Corporate tax avoidance, firm size, and capital misallocation[⋆]

Brent Glover[a] Oliver Levine[b]

[a] *Carnegie Mellon University, Tepper School of Business, 5000 Forbes Avenue, Pittsburgh, PA 15213, USA*
[b] *University of Wisconsin–Madison, Wisconsin School of Business, Finance Department, 975 University Avenue, Madison, WI 53706, USA*

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ABSTRACT

We develop an industry equilibrium model to study how corporate tax avoidance affects firm policies and industry outcomes. In the model, tax avoidance and investment are complementary inputs, leading the largest firms to engage in the most avoidance and face the lowest effective tax rates, consistent with the data. We find that tax avoidance significantly increases both the average firm size and industry concentration, while reducing entry and the number of firms in equilibrium. Tax avoidance also generates capital misallocation, lowering productive efficiency. Larger firms benefit disproportionately from tax avoidance, and consumers gain from a lower product price. We use the model to quantify the costs and benefits of tax avoidance to firms, taxpayers, and consumers, and evaluate the equilibrium effects of changes to the statutory tax rate and costs of avoidance.

[⋆]Glover: gloverb@andrew.cmu.edu, Levine: oliver.levine@wisc.edu.
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1. Introduction

Taxes are one of the major frictions a corporation faces, affecting everything from investment and capital structure to payout policy and geographic location. This research typically takes the tax friction as given and seeks to understand how a firm's policy is altered in its presence. Separately, a large literature suggests that firms expend significant resources in managing and reducing their tax liabilities.[1] These actions, which we broadly define as corporate tax avoidance, do not just lower the average tax rate, but also introduce heterogeneity in effective tax rates across firms. Indeed, many large and prominent firms have received public criticism for achieving tax rates much lower than other firms.[2] This evidence demonstrates that firms do not take taxes as given, but as an endogenous outcome from their corporate decisions. Yet little is known about how tax-related decisions interact with other corporate policies, such as investment, to shape both firm production and the industry landscape.

We develop an industry equilibrium model of firm investment in order to quantitatively assess the effect of tax avoidance on firm policies and industry outcomes. In the model, firms jointly make investment and tax avoidance decisions. Tax avoidance and investment are complementary inputs, leading the largest firms to engage in the most avoidance and face the lowest effective tax rates, consistent with the data. As a result, endogenous tax avoidance affects the cross-sectional distribution of firms. Within our industry equilibrium framework, firms' endogenous tax avoidance policies have important implications for industry concentration, the average firm size, entry, exit, and product prices. We use the model framework to quantify the benefit of tax avoidance to consumers coming through lower product prices, and changes in productive efficiency from tax-induced capital misallocation. We use the model to decompose the benefits and costs of tax avoidance for firms, consumers, and taxpayers. The calibrated model also allows us to evaluate how changes in statutory tax rates and the cost of avoidance affect equilibrium outcomes.

We show that effective tax rates decline substantially with firm size in the data, and the model matches well this empirical relation. In the calibrated model, the endogenous hetero-

[1] See, for example, Shackelford and Shevlin (2001) and Hanlon and Heitzman (2010) for reviews.
[2] See, for example, Kocieniewski (2011) and Fair Tax Mark (2019).

geneity in tax rates from avoidance causes the average firm size to increase substantially, with average capital increasing 15.1%. However, this increase is driven primarily by the largest firms, with the median firm increasing by only 5.4%. Thus, tax avoidance increases industry concentration as large firms produce an even greater share of total output. This increase in firm size and concentration has negative consequences: production becomes less efficient as capital and labor are misallocated in the presence of this heterogeneous tax friction. At the same time, consumers benefit through lower prices and higher output, although this gain is exceeded by the loss in tax revenue from avoidance. Even in the absence of tax avoidance, corporate income taxes are distortionary, and a tax cut increases total surplus—the sum of net benefits to firms, consumers, and taxpayers—when all firms face the same effective rate. However, we find tax avoidance reduces total welfare despite the benefits of the implicit "tax cut" it provides.

We begin by exploring the empirical relation between effective tax rates and firm size in the cross-section. For decades, there has been a concern that large corporations are able to substantially reduce their tax liability using a variety of strategies. This concern has only grown in recent years as the increased importance of intangible assets and global operations has further enabled avoidance practices.[3]. Despite this popular belief, the academic literature has found mixed evidence as to the empirical relation between firm size and ETRs.[4] We reconsider this evidence using the long-term measure of tax avoidance proposed by Dyreng et al. (2008). Over a ten-year horizon, we find that large firms pay a significantly lower cash ETR than small firms. For example, firms in the largest decile pay 10.8 p.p. (26%) lower taxes than those in the smallest decile, and this spread increases to 14.4 p.p. (35%) for the largest 1 percent of firms. These empirical patterns support the conjecture that larger firms engage in greater tax avoidance and suggest that certain tax management practices—such as setting up offshore subsidiaries—may benefit from scale.

In the model, firms make capital and labor decisions frictionlessly as inputs to a decreasing returns to scale production technology. At the same time, firms choose the level of costly tax avoidance to engage in that determines the effective tax rate paid on their profits. We

[3]See, for example, Clausing et al. (2016), Albertus et al. (2019a), and Albertus et al. (2019b).

[4]See, for example, Zimmerman (1983) and Chen et al. (2010).

remain agnostic as to the sources of the costs of tax avoidance; this could be the costs of attorneys and accountants, earnings smoothing and management, operational and investment choices, organizational structures including subsidiaries, etc. The tax avoidance technology is assumed to be complementary to the inputs of production but with decreasing returns to scale. We use the observed effective tax rates in the data to calibrate the unobserved parameters of this avoidance technology that dictate the unit cost and returns to scale. Optimally, more productive firms choose to produce more, generate more profits, and pursue more tax avoidance as they benefit more from a lower tax rate. We find this parsimonious tax avoidance technology does well to match the empirical ETR patterns we document.

Firms operate in a competitive industry with a continuum of firms similar to Miao (2005). Firms make shareholder value-maximizing production, tax avoidance, entry, and exit decisions in response to idiosyncratic productivity shocks. The framework admits a closed-form long-run stationary distribution of firms and a market clearing product price. This industry structure quantifies how interaction between tax avoidance and production decisions influences the distribution of firms.

Using the calibrated model, we quantify the costs of tax avoidance coming from three sources. First, tax avoidance results in a reduction in tax collections by 6.8%. Second, we estimate that the direct costs to firms of tax avoidance are 1.0% of revenue, or 6.7% of profit in aggregate, and that these costs are concentrated in larger firms. Third, we find that tax avoidance generates indirect costs by causing the largest firms to increase production at higher marginal cost. This misallocation generated by tax avoidance results in a loss of 1.5% of revenue in aggregate.

To understand how tax avoidance lowers productive efficiency, consider a simplified model with only two possible productivities, low and high. Assume all entering firms have low productivity and therefore choose to be small; with a tiny probability these firms become high productivity and choose to scale up to a large size. Initially, assume that all firms face the same tax rate. In this case, both types of firms choose their scale by equating after-tax marginal cost and revenue, and all firms have the same marginal products and average costs.[5]

Now suppose that high productivity firms learn how to lower their tax rate. With free

[5]Fixed costs do not play a significant role and are ignored in this example.

entry, the equilibrium requires that the product price declines such that the value of an entering firm equals the cost of entry, a constant. However, the value of this tax innovation to an entering firm is quite modest because it is unlikely that it will ever become high productivity; therefore, the product price declines only a small amount. For high productivity firms, if the benefits of lower taxes exceed the costs of the lower price—i.e., if the after-tax marginal value of revenue goes up—they will respond to the lower tax rate by increasing their scale. With decreasing returns to scale, large firms are now producing less efficiently than before although generating higher profits. In contrast, small firms reduce their scale in response to a lower product price, slightly increasing their productive efficiency.

