sheets of publicly listed companies to estimate the effect of tax rate heterogeneity on productivity and output.

3.1 Data sources and definitions

Our main data source is the Compustat database covering the years from 1980 to 2021. Compustat provides annual balance-sheet data on publicly listed companies. To conduct our calculations we use information on output, employment, and the capital stock. We define output as the sum of sales and changes in inventories during the year.[7] Employment is reported directly. To construct a measure of a firm's capital stock, we use a perpetual inventory method using investment expenditures.[8] This allows us to compute the average productivity of labor and capital for each firm and year.

We supplement these data with estimates of firms' marginal corporate income tax rates, taken from two sources: Graham and Mills (2008) and Blouin et al. (2010). These studies take into account such factors as loss-offset provisions, depreciation allowances, and debt service when calculating an effective rate for

[7]Compustat does not contain information on the cost of intermediate inputs, preventing a measure of value added.

[8]We describe the data in more detail in Appendix B.

each firm.[9] Graham and Mills (2008) and Graham (1996) show that the simulated tax rates provide a close approximation of the actual taxes paid as reported in tax records.

Table 1: Summary statistics of marginal tax rates

Variable	mean	std	p25	p50	p75	N
τ^{GM}	.169	.171	.007	.070	.342	125,048
τ^{BCG}	.240	.136	.108	.283	.342	159,247

Note.– The two effective tax variables are taken from Graham and Mills (2008) and Blouin et al. (2010). See Appendix D for variable definitions and sample selection.

Summary statistics for the two effective marginal tax rate measures are shown in Table 1 and the distributions are plotted in Figure 1. The two tax measures differ somewhat in methodology. Rates estimated by Graham and Mills (2008) show more bunching at zero and at the top statutory marginal tax rate, which has varied over the years. Rates estimated by Blouin et al. (2010) provide a smoother distribution, with a higher average rate and a slightly smaller variance. The two tax measures are highly but imperfectly correlated ($\rho = 0.61$).

3.2 Measuring tax distortions

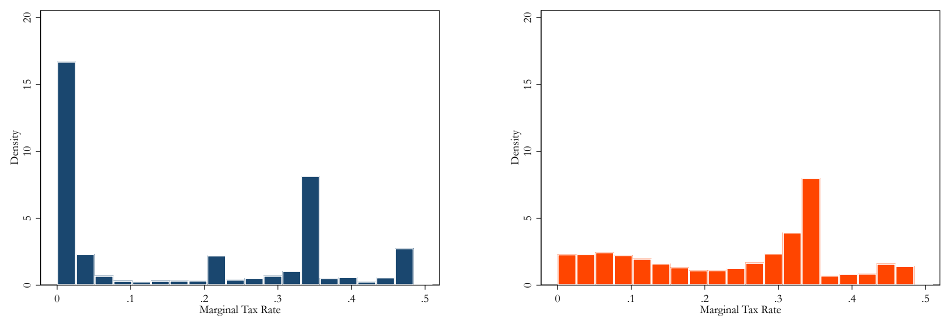
Because we have two distinct tax rate measures that are correlated imperfectly, we treat each measure as an erroneous estimate of the true marginal tax rate. This allows us to leverage the empirical content of each measure by focusing on their common component. Specifically, we interpret each measure as a combination of the true marginal tax rate and a classical measurement error:

$$\ln \omega_{i\tau}^{*} = \ln \omega_{\tau} + \epsilon_i,$$

[9] Each study contains two measures of the marginal tax rates: before and after interest deductions are applied. The marginal tax rates we use in this paper are after interest deductions.

Figure 1: Distribution of marginal tax rates

(a) τ^{GM} (b) τ^{BCG}



Note.- Distribution of effective marginal tax rates across all years. Source: Graham and Mills (2008), Blouin et al. (2010), and authors' calculations.

where $\mathbb{E}[\epsilon_i|\omega_\tau] = 0$ for $i \in \{1, 2\}$. Replacing the tax wedges by their measured counterparts not only biases the estimates of the total allocative effect of tax heterogeneity, but it can also lead to a misinterpretation of how tax rates interact with capital and labor distortions.

To see this, consider equation (14), which we use in our decomposition exercises below. This formula has three empirical moments that depend on the tax measure: the variance of the tax wedge, σ_τ^2, and the interactions of tax wedges with capital and labor productivity, as summarized by the projection coefficients $L_{k\tau}$ and $L_{n\tau}$. When ω_τ is replaced by its measured counterpart, ω_τ^*, all three moments are estimated with a bias. The variance of ω_τ^* is inflated relative to the variance of ω_τ by a factor of $(\sigma_\tau^2 + \sigma_\epsilon^2)/\sigma_\tau^2$. Higher measured dispersion in tax wedges tends to exaggerate the magnitude of the estimated change in TFP. Meanwhile, the estimates of $L_{k\tau}$ and $L_{n\tau}$, projections of capital and labor productivity on tax wedges, are attenuated proportionally by $\sigma_\tau^2/(\sigma_\tau^2 + \sigma_\epsilon^2)$ when ω_τ^* is used. Lower measured correlations between tax wedges and other distortions tend to attenuate the measured change in TFP from eliminating tax heterogeneity. The net effect of these two forces is a downward bias in the estimated gains as summarized by the following proposition.

Proposition 4. *Assume that the tax wedge is measured with error,* $\omega_\tau^* = \omega_\tau + \epsilon$ *with* $\mathbb{E}(\epsilon) = 0$*. Then, replacing the* ω_τ *by* ω_τ^* *in equation (14) underestimates the estimated net TFP gain from eliminating tax heterogeneity:*

$$\ln(Z^*/Z)|\omega_\tau^* = \ln(Z^*/Z)|\omega_\tau - \frac{\sigma_\epsilon^2}{2}\frac{\alpha(1-\beta)}{1-\gamma}. \tag{15}$$

Furthermore, the attenuated estimates of $L_{k\tau}$ and $L_{n\tau}$ result in an inaccurate assessment of the interaction between tax wedges and other capital distortions. The capital component (second term in equation (14)) gets attenuated, and the direct component (first term) gets exaggerated. The labor component (third term) is unaffected because the attenuation bias when estimating $L_{n\tau}$ is offset by the upward bias when estimating σ_τ^2.[10]

We address measurement error when we use equation (14) as follows. First, we estimate the variance of tax wedges with the covariance of the two measures: $\hat{\sigma}_\tau^2 = cov(\ln \omega_{1\tau}^*, \ln \omega_{2\tau}^*)$. To measure the distortions to capital and labor, we appeal to the optimality conditions for factor demands, $\ln \omega_k = \ln \alpha + \ln(y/k)$ and $\ln \omega_n = \ln \beta + \ln(y/n)$, where factor shares α and β are common to all firms in an industry during a given year. To estimate the correlation between total distortions to capital and the tax wedge, we estimate the following specification:

$$\ln(y/k)_{it} = D_{st}^k + L_{k\tau,t} \ln \omega_{\tau,it}^* + e_{it}^k, \tag{16}$$

where i denotes the firm, and t the year of observation. D_{st}^k are indicators for a full set of sector and year interactions. These indicators capture variations in capital shares and average distortions across sectors and years. Therefore, $L_{k\tau,t}$ reflects the correlation between the tax wedge and other capital distortions across firms in a given year, that is, our estimate of $L_{k\tau}$ in equation (14).

[10] This follows from the usual attenuation bias formula: $E[\hat{L}_{n\tau}^{OLS}] \times \sigma_{\omega_\tau^*}^2 = L_{n\tau} \times \sigma_{\omega_\tau}^2$, where $\hat{L}_{n\tau}^{OLS}$ is the OLS coefficient obtained by regressing $\ln \omega_n$ on $\ln \omega_\tau^*$

We estimate the cross-sectional correlation between distortions to labor and tax wedges using a similar specification:

$$\ln(y/n)_{it} = D^n_{st} + L_{n\tau,t} \ln \omega^*_{\tau,it} + e^n_{it}, \tag{17}$$

Because each tax estimate might contain measurement error, the OLS estimates of $L_{k\tau}$ and $L_{n\tau}$ are potentially attenuated. To remedy this issue, we estimate equations (16) and (17) with an instrumental variables approach, where one tax measure is used as an instrument for the other.

We estimate separate values of $L_{k\tau,t}$ and $L_{n\tau,t}$ for each year to compute TFP gains or losses below. In Table 2 we summarize the patterns of correlations between different distortions using a common estimate for all years. The first three columns show the OLS estimates of (16) and (17). The first row in each column shows the estimates obtained by tax measures provided by Graham and Mills (2008), and the second row shows the corresponding estimate using the tax measures from Blouin et al. (2010).

The two measures in the first column disagree about the implied correlation patterns between tax wedges and other distortions to capital. Recall that a value below (above) one indicates that the tax wedge is negatively (positively) correlated with other distortions to capital: $cov(\ln \omega_R, \ln \omega_\tau) < 0 \ (> 0)$. Therefore while Graham and Mills's estimates of the EMTR suggest a negative correlation between the tax wedge and capital distortions, Blouin et al.'s estimates suggest they are orthogonal. Similarly, the two estimates disagree on how strongly labor distortions project on tax wedges in column 2.

Correcting for the attenuation bias yields a more consistent picture across measures as shown in columns 4 and 5. Both estimates in column 4 indicate that other distortions to capital correlate positively with the tax wedges across firms, implying that the heterogeneity in tax rates exacerbates the existing distortions to capital.

The estimates in column 5 imply a positive correlation between labor distortions and the tax wedge. This is surprising because corporate income taxes

Table 2: Tax distortions and factor productivity

	(1) $\ln y/k$	(2) $\ln y/n$	(3) $\ln z$	(4) $\ln y/k$	(5) $\ln y/n$	(6) $\ln z$
			Panel A			
$\ln \omega_{1\tau}$	0.67	0.55	0.65	1.26	1.61	1.72
	(0.04)	(0.03)	(0.02)	(0.08)	(0.06)	(0.05)
			Panel B			
$\ln \omega_{2\tau}$	0.96	1.23	1.30	1.59	1.31	1.56
	(0.06)	(0.04)	(0.04)	(0.09)	(0.06)	(0.06)

Note.– The table shows the results from regressions of productivity on the tax wedge ($1/(1-\tau)$). Columns (1) to (3) report OLS estimates. Columns (4) to (6) report instrumental variable estimates to correct for measurement error. All specifications control for a full interaction of sector and year indicators. Data on productivity come from authors' calculations from Compustat. Data on marginal tax rates come from Graham and Mills (2008) in Panel A and Blouin et al. (2010) in Panel B.

are typically considered to distort capital investment. Because labor costs are deducted from the tax base, employment decisions should not in principle be affected by corporate taxes. The data, however, indicate a strong positive relationship between the two wedges, especially in specifications that address measurement error.

Columns 3 and 6 show the projections of firm-level TFP on the tax wedge, which we use below for some of our results. Consistent with the patterns from average labor and capital productivity, these estimates show that productive firms on average face higher marginal tax rates.

In our calculations below, we use the IV estimates for each year. Because from the two tax measures we obtain two estimates of the same underlying parameter, we combine them by taking an average of the two estimates weighted by the inverse of their variance. Using the estimates for the entire sample period, reported in columns 4 and 5 of Table 2, we obtain a value of 1.41 (s.e. 0.04) for $L_{k\tau}$ and 1.38 (s.e. 0.02) for $L_{n\tau}$ for the entire sample period.[11]

Because the distribution of tax rates in the data does not resemble a log-normal distribution, we also use the generalized formula stated in equation (12) to compute the allocative effects of tax heterogeneity. The implications of measurement error are more subtle in this case. First, the values of ω_k, ω_n, and firm-level productivity z - conditional on the measured tax rate - are biased. To get around this we use the estimates in Table 2 to compute the conditional averages for each of these variables. Letting $b^{IV}_{x\tau}$ denote the consistent estimate for the projection of $\ln x$, where $x \in \{\omega_k, \omega_n\ z\}$, on the tax wedge, $\ln \omega_\tau$, we compute $\hat{x} = \exp(b^{IV}_{x\tau} \times \ln \omega_\tau)$.[12] We then use $\hat{\omega}_k$, $\hat{\omega}_n$ $\hat{z}$ to construct the capital, employment, and output shares of all firms conditional on the value of ω_τ using the optimality conditions for capital and labor demand along with the production function.

The methodology above corrects the expected values of firm-level TFP, and distortions to capital and labor conditional on ω_τ, but it leaves the measurement of ω_τ and its distribution uncorrected. For this step we proceed by assuming that the measurement error ϵ_j, $j \in \{1, 2\}$ is independently normally distributed across the two measures in the data. This allows us to formulate the potential bias associated with replacing ω_τ with ω^*_τ as follows:

$$\ln \frac{\hat{Z}^*_{\tau^*}}{\hat{Z}_{\tau^*}} = \ln \frac{\hat{Z}^*_{\tau}}{\hat{Z}_{\tau}} - \frac{\sigma^2_\epsilon}{2} \frac{\alpha(1-\beta)}{1-\gamma} + \frac{\alpha \sigma^2_\epsilon}{1-\gamma} \left[\beta b^{IV}_{n\tau} + (1-\beta) b^{IV}_{k\tau} \right], \tag{18}$$

which is proportional to σ^2_ϵ, the variance of the measurement error. Whereas

[11] Specifically, the variance minimizing weights are $\lambda_1 = var(b^{IV}_{k\tau,2})/(var(b^{IV}_{k\tau,1}) + var(b^{IV}_{k\tau,2}))$ for $b^{IV}_{k\tau,1}$, and $\lambda_2 = 1 - \lambda_1$ for $b^{IV}_{k\tau,2}$. For $L_{k\tau}$, for instance, the values in column (4) of Table 2 imply a weight of $0.44 = 0.08^2/(0.08^2 + 0.09^2)$ for 1.59 and 0.56 for 1.26, giving a weighted average of 1.41. The standard error for the weighted estimate is given by $var(b^{IV}_{k\tau,1}) \times var(b^{IV}_{k\tau,2})/(var(b^{IV}_{k\tau,1}) + var(b^{IV}_{k\tau,2}))$.