In our calibrated model, we find that the decrease in efficiency of large firms dominates increases by small firms. As a result, aggregate productive efficiency declines as a result of tax avoidance generating an indirect cost from tax-induced misallocation. This loss is a result of the heterogeneity in tax rates across firms. Because small firms face higher tax rates, this discourages entry and causes prices to be "too high." Large firms then "overproduce" at this high price, lowering efficiency. This also causes the average firm size and industry concentration to increase.

In aggregate, firms are better off with tax avoidance with a net benefit of 1.0% of revenue. Tax avoidance also leads to increased output and a lower product price, benefiting consumers. In aggregate, consumer surplus increases by 3.3% of firm revenue. Taken together with the costs described above, tax avoidance causes the total surplus across firms, consumers, and taxpayers to decline by 2.5% of revenue.

The model also allows us to consider policies that affect the difficulty with which firms avoid taxes, as well as the effects of statutory rate changes. For example, policymakers can make tax avoidance more difficult through legislative or enforcement changes. In the model, this is equivalent to an increase in the input cost of avoidance, a policy experiment we consider. While increasing the difficulty of tax avoidance would seem to be beneficial in that it reduces tax avoidance, we find that it actually exacerbates the problem because it further widens the gap between large and small firms. While tax revenue does increase, it further increases the average firm size and decreases productive efficiency. As a result, total surplus declines. These results indicate that policies that attempt to eliminate heavily exploited tax savings strategies may actually have unintended negative consequences for real outcomes.

We also assess the effect of a statutory rate cut in the presence of tax avoidance. Because few firms face the statutory rate, a decrease in that rate has a limited impact on the effective rates that firms pay. Generally, corporate taxes distort capital allocation and lead to inefficiencies. Thus, tax cuts lead to an increase in total surplus. This remains the case when a statutory tax cut occurs in the presence of tax avoidance. However, we find that the gains are muted relative to a tax cut in a world without any avoidance. Thus, tax cuts may be a less potent policy tool to stimulate investment if tax avoidance is allowed to persist.

Finally, we consider a policy in which all firms face the same effective tax rate, but simultaneously lower the rate such that tax revenue remains unchanged. This policy by construction has no effect on taxpayers, but we find that both firms and consumers are, in aggregate, better off. This occurs because it eliminates the tax gap between small and large firms, making entry more attractive which drives down the product price. Critically, the average firm size decreases substantially and the presence of large firms declines, leading to increased productive efficiency. Both firms and consumers capture some of the increased surplus from these productivity gains.

A strand of the tax literature explores the firm characteristics that determine corporate tax outcomes, typically measured as the cash or GAAP effective tax rate (Gupta and Newberry, 1997; Dyreng et al., 2008). Several of these studies investigate the role of firm size (Zimmerman, 1983; Omer et al., 1993; Rego, 2003). The existing empirical literature has not found firm size to be a consistent determinant of tax rates. We provide new evidence on the relation between firm size and effective tax rates using a long-term measure of tax avoidance, a relation we show is not apparent over short horizons.

A large literature investigates the role of corporate taxes on real investment and financing decisions within a neoclassical, or q-theory, framework (Hall and Jorgenson, 1967; Summers, 1981; Hayashi, 1982; Hassett and Hubbard, 2002; Hennessy and Whited, 2005; Barro and Furman, 2018) as well as a focus on the effectiveness of tax incentives in stimulating investment (House and Shapiro, 2008; Yagan, 2015; Zwick and Mahon, 2017). A related literature explores the incidence of corporate taxes on shareholders, workers, and consumers (Harberger, 1962; Fuest et al., 2018; Baker et al., 2020). We contribute to these literatures by demonstrating that tax avoidance is distinct from simple tax rate changes and results in distortions to investment and consumer prices.

Our paper also contributes to a burgeoning literature on increasing industry concentration and the declining labor share (Gutiérrez and Philippon, 2017; Grullon et al., 2019; Hartman-Glaser et al., 2019; Autor et al., 2020; De Loecker et al., 2020). We find that tax avoidance, and the advantage larger firms face in lowering their tax liabilities, may be contributing to increased industry concentration.

From a modeling perspective, our paper relates to a strand of literature in finance and economics that study equilibrium models of industry dynamics.[6] Miao (2005) studies entry, exit, and firm dynamics in a tradeoff model of leverage with default. Gourio and Roys (2014) study how a French tax on firms with more than 50 workers influences the firm size distribution and efficiency. Hartman-Glaser et al. (2019) study how an increase in firm level risk affects aggregate and average capital shares in an equilibrium model with entry and exit where firms insure workers. See Dixit and Pindyck (1994) for an overview of this class of continuous time models of industry dynamics.

The remainder of the paper is organized as follows. In Section 2 we document an empirical negative relation between firm size and long-run effective tax rates. In Section 3 we describe the model setting and equilibrium. We calibrate the model and provide quantitative results on the effects of tax avoidance in Section 4. We perform a series of policy experiments in Section 5 and Section 6 concludes.

2. Empirical Facts

In this section we present evidence on the empirical relationship between firm size and effective tax rates. There are countless strategies firms use to reduce their tax payments, most of which are not easily observable. However, the details of how tax avoidance occurs is not the focus of this study. Therefore, we adopt from Dyreng, Hanlon, and Maydew (2008) the broad definition of tax avoidance as "anything that reduces the firm's cash tax rate over

[6] See, e.g., Jovanovic (1982), Hopenhayn (1992a,b), Ericson and Pakes (1995), Cooley and Quadrini (2001), Clementi and Hopenhayn (2006), Luttmer (2007), Clementi and Palazzo (2016).

a long time period, i.e. ten years."

Our firm-level data are from Compustat Fundamentals Annual covering public US firms for the period 1988–2017. This time period is chosen because of the stability in the statutory corporate tax rate during the interval between the significant corporate tax changes enacted in the Tax Reform Act in 1986 and the Tax Cuts and Jobs Act in 2017.[7] We exclude firms in the utility, financial, and quasi-governmental industries (SIC codes 4900–4999, 6000–6999, and 9000–9999). We require firms to have book asset values of at least $50 million in 2017 dollars and non-missing values for cash taxes paid, pretax income, and market value of equity.

We measure a firm's effective tax rate as the ratio of cash taxes paid to pretax income. While this measure is common in the literature (see Hanlon and Heitzman (2010) for a discussion), it is typical to estimate the effective tax rate at a one-year horizon. In contrast, in this study we focus on the longer term effective tax rate measured using multiple years of data using an approach introduced in Dyreng et al. (2008). Measuring the tax rate over multiple years is advantageous for at least two reasons. First, a long-run measure more accurately reflects the true economic cost of taxes to the firm. The average annual tax rate may misrepresent this cost.[8] Second, as emphasized by Henry and Sansing (2018), a long-run approach mitigates a sample selection problem caused by high-frequency tax rate measures: observations with negative income must be excluded which occurs more frequently at the annual horizon. We believe the benefits of using the long-run measure exceeds the cost of a smaller sample size.

The N-year cash effective tax rate (ETR) in year t for firm i is measured as

$$\mathrm{ETR}_{i,t}^{N} = \frac{\sum_{s=0}^{N-1} \mathrm{TXPD}_{i,t-s}}{\sum_{s=0}^{N-1} \mathrm{PI}_{i,t-s}} \tag{1}$$

where $\mathrm{TXPD}_{i,t}$ is total cash taxes paid (federal, state, and foreign) and $\mathrm{PI}_{i,t}$ is pretax income.[9] The ETR is measured every year and we require data in all N years for inclusion. We focus on the 10-year rate as our benchmark ($\mathrm{ETR}_{i,t}^{10}$), shown in column (1) of Table I. The mean

[7] The top federal corporate income tax rate was 34% from 1988–1992 and 35% from 1993–2017.

[8] An extreme example illustrates this point: suppose a firm pays $1 in taxes every year, but its income alternates between $1 and $1 billion. The long-run tax rate is effectively zero, but the average annual tax rate is 50%.

[9] Consistent with the literature, observations with negative taxes paid or non-positive pretax income are dropped, and tax rates are winsorized above at 1. This results in a possible range of $[0, 1]$ for the ETR measure.

(median) ten-year cash ETR is 35.1% (31.9%) in our sample.

To explore the relationship between firm size and ETR, we sort firms into deciles based on the firm's average (quasi-)market value or book value of assets over the same period.[10] The table reports the average ETR within each decile in columns (1) and (2) sorted on market and book value of assets, respectively. These values, along with the average ETR for the top 1% of firms, are also shown in Figure 1.

We see from column (1) of Table I that ETRs decline significantly in firm size, with the largest firm decile facing a 10.8 percentage point (or 26%) lower tax rate than the smallest firm decile. In addition, this gap grows even larger when we focus on the top 1% of firms, who face a 14.4 percentage point (or 35%) lower ETR than the smallest firm decile. The pattern is similar, although not as pronounced among the very largest and smallest firms, when size is measured as the book value of assets, shown in column (2).

Columns (3) and (4) show that this pattern is robust to alternative approaches to measuring the effective tax rate. Column (3) excludes special items from pretax income in the ETR measure, the benchmark used in Dyreng et al. (2008). This results in a lower mean ETR (29.5%) because special items are on average negative; however, the pattern is very similar. The relationship is also similar when measuring the ETR at the five-year horizon ($\text{ETR}^5_{i,t}$), shown in column (4).

Finally, column (5) reports the average one-year cash ETR, the most common measure used in the literature. The one-year rates are lower on average (29.5%) and slightly more volatile. Strikingly, there is no meaningful variation in tax rates with respect to size. This lack of relationship at the one-year horizon may explain the indeterminate role of size in determining tax rates in the extant tax literature (e.g., Zimmerman, 1983 and Chen et al., 2010).

We have shown that larger firms face a significantly lower effective tax rate than smaller firms in the medium and long term. This superior tax avoidance by large firms is economically meaningful resulting in an effective tax rate 10.8 percentage point (or 26%) difference between the tenth and first deciles over our sample, corresponding roughly to $1.9 trillion in tax

[10] The market value of assets is defined as the book value of debt plus the market value of equity minus the book value of shareholder equity.

savings for the top 10% of firms.

3. Model

Time is continuous and the horizon is infinite. Firms produce a homogeneous good in a competitive market. Industry demand is given by

$$p_t = Y_t^{-1/\epsilon}, \tag{2}$$

where p_t is the product price, Y_t is the aggregate industry output, and $\epsilon > 0$ is the price elasticity of demand. Firms produce using inputs of capital (k) and labor (ℓ) to generate output, y, according to

$$y_{i,t} = z_{i,t} k_{i,t}^{\alpha} \ell_{i,t}^{\beta}, \tag{3}$$

where $0 < \alpha + \beta < 1$. Firm-specific productivity shocks $z_{i,t}$ evolve according to

$$\frac{dz_{i,t}}{z_{i,t}} = \mu dt + \sigma dW_{i,t}, \tag{4}$$

where W_t is a standard Brownian motion. Firms are also subject to idiosyncratic death shocks that arrive with intensity λ.

3.1. Firm production, tax avoidance, and cash flows

Firms can also spend on tax reduction h in order to reduce their effective tax rate, $\tau_{i,t}$. The after-tax profit function for the firm is

$$\pi(z_{i,t}; p_t) = \max_{k_{i,t}, \ell_{i,t}, h_{i,t}} \left\{ (1 - \tau_{i,t}) p_t y_{i,t} - (1 - \bar{\tau})(\delta k_{i,t} + \omega \ell_{i,t}) - r k_{i,t} - b h_{i,t} - c_f \right\}. \tag{5}$$

We assume that depreciation and labor expense are deductible at a rate $\bar{\tau}$. The opportunity cost of capital, r, and the cost of tax avoidance, bh, are not tax deductible. The latter choice is made because we want to capture not just the cost of attorney and accountant fees, which may be a tax deductible expense, but also indirect costs such as inefficient use of resources and foregone or poorly allocated investment.[11] Finally, firms are subject to a fixed operating cost, c_f.

[11] These costs are akin to those of adjustment costs in a standard model, which are not typically considered tax deductible for these reasons.

We depart from standard models in that the the firm's tax rate, $\tau_{i,t}$, is an endogenous choice variable for the firm that depends on the firm's investment in a tax reduction technology. To define the endogenous tax rate, we assume that the tax rate is

$$\tau_{i,t} = \begin{cases} \tau_0 & \text{if } h_{i,t} = 0 \\ 1 - (h_{i,t} + h_0)^{\gamma} & \text{if } 0 < h_{i,t} < \bar{h} \\ \tau_L & \text{if } h_{i,t} \geq \bar{h}. \end{cases} \tag{6}$$

where $\gamma \in (0,1)$ is the returns to scale on the tax reduction technology. There are three regions to the tax rate. In the first region, the firm faces the statutory tax rate τ_0 when they do not spend on tax reduction ($h = 0$). With some spending on tax reduction, the firm faces a decreasing tax rate up until the point $\bar{h}$ where the minimum attainable tax rate is achieved, τ_L. In the second region, the firm faces decreasing returns to scale on tax reduction technology ($\gamma < 0$). We impose continuity across the three regions, which gives $h_0 = (1 - \tau_0)^{\frac{1}{\gamma}}$ and $\bar{h} \equiv (1 - \tau_L)^{\frac{1}{\gamma}} - h_0$.

We will show that the three regions of the tax rate are determined by the firm's productivity $z_{i,t}$. We define z_l and z_h as the thresholds at which the firm moves from region one to two (when the firm first begins to spend on tax reduction) and from region two to three (when the firm has attained the minimum tax rate), respectively. Later, we will derive these thresholds.

The optimal spending on tax reduction is given by

$$h^*_{i,t} = \begin{cases} 0 & \text{if } z_{i,t} \leq z_l \\ \left(\frac{\gamma p_t y_{i,t}}{b}\right)^{\frac{1}{1-\gamma}} - h_0 & \text{if } z_l < z_{i,t} < z_h \\ \bar{h} & \text{if } z_{i,t} \geq z_h \end{cases} \tag{7}$$

where the expression in the middle region comes from the first order condition on the profit function with respect to $h_{i,t}$. Combining Equations (6) and (7) gives the tax rate in terms of the regions of $z_{i,t}$:

$$\tau_{i,t} = \begin{cases} \tau_0 & \text{if } z_{i,t} \leq z_l \\ 1 - \left(\frac{\gamma p_t y_{i,t}}{b}\right)^{\frac{\gamma}{1-\gamma}} & \text{if } z_l < z_{i,t} < z_h \\ \tau_L & \text{if } z_{i,t} \geq z_h. \end{cases} \tag{8}$$