[12] There is a Jensen's gap between $\ln E[x|\omega_\tau]$ and $E[\ln x|\omega_\tau]$, but we expect the effect of this gap on our calculations to be minor, because any discrepancy applies to variables in the numerator and the denominator of equation (12). For instance, when the conditional distribution of x is log-normal, even when the distribution of τ is not, these discrepancies offset each other exactly.

measurement error in tax rates necessarily biased downward the estimated TFP gains using (14), its effect on the estimates using equation (12) is ambiguous. In situations where tax wedges correlate positively with capital and labor distortions, the second term above is likely to dominate the first term, resulting in overestimation of TFP gains from eliminating tax heterogeneity.[13] This turns out to be the case in our application. We accordingly adjust our estimates downward using the expression above.

To generalize the distribution of the tax wedges, we partition the firms into equally sized quantile bins based on their (measured) marginal tax rate in each year. For each group-year cell, we then calculate the average tax wedge and compute the average firm-level TFP, along with capital and labor productivity as described above. Finally, we then compute the TFP gain or loss using equation (12) and adjust for measurement error.

Having two measures allows us to estimate the variance of the potential error in each tax measure by subtracting the covariance between the two measures, our estimate for the true variance, from the total variance of the measured wedge $\hat{\sigma}^2_{\epsilon,jt} = var(\ln \omega^*_{j\tau}) - cov(\ln \omega^*_{1\tau}, \ln \omega^*_{2\tau})$ for $j \in \{1, 2\}$. Because we are interested in the cross-sectional dispersion in tax wedges, we repeat this for each year.

Before we turn to the implications of our estimates for aggregate TFP and output, we need to set values for the parameters of the production function. For our baseline results, we keep those parameters fixed over time. This allows us to highlight the changes in the interactions between distortions when presenting the time trends. To that end, we set $\gamma = 0.85$, which implies a profit share of 15 percent in output. We set $\beta = 0.85 \times 2/3$, which gives a labor share of 0.57. These two choices imply a capital share of $\alpha = 0.28$. Given the downward trend in the labor share of income during our sample period, we also consider alternative scenarios for these parameters and discuss their implications for our findings below.

[13]This is akin to correcting estimates of $L_{k\tau}$ and $L_{n\tau}$ for measurement error, but not σ^2_τ when implementing equation (14).

4 Results

In this section, we report our estimates for the effect of eliminating cross-sectional differences in tax wedges on total factor productivity. Our primary finding is that tax heterogeneity has lowered TFP in the United States. Our baseline estimates put this loss at around 3 percent. We find that this result is robust to including macroeconomic trends in the decline of the labor share or an increase in markups. While those trends slightly alter the source of the TFP loss, the overall magnitudes are hardly affected. Finally, we decompose the TFP losses associated with tax heterogeneity into its three components (*cf.* equation (14)). The pure dispersion in tax rates explains a sizeable part of the estimated TFP losses, but this component became smaller after the tax reforms of the 1980s. The correlation of tax rates with capital and - especially - labor make up the largest component of losses from tax misallocation.

4.1 TFP losses

We begin with the estimates of the overall TFP gains from eliminating tax heterogeneity using the general formula in equation (12). The results obtained by using the two tax measures are shown in Figure 2.

The change in TFP from eliminating tax heterogeneity is positive throughout our sample period. This suggests that differential tax rates do not offset other distortions to capital and labor. On the contrary, our estimates imply that factors are likely more productive at firms that have higher marginal tax rates. The two measures yield very similar estimates of TFP gains. The average gain in TFP over the sample period is around 3 percent across years and measures. This is large considering that the tax rates primarily distort capital, which accounts for about a third of production.

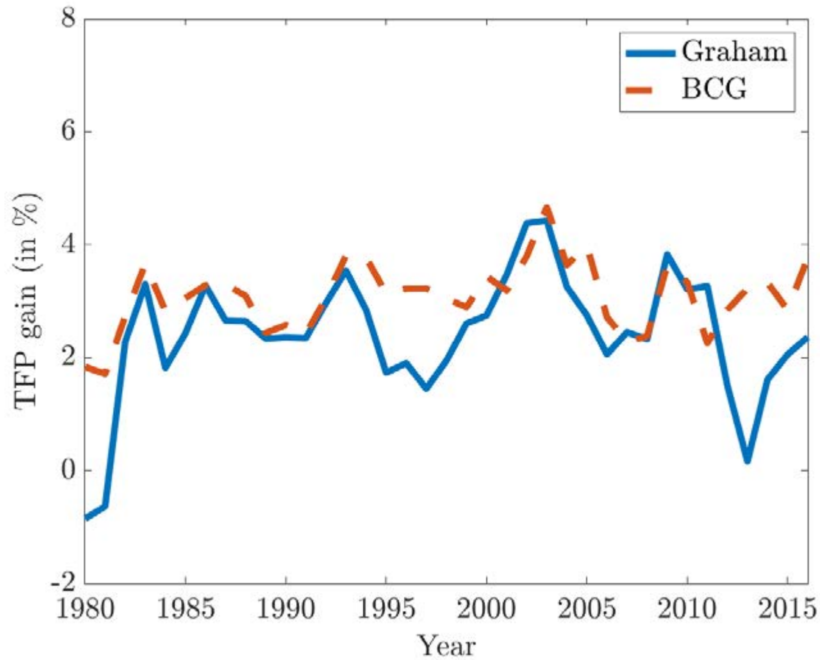


Figure 2: TFP gains from tax rate equalization

Note.– The figure shows the estimated change in TFP if all firms were to face a common tax rate.

4.2 Macroeconomic trends and estimated TFP gains

The TFP losses in Figure 2 appear to be roughly stable over time. When computing these gains, we assumed constant values for the macroeconomic parameters of factor shares and markups. Empirically, however, we observe a downward trend in the labor share of income during our sample. Recent work has argued that the decline in the labor share is associated with a rise in price markups and/or an increase in the capital share. In this subsection, we investigate how these changes might affect the trends in estimated TFP losses associated with tax heterogeneity.