The profit function for the firm at the optimal choice of tax reduction, capital, and labor is given by

$$\pi(z_{i,t};p_t) = \begin{cases} (1-\alpha-\beta) \left[\left(\frac{\alpha}{r+\delta(1-\bar{\tau})}\right)^{\alpha}\left(\frac{\beta}{\omega(1-\bar{\tau})}\right)^{\beta}(1-\tau_0)p_t z_{i,t}\right]^{\frac{1}{1-\alpha-\beta}} - c_f & \text{if } z_{i,t} \leq z_l \\ (1-\alpha-\beta-\gamma)\left[\left(\frac{\alpha}{r+\delta(1-\bar{\tau})}\right)^{\alpha}\left(\frac{\beta}{\omega(1-\bar{\tau})}\right)^{\beta}\left(\frac{\gamma}{b}\right)^{\gamma} p_t z_{i,t}\right]^{\frac{1}{1-\alpha-\beta-\gamma}} + bh_0 - c_f & \text{if } z_l < z_{i,t} < z_h \\ (1-\alpha-\beta) \left[\left(\frac{\alpha}{r+\delta(1-\bar{\tau})}\right)^{\alpha}\left(\frac{\beta}{\omega(1-\bar{\tau})}\right)^{\beta}(1-\tau_L)p_t z_{i,t}\right]^{\frac{1}{1-\alpha-\beta}} - b\bar{h} - c_f & \text{if } z_{i,t} \geq z_h \end{cases} \tag{9}$$

3.2. *Firm valuation*

Firms choose capital (k), labor (ℓ), and tax reduction (h), to maximize the flow of cash flows $\pi(z_{i,t};p_t)$. Given the fixed operating costs, c_f, they also choose an optimal stopping time, denoted T_D, to exit. Firm value is then given by

$$v(z_{i,t};p_t) = \sup_{\{k_{i,s},\ell_{i,s},h_{i,s}\}_{s\geq t},T_D} \int_t^{T_D} e^{-(r+\lambda)s}\pi(z_{i,s};p_s)ds. \tag{10}$$

The firm value is the discounted value of the stream of cash flows, $\pi(z;p)$ until the firm exits, either endogenously because its productivity falls to a sufficiently low level or exogenously via the arrival of an obsolescence shock.

Proposition 1. *Define $\eta = 1-\alpha-\beta$ and assume*

$$r+\lambda-\frac{\mu}{\eta}-\frac{\sigma^2}{2}\frac{1}{\eta}\left(\frac{1}{\eta}-1\right) > 0. \tag{11}$$

The value of a firm with product price p and current productivity z is given by

$$v(z;p) = \begin{cases} B_1 z^{\xi_1} + B_2 z^{\xi_2} + \frac{A_1 z^{1/\eta}}{\kappa_1} - \frac{c_f}{r+\lambda} & \text{if } z \leq z_l \\ C_1 z^{\xi_1} + C_2 z^{\xi_2} + \frac{A_2 z^{\frac{1}{\eta-\gamma}}}{\kappa_2} + \frac{bh_0 - c_f}{r+\lambda} & \text{if } z_l < z < z_h \\ D_2 z^{\xi_2} + \frac{A_3 z^{1/\eta}}{\kappa_1} - \frac{b\bar{h}+c_f}{r+\lambda} & \text{if } z \geq z_h, \end{cases} \tag{12}$$

where

$$
\begin{aligned}
A_1 &= \eta \left[\left(\frac{\alpha}{r+\delta(1-\bar{\tau})} \right)^{\alpha} \left(\frac{\beta}{\omega(1-\bar{\tau})} \right)^{\beta} (1-\tau_0) p_t \right]^{1/\eta} \\
A_2 &= \frac{1}{\eta-\gamma} \left[\left(\frac{\alpha}{r+\delta(1-\bar{\tau})} \right)^{\alpha} \left(\frac{\beta}{\omega(1-\bar{\tau})} \right)^{\beta} \left(\frac{\gamma}{b} \right)^{\gamma} p_t \right]^{\frac{1}{\eta-\gamma}} \\
A_3 &= \eta \left[\left(\frac{\alpha}{r+\delta(1-\bar{\tau})} \right)^{\alpha} \left(\frac{\beta}{\omega(1-\bar{\tau})} \right)^{\beta} (1-\tau_L) p_t \right]^{1/\eta} \\
\kappa_1 &= r + \lambda - \frac{\mu}{\eta} - \frac{\sigma^2}{2} \frac{1}{\eta} \left(\frac{1}{\eta} - 1 \right) \\
\kappa_2 &= r + \lambda - \frac{\mu}{\eta-\gamma} - \frac{\sigma^2}{2} (\frac{1}{\eta-\gamma})(\frac{1}{\eta-\gamma} - 1)
\end{aligned}
$$

and ξ_1, ξ_2 are the roots of the fundamental quadratic, given by

$$
\xi_1 = \frac{1}{2} - \frac{\mu}{\sigma^2} + \sqrt{\left(\frac{\mu}{\sigma^2} - \frac{1}{2} \right)^2 + \frac{2(r+\lambda)}{\sigma^2}}, \quad \xi_2 = \frac{1}{2} - \frac{\mu}{\sigma^2} - \sqrt{\left(\frac{\mu}{\sigma^2} - \frac{1}{2} \right)^2 + \frac{2(r+\lambda)}{\sigma^2}}, \tag{13}
$$

with $\xi_1 > 1$ and $\xi_2 < 0$. The coefficients B_1, B_2, C_1, C_2, D_2 are determined by the boundary conditions.

3.3. Model with no tax avoidance

To evaluate the effects of tax avoidance, we also consider a special case of the model where firms are not able to engage in any tax avoidance. This can be thought of the case as the costs of avoidance become infinitely large: $b \to \infty$. In this "no avoidance" case, firms face a single, constant tax rate, τ_{NA}, on their operating income and there is no longer a choice of h. In the no avoidance case, the firm's profits are given by

$$
\pi^{NA}(z_{i,t}; p_t^{NA}) = \max_{k_{i,t}, \ell_{i,t}} \left\{ (1-\tau^{NA})(p_t^{NA} y_{i,t} - \delta k_{i,t} - \omega \ell_{i,t}) - r k_{i,t} - c_f \right\}. \tag{14}
$$

As before, the firm chooses capital, labor, and an optimal stopping time to exit to maximize its expected discounted cash flows:

$$
v(z_{i,t}; p_t^{NA}) = \sup_{\{k_{i,s}, \ell_{i,s}\}_{s \geq t}, T_D} \int_t^{T_D} e^{-(r+\lambda)s} \pi^{NA}(z_{i,s}; p_s^{NA}) ds. \tag{15}
$$

In general, the equilibrium product price and firm policies will differ in the no avoidance case relative to the baseline model in which firms are able to avoid taxes. In the analyses that follow we compare the firm's policies as well as equilibrium outcomes between these two cases to illustrate the effects of tax avoidance.

3.4. Entry and exit

Firms can pay a one-time fixed cost of c_E to enter the market. At entry, all firms begin with initial productivity of z_0 after which their productivity evolves according to their idiosyncratic shocks. We assume free entry, which means that in equilibrium if there is positive entry flow, the expected value at entry must be equal to the entry cost:

$$v(z_0; p) = c_E. \tag{16}$$

The flow of new entrants, which we denote as N, is determined endogenously in equilibrium. Firms exit for two reasons: they are hit with an exogenous exit shock with intensity λ or their productivity falls to z_D, at which point they find it optimal to shut down.

3.5. Firm distribution

We now derive the stationary distribution of firm productivity. Given the presence of fixed operating costs and an endogenous exit decision, the productivity of incumbent firms is over the domain (z_D, ∞). Let $\phi(z)$ denote the probability density function of firm productivity.

Proposition 2. *The stationary distribution of firm productivity is*

$$\phi(z) = \begin{cases} H_1 z^{\zeta_1 - 1} + H_2 z^{\zeta_2 - 1} & \text{if } z_D < z < z_0 \\ J_2 z^{\zeta_2 - 1} & \text{if } z > z_0, \end{cases} \tag{17}$$

where

$$\zeta_1 = \frac{\mu}{\sigma^2} - \frac{1}{2} + \frac{\sqrt{2\lambda\sigma^2 + (\mu - \sigma^2/2)^2}}{\sigma^2}, \qquad \zeta_2 = \frac{\mu}{\sigma^2} - \frac{1}{2} - \frac{\sqrt{2\lambda\sigma^2 + (\mu - \sigma^2/2)^2}}{\sigma^2}, \tag{18}$$

and the coefficients H_1, H_2, J_2 are solved by imposing the boundary conditions.

Let Q denote the mass of operating firms, which is determined in equilibrium. In a steady state equilibrium, Q is constant, though individual firms are entering and exiting and evolving with their productivity shocks. For the mass of firms to be constant, we need the flow of new entrants, N, to equal the flow of exiting firms. Firms exit for two reasons:

either they are hit with an exit shock, which arrives with intensity λ, or they reach the productivity threshold z_D such that it is optimal to shut down. Thus the flow of entrants, N, in a stationary equilibrium is given by

$$N = \lambda Q + \frac{1}{2}\sigma^2 Q \left(\zeta_1 H_1 z_D^{\zeta_1} + \zeta_2 H_2 z_D^{\zeta_2} \right). \tag{19}$$

The firm distribution for productivity, z, has a right tail that follows a Pareto distribution with parameter $\zeta_2 < 0$. The probability a firm's productivity $z_{i,t}$ is above some value $\hat{z}$ is

$$Pr[z_{i,t} > \hat{z}] = \left(\frac{-J_2}{\zeta_2} \right) \hat{z}^{\zeta_2}. \tag{20}$$

3.6. Aggregates

Given the optimal firm policies, the stationary distribution of firm productivity, and the mass of operating firms, we can now construct industry-level aggregates in the model. We use capital letters to denote industry-level aggregates. We define aggregate output (Y), capital (K), labor (L), tax avoidance (H), cash flow (Π), and firm value (V) as

$$Y = Q \int_{z_D}^{\infty} y(z;p)\phi(z)dz \tag{21}$$

$$K = Q \int_{z_D}^{\infty} k(z;p)\phi(z)dz \tag{22}$$

$$L = Q \int_{z_D}^{\infty} \ell(z;p)\phi(z)dz \tag{23}$$

$$H = Q \int_{z_D}^{\infty} h(z;p)\phi(z)dz \tag{24}$$

$$\Pi = Q \int_{z_D}^{\infty} \pi(z;p)\phi(z)dz \tag{25}$$

$$V = Q \int_{z_D}^{\infty} v(z;p)\phi(z)dz. \tag{26}$$

Given that the stationary distribution function, $\phi(z)$, is a probability density function that integrates to one (i.e., $\int_{z_D}^{\infty} \phi(z)dz = 1$), the total mass of incumbent firms, Q, scales each of the aggregate quantities in the model. While individual firms are continuously entering, exiting, and moving through the productivity distribution due to different realizations of their individual productivity shocks, the aggregate quantities in the model are constant. The aggregate quantities for the case of no tax avoidance, $Y_{NA}, K_{NA}, L_{NA}, \Pi_{NA}, V_{NA}$, are defined analogously.

3.7. Equilibrium

We now proceed to characterize the stationary equilibrium in the model. In a stationary equilibrium, firms are continuously entering and exiting. While individual firms are moving around due to the realizations of their idiosyncratic productivity shocks, the aggregate mass of firms and distribution remain constant as there are no aggregate shocks in the model.

Definition 1. *A stationary industry equilibrium consists of a product price p, firm policy functions for capital k, labor ℓ, tax reduction h, an exit threshold z_D, a stationary distribution $\phi(z)$, a flow of entrants N, and a mass of incumbent firms Q, such that*

i. Firm policies, k, ℓ, h, and z_D solve the firm's problem given in Equation (10)

ii. The free entry condition in Equation (16) *holds*

iii. The product market clears

iv. The distribution $\phi(z)$ is stationary with support $[z_D, \infty)$.

In this model, the free entry condition determines the equilibrium price p. That is, the equilibrium price adjusts so that a firm's expected value upon entry is equal to the entry cost c_E. Given the equilibrium price, the market clearing condition determines the stationary mass of incumbent firms, which we denote by Q. Using the assumed demand function given in Equation (2), the mass of firms, Q, in equilibrium satisfies

$$p^{-\epsilon} = Q \int_{z_D}^{\infty} y(z;p)\phi(z)dz. \tag{27}$$

In the no avoidance case, the equilibrium is defined similarly. The difference is that firms do not choose a tax avoidance policy (h). As a result, firms' effective tax rates and their optimal policies for capital, labor, entry, and exit are different as well. This results in a different equilibrium mass of firms and product market price compared to the baseline model with tax avoidance. In general, when comparing the results from these two cases of the model — with and without tax avoidance — we solve and compute the model equilibrium separately.

3.8. Firm policies

We now illustrate firm policies from the model and focus in particular on how tax avoidance affects these policies. We use the parameter values from the calibration, which is discussed in Section 4.1.

In Figure 2, we plot firms optimal policies for capital, labor, output, and cash flow as a function of their underlying level of productivity, z. In each panel, the solid blue line shows the optimal policy in the baseline model with tax avoidance and the dashed red line shows the optimal policy in the no avoidance version of the model. In all cases we fix the product market price to be a constant value when comparing the baseline and no avoidance model policies. Our goal is to show how firm policies vary with firm productivity and how these differ in the presence of tax avoidance. We see that all four of these policies are increasing in the firm's productivity and are higher for the model with tax avoidance. That is, holding fixed the product price and a firm's level of productivity, tax avoidance leads firms to optimal choose higher levels of capital and labor, which corresponds to higher levels of output and cash flow.

In Figure 3 we show how firm taxes and optimal choice of tax avoidance vary with firm productivity. Again, we compare the baseline case with tax avoidance (solid blue line) to the case of no tax avoidance (dashed red line). Panel A of Figure 3 plots a firm's optimal tax avoidance expense, $b \times h$, as a function of its productivity. As productivity increases, a firm optimally spends more on avoiding taxes. Eventually, the avoidance expenditure becomes flat in productivity when $z > z_H$ and the firm has reached the minimum effective tax rate it can attain. Panels B and C plot this measure of tax avoidance expenditure divided by firm revenue and taxes paid, respectively. For $z \in [z_L, z_H]$, the firm's expenditure on tax avoidance as a share of its revenue and taxes paid are both increasing in firm productivity, z. Once the productivity reaches z_H, the firm has attained the minimum effective tax rate possible. For values of $z > z_H$, as productivity increases the firm's revenue and taxed paid are both increasing but its expenditure on tax avoidance is constant, as shown in Panel A. As a result, the firm's tax avoidance expenditure as a share of revenue and taxes paid declines.

In the right column of Figure 3, we compare how a firm's taxes paid and effective tax rate vary with its productivity. For a firm with productivity z facing product price p, its effective tax rate is

$$ETR(z;p) = \frac{\tau^* py + \overline{\tau}(\delta k + w\ell)}{py - \delta k - w\ell} \tag{28}$$

As shown by Equation (28), a firm's effective tax rate is endogenously determined in the model and varies with the level of productivity, the product price, as well as other model parameters. In contrast, in the no avoidance model, the firm's effective tax rate is just a fixed value of τ^{NA}.

In Panel D of Figure 3, we plot the firm's effective tax rate as a function of its productivity. The solid blue line shows the baseline model case with tax avoidance and the dashed red line shows the case of no tax avoidance. With no tax avoidance, the effective tax rate is constant and does not change with firm productivity. In the model with avoidance, the effective tax rate is an endogenous outcome of the firm's policies, both for avoidance as well as capital and labor. With tax avoidance, we see that the effective tax rate is declining in firm productivity. For a sufficiently high level of productivity, $z > z_H$, the firm's effective tax rate is constant as it has attained the minimum possible tax rate.