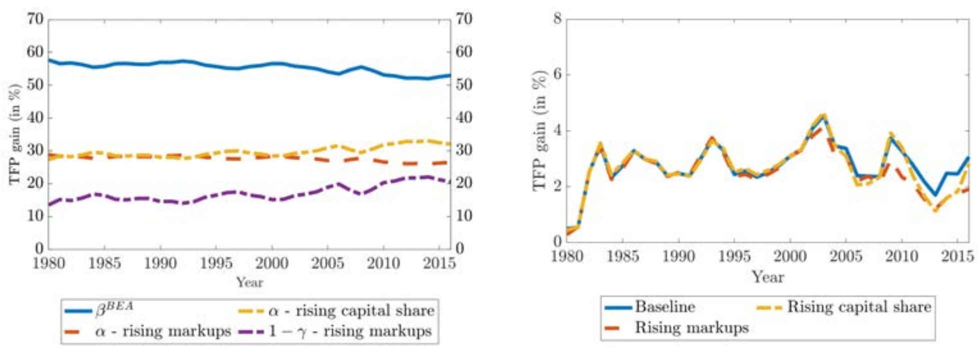
Because the changes in the composition of income alter three parameters at once, α, β, and γ, and because of the non-linear nature of the equation in (12), it is *a priori* not clear how the macroeconomic trends might change our estimates. Nonetheless, an inspection of the linearized approximation in equation (14) provides some insights.

A higher markup rate is equivalent to a lower value for γ, i.e., more weakly diminishing returns to scale. Ceteris paribus, lower values of γ are associated with lower TFP losses from tax heterogeneity as indicated by equation (14). Therefore rising markups would tend to reduce the TFP losses over time. Intuitively, this is because higher values of γ bring the economy closer to a linear technology (or, equivalently, to perfect competition), where the best firm can absorb all the resources without facing diminishing returns to scale. That possibility raises the total gains to reallocating inputs more efficiently.

A higher value of α, capital's income share, raises the TFP losses, ceteris paribus. Intuitively, the larger the importance of the distorted factor in production is, the larger are the losses from tax distortions.

Changes in the labor share of income, ceteris paribus, have an ambiguous effect on estimated TFP losses. Note that labor's share of income acts as a weight in equation (14) when considering distortions that are related to the allocation of labor versus capital. A decline in the income share of labor, β, shifts the weight from the correlation between tax distortions and other labor distortions to tax distortions to capital. Because the effect of tax heterogeneity on allocative efficiency is generally ambiguous in a distorted economy - it depends on the correlations of tax rates with other distortions to capital and labor- the net effect of a change in the labor share is ambiguous as well. For instance, if labor productivity is generally high and capital productivity is generally low among firms that face higher tax rates, then a lower labor share should be associated with smaller TFP losses from tax heterogeneity.

Of course, the shares of capital, labor and profits sum to one, and a change in one parameter necessarily changes at least one other. While the evidence on the decline in the aggregate labor share is relatively well-accepted, how much of that decline was redistributed to capital versus profits is less clear. It turns out that the precise answer does not change our findings very much. In our exercises below, we benchmark the decline in the labor share parameter to the BEA's measure for each year of our analysis, and consider two alternatives. First, we assume that the decline in the labor share was matched one for one by a rise in the capital share of income, keeping the share of profits constant over time. Second, we assume the capital share in profits declines proportional to the labor share, raising profits' share over time.



(a) Parameters (b) Misallocation

Figure 3: Macro trend scenarios

Note.– Panel (a) shows the labor share of income (β) from the BEA, and the associated changes in the shares of capital (α) and profits ($1-\gamma$) under two alternative scenarios. Panel (b) shows the TFP gains from tax rate equalization in each scenario. Parameters are constant in the baseline scenario.

The resulting values for α, β, and γ are shown in Panel (a) of Figure 3. The solid line shows the labor share of income published by the BEA. It declines from 57.7 percent in 1980 to 53.0 percent in 2016. In the first scenario we consider, this is matched by a 4.7 percent increase in α, shown in yellow in the figure. In the second scenario, it is instead matched with a proportional decline in the capital share from 28.8 percent to 26.5 percent (the red line). This keeps the cost share of labor fixed at 2/3. The decline in total capital and labor costs then implies a rise in the profit share from 13.5 in 1980 to 20.5 in 2016, or, equivalently, a rise in the markup rate from 15.6 to 25.7 percent (shown as the purple line).

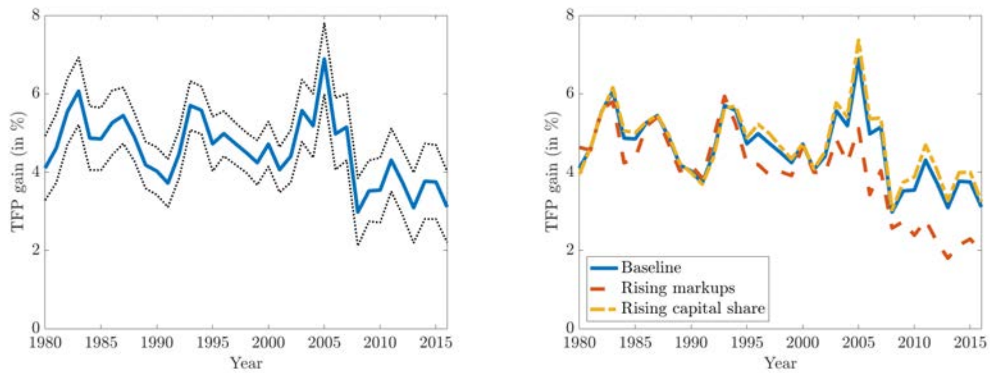
Panel (b) of Figure 3 shows the TFP gains under these scenarios. Because the two tax measures yield similar estimates, we only report the average of the two estimates in each scenario. Overall, all scenarios yield similar magnitudes. Relative to the benchmark with constant factor share, the declining labor share results point to approximately 1 percentage point lower TFP losses from tax heterogeneity in recent years.

4.3 Decomposing TFP losses

Next, we decompose the effect of tax heterogeneity on TFP into its components. Because of its ease of interpretation, we rely on our linear approximation in equation (14) for this subsection. First, we compute the total TFP losses. The resulting estimates of the TFP gains from eliminating tax heterogeneity are shown in Figure 4. The dashed lines represent the error bands corresponding to two standard errors above and below the point estimate.

As in the previous section, we find that eliminating tax heterogeneity results in TFP gains. The magnitude of the gain is 4.6 percent on average, slightly larger than the 3 percent above, albeit within the margin of statistical error. The estimated gains range from around 5 percent during the early 1980s to around 3 percent in recent years, suggesting a 2 percent improvement over the years in our baseline. Under alternative macro-trend scenarios, shown in the right panel, the magnitudes remain roughly similar, implying a 2 to 3 percent TFP gain over the years. These findings are broadly consistent with our findings above.

From equation (14) the total TFP gains reflect not only the dispersion in tax rates, but also the estimated correlation between the tax wedge and other distortions to capital and labor. The stacked bars in Figure 5 show these components separately for our baseline scenario. The blue bars reflect the misallocation caused purely by the heterogeneity in tax rates. If tax wedges were uncorrelated with the marginal products of capital and labor, the blue bars would represent the total gains in TFP. They can therefore be interpreted as the TFP distortion



(a) Baseline

(b) Macro-Trend Alternatives

Figure 4: TFP gains from eliminating tax heterogeneity

Note.– The figure shows the estimated change in TFP implied by a common tax rate across firms. The baseline scenario in Panel (a) assumes constant aggregate shares of labor, capital and profits. Dashed lines indicate the 95 percent confidence interval. Panel (b) features a declining labor share either from rising markups or from rising capital share.

caused by tax heterogeneity in an otherwise frictionless economy. From Figure 5 this component of the TFP gain was 1 to 2 percent prior to 1986, due in part to the higher statutory corporate tax rate, and has been under 1 percent since then. Overall, it represents less than a quarter of the total TFP gains. This highlights the importance of taking other distortions into account when studying the allocative effects of a particular distortion.

The red bars in Figure 5 represent the TFP losses that stem from how tax rates correlate with capital productivity. There are two hypothetical cases. If $cov(\omega_R, \omega_\tau) < 0$, or equivalently, $L_{k\tau} < 1$, the heterogeneity in tax rate *reduces* the distortionary effects of other distortions. This could be the case if firms that face relatively large distortions, for example, due to credit constraints or adjustment costs, face *lower* tax rates. In that situation, which is observed for several years in the figure, the red bars contribute negatively to the TFP gain. The second case, i.e., when $cov(\omega_R, \omega_\tau) > 0$ is the more common case, however. This implies

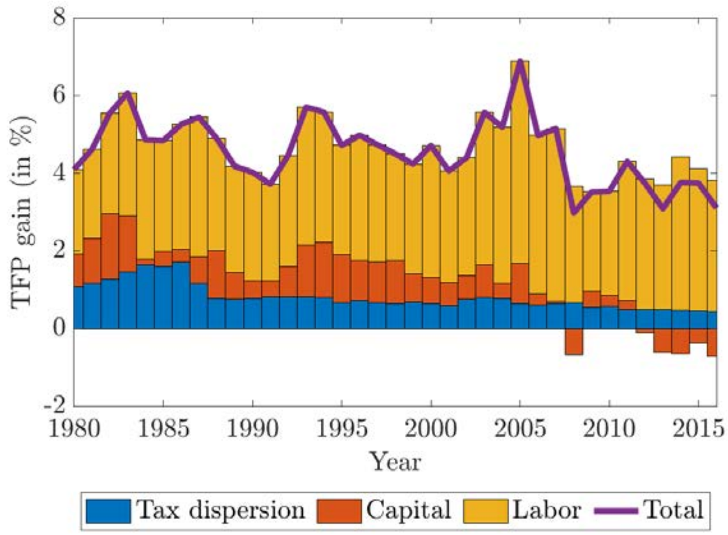
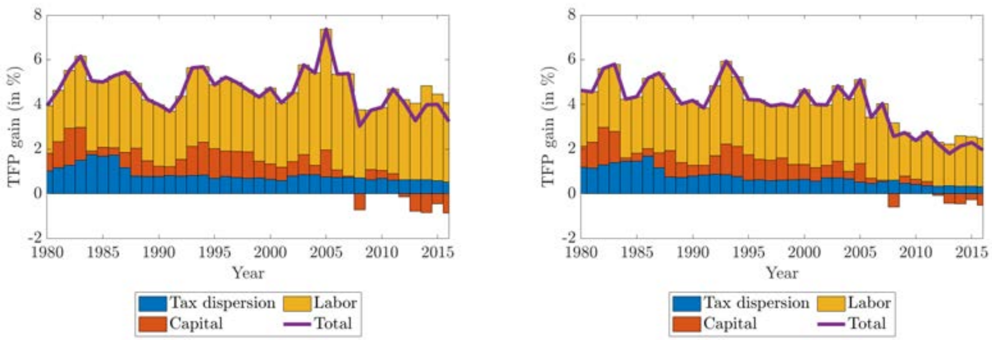


Figure 5: Components of TFP gains from eliminating tax heterogeneity

Note.– The figure shows the three components of TFP gains from tax rate equalization across firms (see equation (14)). The blue bars labeled "Tax dispersion" represent gains in an otherwise frictionless economy. The red bars labeled "Capital" show additional gains/losses in an economy with capital distortions. The bars labeled "Labor" show additional gains in an economy with capital and labor distortions.

that tax rates are positively correlated with capital distortions. From the figure this correlation is not very strong, however, resulting in less than 1 percent of additional TFP gains. Over the years, the potential gains implied by this component have been highest during the 1990s and early 2000s and have diminished in more recent years. This suggests an improvement from an efficiency perspective in the distribution of tax rates across firms over time.

The third component of the TFP gain comes from the correlation between labor distortions and tax wedges. This is shown as the yellow bars in Figure 5. When that correlation is positive, equalizing taxes results in lower tax rates for firms where the marginal product of labor is typically higher. This implies



(a) Rising Capital Share

(b) Rising Markups

Figure 6: Sources of TFP gains under alternative macro scenarios

a reallocation of employment toward high marginal product firms and creates an additional gain in TFP. Quantitatively, those gains represent a majority of the total gains depicted in Figure 4. This is partly because the share of labor in total income is roughly twice as large as that of capital.

Overall, tax heterogeneity alone represents less than 1 percent of the total gains. The majority of the 3 to 6 percent projected gain in TFP is due to the fact that tax wedges are correlated positively with other labor distortions.

The figure 6 shows the decomposition of TFP gains under alternative macro scenarios where the labor share declines. As before, the left panel attributes that decline to a rise in the capital share of income and the right panel to a rise in markups. The relative magnitudes of the interaction between tax wedges and capital or labor distortions are broadly similar across scenarios. Under rising markups, overall TFP gains from eliminating tax heterogeneity decline by more, especially toward the end of the sample. This is attributable to a lower value of γ, which reduces the TFP losses associated with each component (see equation (14)), although the decline in the labor component is the most apparent.

5 Conclusion

Our findings show that policies that seek to reduce differences in marginal corporate income tax rates would result in aggregate productivity gains. The majority of these gains are attributable to the empirical patterns of various distortions to input allocation. Firms that face higher tax rates are typically those where capital and especially labor are more productive on the margin.

These findings highlight the importance of modeling frictions in the economy when studying the implications of a specific distortion to aggregate efficiency. In our case, the strong correlation between labor productivity and the corporate tax rate is surprising because corporate tax rates are thought to primarily affect investment decisions. Because labor costs are deducted from the corporate income tax base, the allocation of employment should be efficient in a standard setting.