Panel E of Figure 3 shows that the amount of taxes paid is increasing in a firm's productivity, but at a lower rate for the case in which a firm can avoid taxes. For any level of productivity, a firm pays lower taxes in the baseline case than what it would pay in the case with no avoidance. Similar to the effective tax rate, Panel F shows that taxes paid as a share of revenue are declining in productivity for the baseline model but flat for the no avoidance case.

In Figure 4, we plot measures of firm productivity on the level of shock z. As before, we compare the firm policies in the baseline model with avoidance (solid blue line) to the policies in the no avoidance case (dashed red line). In Panels A and B we plot the marginal revenue product of capital and labor on the level of the shock z. In the no avoidance case, the level of marginal products are constant in the shock z. When firms can avoid taxes in the baseline model, the marginal revenue products are declining in z up to z_H. For values of $z > z_H$, the marginal products become flat again. In the right column of Figure 3, Panels C and D show that firms produce less output per unit of capital and have higher average costs as a function of productivity in the baseline model compared to the case with no avoidance.

4. Calibration and quantitative results

In this section we examine the quantitative implications of the model. We start by calibrating the model parameters to match key moments of interest and then examine the quantitative results from the calibrated model.

4.1. Calibration

We calibrate the model to match moments for the firms in our sample of US public companies over the period 1988–2017. Some of the model parameters are set following the literature and others are directly calibrated to match the data. The parameter values are displayed in Table II. In Table III, we show the moments for firm earnings dynamics, the right tail of the size distribution, and the ETRs by size that are used in our calibration. The table compares the empirical values in the data to those in our calibrated model.

We set the capital and labor returns to scale parameters, α and β, to 0.44 and 0.22, respectively. This gives $\alpha + \beta = 0.66$, a value consistent with the investment literature. We set $r = 0.05$ and $\delta = 0.10$. We fix the wage rate, $w = 1$, and normalize the initial level of firm productivity, z_0 to 1. The firm's fixed operating costs, c_f, are set to 0.2, and the entry cost c_E is 0.8. Under the free entry assumption, the entry cost effectively acts to scale the product price, which can be viewed as a normalization. We set the price elasticity of demand, ϵ, to 0.75, which is consistent with values used in related industry equilibrium models (Miao, 2005) and in the range of empirical estimates in the literature (Phillips, 1995).

We calibrate the productivity shock parameters, μ and σ, to match the mean and volatility of firm earnings growth in the data. As discussed in Section 3.5, the right tail of the firm distribution has a Pareto tail. Given the parameter values for α, β, μ, and σ, we set the intensity of the exit shock, λ, to match the estimated Pareto coefficient from the top 5% of the size distribution in the data. In Table III we list these empirical moment targets, along with the targeted ETRs by size, as well as the moments in the calibrated model.

The tax rate parameters are set to match the observed tax rates in our sample. We set $\tau_0 = \overline{\tau} = 0.414$ to match the highest effective tax rate by size decile that we estimate in the data (see Table III). We set $\tau_L^{ETR} = 0.261$ to match the minimum effective tax rate by decile that we observe in the data. Finally, we choose the returns to scale and marginal cost of tax avoidance, γ and b, to match the cross-sectional ETRs by size in the data. Section 2 provides a description of how we estimate ETRs by firm size percentile in the data. In Table III we compare the eleven ETRs by size percentile that we target in the data with their values in the calibrated model. The table shows that the model is able to capture the cross-sectional pattern in ETRs across the firm size distribution. In both the model and data, we see a negative relation between firm size and effective tax rate.

In Figure 6, we plot the relation between firm size percentile and ETRs for both cases of the model as well as the values in the data. The red circles show the empirical ETRs by size percentile, where we compute these following the approach discussed in Section 2. As previously noted, we see a downward sloping relation between firm size and ETR in the data. The solid blue line shows the ETRs as a function of firm size percentile from our calibrated model. The parameters b and γ, which determine the cost and returns to scale of the tax avoidance technology, are calibrated to match the 11 ETR-size percentile values shown in the data. The model does relatively well in capturing this cross-sectional pattern. Finally, the dashed black line shows the ETRs across the size distribution in the no avoidance case of the model. When firms are not able to invest in h to reduce their taxes, they all face the same ETR, resulting in a flat relation between firm size and tax rates.

4.2. The effects of tax avoidance

Table IV reports aggregate outcomes related to taxes and the direct cost of tax avoidance under the baseline model. In aggregate, the effective tax rate is 29.4%, significantly lower than the statutory rate. This rate is also lower than the average ETR of 34.8%, a result of larger firms engaging in more tax avoidance and facing lower tax rates. Taxes collected represent 11.6% of total revenue.

The last three columns present the model estimates of the aggregate direct costs of tax avoidance ($b \times H$) as a fraction of taxes paid, profits, and revenue, respectively. The direct cost of engaging in tax avoidance is 1.0% of revenue, or 6.7% of profits. We will see later in this section that the benefits of this tax avoidance activity that is captured by firms is about twice as large as these costs.

Next, we consider the equilibrium effect of tax avoidance on firm and industry outcomes by comparing outcomes under the baseline relative to a version of the model where tax avoidance has been shut down (the *no avoidance*, or *NA* case). The no avoidance equilibrium is solved by setting the unit cost of tax avoidance to infinity ($b \to \infty$), meaning all firms face the maximum statutory rate τ_0^{ETR}, while leaving all other parameters unchanged.

Table V reports the effects of tax avoidance on aggregate and firm-average quantities. Reported values are the percent increase in each quantity due to tax avoidance. These are constructed by comparing the baseline model steady state equilibrium with the counterfactual no avoidance steady state equilibrium. Panel A reports aggregate quantities and Panel B reports firm averages.

Focusing on the aggregates in Panel A, aggregate firm value is 9.0% higher because of tax avoidance, with a corresponding increase in capital, labor, and profit. The ability to avoid taxes represents a significant reduction in taxation for firms, seen by the 36.9% reduction in taxes paid and a 12 p.p. decrease in the aggregate ETR, which encourages investment and production. The increase in output corresponds to a lower product price (-3.3%). Overall, revenue declines slightly despite an increase in output.

4.2.1. Average firm size

The average firm size in equilibrium, shown in Panel B of Table V, is significantly larger due to tax avoidance, with average firm value, capital, and profit are 16.9, 15.1, and 14.7% higher, respectively. Average output is also higher by 10.0%. The effect on the average firm is larger than on the aggregate, which is consistent with a smaller total mass of firms (-6.8%). In other words, tax avoidance means that there are fewer firms in equilibrium, but the average firm is also larger to an extent that total output is still higher.

While the average firm size is significantly higher due to tax avoidance, most of this increase in the average is due to growth in the largest firms. Panel A of Table VI reports the percent increase in the percentiles of four measures of size due to tax avoidance. We see that firms from the left half of the distribution are similar in size; however, in the right tail the firm size is significantly larger. For example, at the 95th percentile firms have 17.0% higher value, and 21.4% more capital, because of tax avoidance. This is because the incentives to invest and produce coming from tax avoidance are increasing in size.

4.2.2. Industry concentration

Panel B of Table VI shows that the distortion of the size distribution coming from tax avoidance also has implications for industry concentration. We see that tax avoidance leads to increased concentration: for example, the share of revenue from the top 10% of firms increases by 3.6% due to tax avoidance. The effect on capital is even greater, with the top 10% increasing their share of capital by 5.4%. As expected, tax avoidance has the opposite effect on the concentration of taxes paid, with the top 10% reducing their share of taxes by 10.2%. In addition, the top 10% account for 37.4% of the direct costs of tax avoidance (TAC).