Our methodology does not speak to the nature of that correlation as it does not distinguish a spurious relationship from a causal one. Our measurement approach treats this correlation as non-causal. As a result, removing tax heterogeneity does not alleviate the distortions to labor. If the correlation between tax rates and labor productivity is in fact causal, then our findings should be viewed as a lower bound for potential gains in efficiency. When the correlation is causal, we estimate that the potential efficiency loss from tax heterogeneity can be as high as 7 to 8 percent. Therefore, models of production where labor is chosen dynamically, or those with liquidity constraints where payments to labor are made prior to obtaining sales revenue, are promising avenues for future research that seeks to determine whether employment decisions are causally distorted by corporate tax rates.

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A Theoretical Appendix

This appendix details the derivations in the text and gives the formal proofs for the propositions.

Firm's problem with multiple distortions The optimality conditions for investment and future capital of the firm's problem in (1) are given by the first-order condition with respect to investment:

$$i: \quad -1 - \Phi'\left(\frac{i}{k}\right) + q - \mu = 0 \quad \Leftrightarrow \quad q = 1 + \Phi'\left(\frac{i}{k}\right) + \mu. \tag{A1}$$

and

$$k': \quad \beta\left[(1-\tau)zF_k(k', n) + E_{z'|z}V_k(z', k')\right] - q = 0, \tag{A2}$$

with the envelope condition

$$V_k(z, k) = -\Phi\left(\frac{i}{k}\right) + \Phi'\left(\frac{i}{k}\right)\frac{i}{k} + q(1-\delta) + \mu\zeta q. \tag{A3}$$

This implies an optimality condition for the choice of capital given by (5).

Proposition 1. *Total factor productivity in the distorted economy is:*

$$Z = \frac{Y}{K^\alpha N^\beta} = \frac{\int z^{\frac{1}{1-\gamma}} \omega_n^{-\frac{\beta}{1-\gamma}} \omega_k^{-\frac{\alpha}{1-\gamma}} dG}{\left[\int z^{\frac{1}{1-\gamma}} \omega_n^{-\frac{\beta}{1-\gamma}} \omega_k^{-\frac{1-\beta}{1-\gamma}} dG\right]^\alpha \left[\int z^{\frac{1}{1-\gamma}} \omega_n^{-\frac{1-\alpha}{1-\gamma}} \omega_k^{-\frac{\alpha}{1-\gamma}} dG\right]^\beta} \tag{A4}$$

Proof. The profit-maximizing levels of capital, labor, and output are:

$$n = z^{\frac{1}{1-\gamma}} \left(\frac{\beta}{\omega_n}\right)^{\frac{1-\alpha}{1-\gamma}} \left(\frac{\alpha}{\omega_k}\right)^{\frac{\alpha}{1-\gamma}} \tag{A5}$$

$$k = z^{\frac{1}{1-\gamma}} \left(\frac{\beta}{\omega_n}\right)^{\frac{\beta}{1-\gamma}} \left(\frac{\alpha}{\omega_k}\right)^{\frac{1-\beta}{1-\gamma}} \tag{A6}$$

$$y = z^{\frac{1}{1-\gamma}} \left(\frac{\beta}{\omega_n}\right)^{\frac{\beta}{1-\gamma}} \left(\frac{\alpha}{\omega_k}\right)^{\frac{\alpha}{1-\gamma}} \tag{A7}$$

Substituting in the definition of TFP gives the following:

$$Z = \frac{Y}{K^\alpha N^\beta} = \frac{\int z^{\frac{1}{1-\gamma}} \omega_n^{-\frac{\beta}{1-\gamma}} \omega_k^{-\frac{\alpha}{1-\gamma}} dG}{\left[\int z^{\frac{1}{1-\gamma}} \omega_n^{-\frac{\beta}{1-\gamma}} \omega_k^{-\frac{1-\beta}{1-\gamma}} dG\right]^\alpha \left[\int z^{\frac{1}{1-\gamma}} \omega_n^{-\frac{1-\alpha}{1-\gamma}} \omega_k^{-\frac{\alpha}{1-\gamma}} dG\right]^\beta}$$

□

Proposition 2. *The gains in TFP from eliminating tax differentials across firms is:*

$$\frac{TFP^*}{TFP} = \frac{\int \frac{y}{Y} \omega_\tau^{\frac{\alpha}{1-\gamma}}}{(\int \frac{k}{K} \omega_\tau^{\frac{1-\beta}{1-\gamma}})^\alpha (\int \frac{n}{N} \omega_\tau^{\frac{\alpha}{1-\gamma}})^\beta} \tag{A8}$$

Proof. Let ω'_τ be the hypothetical distribution of tax distortions. Define $\omega'_k = \omega'_\tau \omega_R$ to be the corresponding wedge on capital choice. Let k', n' and y' be the optimal capital, labor and output choices under the alternative taxes. Given the formulas for these above, the following are true:

$$\frac{k'}{k} = \left(\frac{\omega'_k}{\omega_k}\right)^{-\frac{1-\beta}{1-\gamma}} \quad \frac{n'}{n} = \frac{y'}{y} = \left(\frac{\omega'_k}{\omega_k}\right)^{-\frac{\alpha}{1-\gamma}},$$

where $\omega'_k/\omega_k = \omega'_\tau/\omega_\tau$ by construction.

Recall that TFP under new distortions is defined as:

$$TFP' = \frac{\int y'}{(\int k')^\alpha (\int n')^\beta} = \frac{\int y \left(\frac{\omega_\tau}{\omega'_\tau}\right)^{\frac{\alpha}{1-\gamma}}}{(\int k \left(\frac{\omega_\tau}{\omega'_\tau}\right)^{\frac{1-\beta}{1-\gamma}})^\alpha (\int n \left(\frac{\omega_\tau}{\omega'_\tau}\right)^{\frac{\alpha}{1-\gamma}})^\beta}$$

Note that the TFP is scale independent with respect to ω'_τ, i.e. for any scalar $c, c' > 0$, $c\omega'_\tau$ and $c'\omega_\tau$ give the same TFP. Therefore, without loss of generality, we set $\omega'_\tau = 1$ for all firms.

This yields the following:

$$\frac{TFP'}{TFP} = \frac{\int y'}{(\int k')^{\alpha}(\int n')^{\beta}} \div \frac{Y}{K^{\alpha}N^{\beta}} = \frac{\int \frac{y}{Y}\omega_{\tau}^{\frac{\alpha}{1-\gamma}}}{(\int \frac{k}{K}\omega_{\tau}{}^{\frac{1-\beta}{1-\gamma}})^{\alpha}(\int \frac{n}{N}\omega_{\tau}{}^{\frac{\alpha}{1-\gamma}})^{\beta}},$$

which is equivalent to

$$\frac{\int_{\tau} y(\tau)\omega_{\tau}^{\frac{\alpha}{1-\gamma}} dG}{\left(\int_{\tau} k(\tau)\omega_{\tau}{}^{\frac{1-\beta}{1-\gamma}} dG\right)^{\alpha}\left(\int_{\tau} n(\tau)\omega_{\tau}{}^{\frac{\alpha}{1-\gamma}} dG\right)^{\beta}},$$

where $y(\tau), k(\tau)$, and $n(\tau)$ denote the output, capital and employment shares of firms that are subject to the same tax rate τ.