Our results indicate that tax avoidance has the potential to contribute to an increase in industry concentration. Indeed, a substantial increase in concentration over the last three decades (Grullon, Larkin, and Michaely (2019)) has coincided with a decline in effective tax rates (Dyreng, Hanlon, Maydew, and Thornock (2017)). While our model does not feature imperfect competition, our results indicate that tax avoidance may exacerbate concentration and should be considered when addressing concerns of increasing market power and reduced competition.

4.2.3. Productive efficiency

We saw in Table V that the increased aggregate output due to tax avoidance comes from growth in the average firm size (rather than the mass of firms). This has important implications for productive efficiency. Firms operate a decreasing returns to scale production technology which means that the marginal product is declining (and average cost increasing) in scale. Because tax avoidance causes the average, and in particular the largest, firms to increase their scale of production, this reduces both the average and aggregate productive efficiency.

The effect of tax avoidance on productive efficiency can be seen in Figure 7 which shows the distribution of the marginal revenue product of capital (MRPK) for the baseline model (solid line) and the case without tax avoidance (dashed line). Firms choose their optimal scale such that their MRPK equals the sum of the marginal cost of capital (a constant) and the marginal taxes paid. With no tax avoidance, all firms face the same marginal tax rate and therefore firms choose capital such that the MRPK is homogeneous across firms. With tax avoidance, the marginal tax cost of production is declining in size leading to heterogeneous MRPK in equilibrium: firms scale up due to their ability to avoid taxes, and this higher investment is increasing in size. In effect, larger firms become less productive and have the lower MRPKs because of what is effectively a tax subsidy that increases with size.

The decline in aggregate and average productivity is also seen in Table V. Panel B shows that tax avoidance leads to the marginal revenue products of capital and labor to be 4.3% lower for the average firm reflecting the larger average scale coming from tax subsidies that increase in size. In aggregate, this results in a 4.6% higher average cost of production. Another way to see this effect on productive efficiency is as follows: firms choose inputs to maximize their after-tax profits, which can cause them to make seemingly inefficient production choices on a pretax basis. Panel A shows that tax avoidance leads to lower pretax profit margins by 13.1% (5.0 p.p.); however, this results in an after-tax profit margin that is 7.8% (1.1 p.p.) higher.

4.2.4. Welfare

To evaluate the welfare consequences of tax avoidance, we consider the three parties affected by tax policy in our model: firms, consumers, and taxpayers (or more precisely, the beneficiaries of tax revenue). Panel A of Table VII reports the equilibrium effects of tax avoidance on these three groups as a percent of total firm revenue. Aggregate firm profits—including entry, fixed, and direct tax avoidance costs—are higher by 1.02% of revenue because of tax avoidance. As direct tax avoidance costs are 0.97% of revenue, this means in aggregate firms receive about $2 in benefit for every dollar spent on tax avoidance.

Consumers are also better off as a result of tax avoidance: consumer surplus is higher by 3.31% of revenue because of a combination of a 3.25% lower product price and 2.51% higher output. However, tax revenue drops significantly because of tax avoidance: taxes collected are 6.79% of revenue lower because of tax avoidance. Summing the firm, consumer, and taxpayer benefits shows a reduction in total surplus of 2.45% of revenue. This means that it would be welfare improving to eliminate tax avoidance and have all firms face the statutory rate, even though this would significantly increase effective tax rates.

The welfare costs of tax avoidance come from both the direct costs of tax avoidance ($b \times h_{i,t}$) and indirect costs from misallocation of capital and labor that results in productive inefficiencies. Adding the direct costs (0.97% of revenue) to the total surplus (-2.45%) reveals that tax avoidance results in a reduction in productive efficiency of 1.49% of revenue.[12]

To understand this productive efficiency loss, we must consider the two effects of tax avoidance. First, larger firms face lower effective tax rates which causes them to invest and produce more. This by itself does not lower the surplus: ignoring the direct costs of tax avoidance, this is equivalent to a tax cut for larger firms. In fact, lower tax rates, when applied to all firms, improve welfare. This is shown in Panel B of Table VII which performs a similar welfare analysis for a 14 p.p. tax cut in a world without tax avoidance. In this case, the total surplus grows by 4.94% of revenue due to the tax cut. As there are no direct costs of tax avoidance in this counterfactual, all of the surplus is achieved through productive efficiency gains. In other words, corporate income taxation is distortionary and a lower tax rate leads to more efficient investment.

Why does a tax cut in a world without avoidance cause an increase in efficiency while tax avoidance, which lowers effective tax rates, have the opposite effect? This brings us to the second effect of tax avoidance: price impact. With free entry, the equilibrium product price must satisfy the market clearing condition and is determined by the firm entry condition: the expected firm value at entry must equal the fixed costs of entry. In a world where all firms face the same tax rate, a tax cut would increase the entry value, all else equal, and therefore the price must decline in equilibrium. Entrants compete away benefits from the lower tax rate through the new lower price. Total output increases, but each firm produces less—and therefore more efficiently due to decreasing returns to scale—as the new lower price decreases their optimal scale. Put another way, the average cost of production declines. Thus, without avoidance, a lower tax rate increases efficiency because the price is lowered to an extent that the average firm size declines.

In the baseline model, tax avoidance makes production less efficient because this price

[12]The total surplus is the gain from increases in productive efficiency minus the direct cost of tax avoidance.

channel breaks down. Tax avoidance lowers the tax rate disproportionately for large firm, and thus the increase in value to the entrant coming from tax avoidance is muted. In turn, the price doesn't drop as much as it would in the case of a comparable cut in the tax rate without avoidance. The lower price is still high enough that larger firms invest to a level that is less efficient, increasing the average firm size and lowering the average efficiency: the average cost of production increases. In a sense, tax avoidance helps large firms because it disadvantages small firms who benefit less from tax avoidance. Lower value for small firms deters entry which keeps the product price high and in turn makes inefficient investment profitable for larger firms.

5. Policy Experiments

In this section we evaluate outcomes under a variety of policy experiments. We start by considering the effect of varying the difficulty with which firms are able to lower their tax rate. We then consider a policy where all firms face the same tax rate such that total tax collections are unchanged. Finally, we evaluate the effect of a statutory rate cut, including that enacted in the Tax Cuts and Jobs Act of 2017.

5.1. Varying the difficulty of tax avoidance

The tax code provides countless opportunities for firms to reduce their effective tax rate, and these opportunities vary in their cost and difficulty. For example, claiming an investment tax credit may be fairly easy while restructuring operations to low tax jurisdictions may be quite costly. Policies which increase or decrease the firm's cost of engaging in tax avoidance are captured in the model with the unit cost parameter b.

Table VIII considers the equilibrium outcomes if these costs are decreased (column 1) or increased (column 2). As the cost parameter b is difficult to interpret, the change is chosen such the aggregate effective tax rate decreases or increases by approximately 1 percentage point. The table reports the percent increase in each quantity under the new policy.

The first observation is that the aggregate effective tax rate is fairly inelastic with respect to b: a 0.92 (1.05) percentage point increase (decrease) in ETR requires an increase (decrease) of 40% (35%) in b. This is in part because the aggregate ETR depends more on the larger firms that will continue to maximize tax avoidance. This can be seen in the larger movements in the firm average ETR (-2.28% and 1.76%).

An increase in the unit cost of tax avoidance b decreases aggregate investment and output by 0.3% and 0.5%, respectively. This corresponds to a 0.7% increase in the product price, reducing consumer surplus by 0.7%. Reflecting the higher avoidance cost, firms in aggregate incur 3.3% less in tax avoidance costs (as a fraction of profits), and pay 4.1% more in taxes. These outcomes are all consistent with the new higher effective tax rate.