□

Proposition 3. *Eliminating the heterogeneity in the marginal tax rates ($\sigma_{\tau} = 0$) yields the following change in aggregate TFP:*

$$\ln\frac{Z^{*}}{Z} = \frac{\alpha(1-\beta)}{1-\gamma}\frac{\sigma_{\tau}^{2}}{2} + \frac{\alpha(1-\beta)}{1-\gamma}\frac{\sigma_{\tau}^{2}}{2}(L_{k\tau}-1) + \frac{\alpha\beta}{1-\gamma}\frac{\sigma_{\tau}^{2}}{2}L_{n\tau}, \tag{A9}$$

where $L_{k\tau} = \sigma_{k\tau}/\sigma_{\tau}^{2}$ and $L_{n\tau} = \sigma_{n\tau}/\sigma_{\tau}^{2}$ denote the slope coefficients from a linear projection of ω_k and ω_n on ω_{τ}.

Proof. Let $\mu_x = \mathbb{E}[\ln x]$ and $\sigma_x^2 = \mathbb{V}[\ln x]$ be the mean and variance of the log of a variable x. Under joint log-normality:

$$\begin{aligned}\ln\int y \quad &= \quad \frac{\alpha}{1-\gamma}\ln\alpha + \frac{\beta}{1-\gamma}\ln\beta + \frac{1}{1-\gamma}(\mu_z - \alpha\mu_k - \beta\mu_n) \\ &\quad + \frac{1}{2}\frac{1}{(1-\gamma)^2}(\sigma_z^2 + \alpha^2\sigma_k^2 + \beta^2\sigma_n^2 - 2\alpha\sigma_{zk} - 2\beta\sigma_{zn} + 2\alpha\beta\sigma_{kn})\end{aligned}$$

$$\ln \int k = \frac{(1-\beta)}{1-\gamma}\ln\alpha + \frac{\beta}{1-\gamma}\ln\beta + \frac{1}{1-\gamma}(\mu_z - (1-\beta)\mu_k - \beta\mu_n) + \frac{1}{2}\frac{1}{(1-\gamma)^2}(\sigma_z^2 + (1-\beta)^2\sigma_k^2 + \beta^2\sigma_n^2 - 2(1-\beta)\sigma_{zk} - 2\beta\sigma_{zn} + 2(1-\beta)\beta\sigma_{kn})$$

$$\ln \int n = \frac{\alpha}{1-\gamma}\ln\alpha + \frac{(1-\alpha)}{1-\gamma}\ln\beta + \frac{1}{1-\gamma}(\mu_z - \alpha\mu_k - (1-\alpha)\mu_n) + \frac{1}{2}\frac{1}{(1-\gamma)^2}(\sigma_z^2 + \alpha^2\sigma_k^2 + (1-\alpha)^2\sigma_n^2 - 2\alpha\sigma_{zk} - 2(1-\alpha)\sigma_{zn} + 2\alpha(1-\alpha)\sigma_{kn})$$

Using these equations, the TFP in the distorted economy is:

$$\ln Z = \mu_z + \frac{1}{2}\frac{1}{1-\gamma}\left[\sigma_z^2 - \alpha(1-\beta)\sigma_k^2 - \beta(1-\alpha)\sigma_n^2 - 2\alpha\beta\sigma_{kn}\right]. \quad \text{(A10)}$$

When tax differentials are eliminated capital distortions are given simply by ω_R, which gives the TFP in that counterfactual as:

$$\ln Z^* = \mu_z + \frac{1}{2}\frac{1}{1-\gamma}\left[\sigma_z^2 - \alpha(1-\beta)\sigma_R^2 - \beta(1-\alpha)\sigma_n^2 - 2\alpha\beta\sigma_{Rn}\right]. \quad \text{(A11)}$$

Note that $\sigma_k^2 - \sigma_R^2 = \sigma_\tau^2 + \sigma_{R\tau}$ and $\sigma_{kn} - \sigma_{Rn} = \sigma_{n\tau}$. Rearranging the terms and netting out μ_z, σ_z^2 and σ_n^2 terms, the efficiency losses from distortions are equivalent to:

$$\ln\frac{Z^*}{Z} = \frac{1}{2}\frac{1}{1-\gamma}\left[\alpha(1-\beta)(\sigma_k^2-\sigma_R^2)+2\alpha\beta(\sigma_{kn}-\sigma_{Rn})\right] \quad \text{(A12)}$$

$$= \frac{1}{2}\frac{1}{1-\gamma}\left[\alpha(1-\beta)(\sigma_\tau^2+\sigma_{R\tau})+2\alpha\beta\sigma_{n\tau}\right] \quad \text{(A13)}$$

$$= \frac{\sigma_\tau^2}{2}\frac{1}{1-\gamma}\left[\alpha(1-\beta)(1+\frac{\sigma_{R\tau}}{\sigma_\tau^2})+2\alpha\beta\frac{\sigma_{n\tau}}{\sigma_\tau^2}\right] \quad \text{(A14)}$$

$$= \frac{\sigma_\tau^2}{2}\frac{1}{1-\gamma}\left[\alpha(1-\beta)L_{k\tau}+2\alpha\beta L_{n\tau}\right] \quad \text{(A15)}$$

The last equality substitutes the linear projection coefficients for $\frac{\sigma_{R\tau}}{\sigma_\tau^2} = L_{R\tau} = L_{k\tau} - 1$ and $\frac{\sigma_{n\tau}}{\sigma_\tau^2} = L_{n\tau}$. Rearranging terms gives the formula in the proposition.

□

Proposition 4. *Assume that the tax wedge is measured with error,* $\omega_\tau^* = \omega_\tau + \epsilon$ *with* $\mathbb{E}(\epsilon) = 0$. *Then, replacing the* ω_τ *by* ω_τ^* *in equation* (14) *underestimates the net TFP gain from eliminating tax heterogeneity:*

$$\ln(Z^*/Z)|\omega_\tau^* = \ln(Z^*/Z)|\omega_\tau - \frac{\sigma_\epsilon^2}{2}\frac{\alpha(1-\beta)}{1-\gamma}, \quad \text{(A16)}$$

Proof. Let $\sigma_{\tau^*}^2 = \sigma_\tau^2 + \sigma_\epsilon^2$ denote the variance of the measured tax wedge. Define the projection $x = L_{x\tau} \times \ln\omega_\tau + e_x$, where ω_τ is the true tax wedge. The OLS estimate of $L_{x\tau}$ from the projection of x on $\ln\omega_{\tau^*}^2$ is: $\hat{L}_{x\tau}^{OLS} = L_{x\tau} \times \frac{\sigma_\tau^2}{\sigma_{\tau^*}^2}$.

$$\begin{aligned}
\ln(Z^*/Z)|\omega_\tau^* &= \frac{\alpha(1-\beta)}{1-\gamma}\frac{\sigma_{\tau^*}^2}{2} + \frac{\alpha(1-\beta)}{1-\gamma}\frac{\sigma_{\tau^*}^2}{2}(\hat{L}_{k\tau}^{OLS}-1) + \frac{\alpha\beta}{1-\gamma}\frac{\sigma_{\tau^*}^2}{2}\hat{L}_{n\tau}^{OLS} \\
&= -\frac{\sigma_\tau^2+\sigma_\epsilon^2}{2}\frac{\alpha(1-\beta)}{1-\gamma} + \frac{\alpha(1-\beta)}{1-\gamma}\frac{\sigma_\tau^2}{2}L_{k\tau} + \frac{\alpha\beta}{1-\gamma}\frac{\sigma_\tau^2}{2Ln\tau} \\
&= \ln(Z^*/Z)|\omega_\tau - \frac{\sigma_\epsilon^2}{2}\frac{\alpha(1-\beta)}{1-\gamma}.
\end{aligned}$$

□

Computation of the nonlinear gains and measurement error correction For each $x \in \{\omega_k, \omega_n\ z\}$, define $\hat{x} = \exp(b^{IV}_{x\tau} \times \ln \omega_\tau)$, where $b^{IV}_{x\tau}$ is a consistent estimator of $L_{x\tau}$.

Then compute current TFP by substituting $\hat{\omega}_k$, $\hat{\omega}_n$ and $\hat{z}$ in equation (10), and the ideal TFP by substituting $\hat{\omega}_n$, $\hat{z}$, and $\omega'_k = \hat{\omega}_k/\omega_{\tau^*}$ for ω_k in the same equation. This yields the following equations:

$$\hat{Z}_{\tau^*} = \frac{\int (\omega_{\tau^*})^{\frac{1}{1-\gamma}\left(b^{IV}_{z\tau} - \beta b^{IV}_{n\tau} - \alpha b^{IV}_{k\tau}\right)} dG_{\tau^*}}{\left[\int (\omega_{\tau^*})^{\frac{1}{1-\gamma}\left(b^{IV}_{z\tau} - \beta b^{IV}_{n\tau} - (1-\beta) b^{IV}_{k\tau}\right)} dG_{\tau^*}\right]^{\alpha} \left[\int (\omega_{\tau^*})^{\frac{1}{1-\gamma}\left(b^{IV}_{z\tau} - (1-\alpha) b^{IV}_{n\tau} - \alpha b^{IV}_{k\tau}\right)} dG_{\tau^*}\right]^{\beta}}$$

$$\hat{Z}^*_{\tau^*} = \frac{\int (\omega_{\tau^*})^{\frac{1}{1-\gamma}\left(b^{IV}_{z\tau} - \beta b^{IV}_{n\tau} - \alpha b^{IV}_{R\tau}\right)} dG_{\tau^*}}{\left[\int (\omega_{\tau^*})^{\frac{1}{1-\gamma}\left(b^{IV}_{z\tau} - \beta b^{IV}_{n\tau} - (1-\beta) b^{IV}_{R\tau}\right)} dG_{\tau^*}\right]^{\alpha} \left[\int (\omega_{\tau^*})^{\frac{1}{1-\gamma}\left(b^{IV}_{z\tau} - (1-\alpha) b^{IV}_{n\tau} - \alpha b^{IV}_{R\tau}\right)} dG_{\tau^*}\right]^{\beta}},$$

where $b^{IV}_{R\tau} = b^{IV}_{k\tau} - 1$ is the projection coefficient of $\ln \omega_R$ on $\ln \omega_{\tau^*}$ and G_{τ^*} is the marginal distribution of the measured tax wedge.

When ϵ is distributed independently log-normal, then for any scalar $c > 0$, $E[\omega^c_{\tau^*}] = E[\omega^c_\tau \epsilon^c] = E[\omega^c_\tau] \cdot E[\epsilon^c] = E[\omega^c_\tau] \cdot \exp(c^2 \sigma^2_\epsilon / 2)$. Replacing c with the appropriate power component for each term gives:

$$\ln \frac{\hat{Z}^*_{\tau^*}}{\hat{Z}_{\tau^*}} = \ln \frac{\hat{Z}^*_\tau}{\hat{Z}_\tau} - \frac{\sigma^2_\epsilon}{2} \frac{\alpha(1-\beta)}{1-\gamma} + \frac{\alpha \sigma^2_\epsilon}{1-\gamma} \left[\beta b^{IV}_{n\tau} + (1-\beta) b^{IV}_{k\tau}\right]. \tag{A17}$$

B Data Appendix

The firm-level data used in Section 3 were constructed as follows. We use the annual Compustat database, which provides balance-sheet data on publicly listed companies in the US. Our sample includes the years 1980–2021. We perform the following sample selection and data-cleaning steps. We restrict attention to firms registered in the US. We exclude firms in the finance, insurance, and real estate sectors, as well as in utilities and public administration. We remove observations with negative sales.

We construct firm-level capital stocks by using a perpetual inventory method. For each firm, we start with the year in which information on gross and net property, plant, and equipment (PPEGT and PPENT) is available. We then build the capital stock by adding the change in PPENT deflated by the investment price deflator to the calculated capital stock for that year.

We supplement these data with information on firms' marginal tax rates, taken from two sources, *i)* Graham and Mills (2008) (abbreviated as "GM") and *ii)* Blouin et al. (2010) (abbreviated as "BCG"). While the GM database covers the years 1980–2021, the BCG data are only available from 1980 until 2016. We link the Compustat data to the marginal tax rate data via the firm identifier GVKEY. Finally, we remove firm-year observations for which both tax rates are missing.

This results in a sample of 185,203 unique firm-year observations, averaging about 4,600 firms per year. Marginal effective tax rates are available for 70.3 percent of our observations (90.2 percent for the BCG tax rates).

Estimation of firm-level TFP We estimate firm-level TFP using a three-step control function approach following Olley and Pakes (1996). The key variables are value added, employment, and physical capital for each firm and factor shares in the production function. Value added is defined as sales plus the change in inventories.

We begin by estimating factor shares at the two-digit NAICS level in three steps. First, we regress log of output on second-order polynomials in the logs of the capital stock and investment expenditures, including an interaction term as well as log employment. We control for a full set of indicator variables for year and 2-digit NAICS classifications. Sectors with fewer than 100 observations were dropped from this estimation. Second, to correct for survival bias, we estimate a probit specification for firm survival in the Compustat data (using the same polynomials and year-industry dummies). In a third step, we estimate capital shares for each industry by regressing log output on the log capital stock, controlling for industry-year effects and the predicted survival probability from the previous step. We then compute log TFP assuming a Cobb-Douglas production function and normalize it to have a mean of zero in each year and industry.