However, the response to an increase in b is quite different from a simple tax increase in a no avoidance world. In particular, the average firm size increases: this results in higher average cost and a lower productive efficiency. Thus, while increasing the difficulty of tax avoidance would seem to be beneficial in that it reduces tax avoidance, it actually exacerbates the problem because it further widens the gap between large and small firms. Large firms continue to minimize taxes while the threshold for smaller firms to benefit from tax avoidance becomes higher. In turn, the value of tax avoidance for an entrant declines, while it remains similar for larger firms. This results in a higher product price which disproportionately benefits larger firms.

These results should signal caution for policymakers who attempt to remedy the negative consequences of tax avoidance by closing heavily exploited "loopholes" and by generally making tax avoidance more difficult to achieve: these actions may have the unintended effect of exacerbating the inequality of tax avoidance, further benefiting large firms at the expense of productive efficiency and welfare. Indeed, our results indicate that making tax avoidance less costly to achieve improves efficiency by encouraging entry and leveling the playing field between large and small firms. In the limit, as the unit cost of tax avoidance goes to zero or infinity, the outcome is the same: all firms face the same tax rate. These results indicate that the inequality in effective tax rates across firms creates significant inefficiency, and any policy that has the potential to exacerbate tax outcomes across firms should be viewed with caution.

5.2. *Revenue-neutral flat tax rate*

The tax code is very complicated and creates significant room for tax avoidance, whether intentional or inadvertent. We saw in Section 4.2.4 that eliminating tax avoidance would significantly increase tax revenue and lead to an increase in total surplus. However, it would also increase prices, and lower consumer surplus and firm profits. In this section we consider the effect of eliminating tax avoidance while adjusting the statutory tax rate to be tax revenue-neutral.

Column 1 of Table IX reports the percent increase relative to the baseline in each quantity when tax avoidance is eliminated and the flat tax rate is set to 27.4%, the tax revenue-neutral level. We see that taxes paid are (approximately) unchanged, however, the aggregate ETR declines by 2.0 p.p. This reflects the fact that output and profits increase significantly under the new policy, increasing the tax base. The homogeneous tax rate also lowers the firm average ETR by 7.5 p.p.

Despite the 4.6% higher level of output, and corresponding 5.9% lower price, the average firm is significantly smaller: average value and output decrease by 14.5 and 19.4%, respectively. The lower tax rate for small firms and entrants lowers the equilibrium price and in turn the optimal scale for firms. This results in a lower average cost (10.5%) and increased productive efficiency (6.45% of revenue). The mass of firms increases by 30.0% broadening the source of output. Firms are better off (1.39% of revenue) because of lower tax rates and eliminating the costs of tax avoidance. Consumers capture most (6.07% of revenue) of the increase in surplus.

Eliminating tax avoidance, even in a tax revenue-neutral way, improves productive efficiency, consumer and total surplus. While eliminating the deadweight direct costs of tax avoidance accounts for 13% of this increased surplus, improvements in capital and labor allocation contribute the remaining 87%.

5.3. *Tax cuts in the presence of avoidance*

Policy discussion around taxation often focus on changes in the statutory tax rate. However, firm behavior and outcomes depend on the effective tax rate, and changes in the statutory rate can have ambiguous effects on the ETR. In this section we evaluate the effect of a tax cut with and without the presence of tax avoidance.

In the model, performing a policy experiment on a cut in the statutory tax rate requires us to take a stance on how this rate change interacts with tax avoidance. In particular, how does cutting the top rate affect the ability of a firm to reduce their effective tax rate? We consider two possibilities. The first assumption is that a statutory tax rate cut truncates the effective tax rate function from above but leaves the minimum achievable ETR unchanged. The second assumption is that a lower statutory rate *shifts* the entire ETR function downward, such that both the maximum and minimum rates are lower proportionately. These two assumptions are shown in Figure 8.

We evaluate the effect of a 5 p.p. statutory tax rate cut in columns 2–4 of Table IX. The table reports the percent increase relative to the baseline in each quantity under the new policy.

Column 2 shows the results of a 5 p.p. tax cut in a world with no tax avoidance. In this case, both the aggregate and average ETR decreases by 5 p.p. As expected, aggregate firm value increases, along with aggregate profits. Aggregate output increases and the price declines, increasing consumer surplus. In fact, the loss in tax revenue is smaller than the gain to consumers and firms, leading to an increase in total surplus. As there are no deadweight cost of tax avoidance, all of the increase in surplus comes from improved productive efficiency as the distortionary corporate tax is lowered. This is seen in the increase in mass of firms and decrease in the average firm size.

Columns 3 and 4 reports the outcomes with a 5 p.p. statutory tax cut in the presence of tax avoidance. Column 3 assumes that the ETR function is truncated above, but the minimum rate is unchanged. We see that the effect of a tax cut has an insignificant effect on the ETR: the 5 p.p. statutory cut translates into only a 0.1 p.p. reduction in the aggregate ETR. Similarly, the average ETR declines by only 0.7 p.p. This is because the new lower statutory rate disproportionately affects the smallest firms that produce only a small fraction of total output. The direct costs of tax avoidance decline substantially, lowering this deadweight loss, as smaller firms now automatically receive the lower rate without any cost.

Despite little effect on the aggregate and average ETR, output increases following the tax cut. This is because the new lower rate mostly affects the smaller firms and translates into a higher value for entrants and a lower product price. At the lower product price, the optimal firm scale declines as the new policy is detrimental to large firm. This can be seen with lower firm average value, output, capital, etc, and the increased aggregate output is generated by a 9.3% increase in the mass of firms. At this smaller average scale, production is more efficient which is seen by lower average costs and higher average marginal products of capital and labor. Overall, the increase in productive efficiency adds 2.2% of revenue in the aggregate. Interestingly, all three parties—firms, consumers, and taxpayers—are made better off. Total taxes paid increases by 3.1% reflecting the increase in total output.

Column 4 considers the same 5 p.p. statutory rate cut but under the assumption that the ETR function is shifted down proportionately, allowing firms to achieve new minimum rates. In this case, the reduction in the aggregate ETR is larger at 1.7 p.p. but it is still far less than the statutory cut. The effect on output and prices, and therefore consumer surplus, is similar to truncation case in columns 3, but still much more modest than the tax cut without tax avoidance shown in column 2. The policy change reduces the average firm size, but to a lesser extent than in column 3. In general, the shifting of the ETR makes taxes collected more sensitive to statutory tax rate changes but does less to reduce the inefficiency generated by tax avoidance and heterogeneous ETRs.

At the end of 2017, the Tax Cuts and Jobs Act was enacted, representing the most significant corporate tax legislation in three decades. One of the key provisions was the lowering of the federal corporate income tax rate by 14 p.p., from 35% to 21%. In the final column of Table IX, we use the model to evaluate the effect of this statutory rate cut. We assume that the change did not eliminate tax avoidance, instead that it proportionately shifted the achievable tax rates as shown in Panel B of Figure 8.

We find that the model predicts an increase in output of 4.9% and a corresponding decrease in prices by 6.2% leading to an increase in consumer surplus. Aggregate firm value increases significantly, and the reduces the average firm value by 6.8%. This reduces the size of the largest firms in particular. This is caused by reducing the gap between small and large firms as tax avoidance becomes less utilized at the lower tax rate. In addition, because firms operate a smaller scale productive efficiency increases. In aggregate, the surplus across firms, consumers, and taxpayers increases as the tax distortions are reduced.

6. Conclusion

We develop an industry equilibrium model to study how corporate tax avoidance affects firm policies and industry outcomes. In both the model and data, effective rates decline in firm size, leading larger firms to receive the greatest benefit from tax avoidance. We find that the heterogeneity in tax rates induced by tax avoidance has important consequences for investment and competitive outcomes, and that these tax distortions differ from those in a neoclassical model where all firms face the same tax rate. In particular, tax avoidance increases the average firm size substantially, with much of this increase coming from the largest firms. Thus, tax avoidance increases concentration despite lowering the tax rate firms face; in contrast, a tax cut decreases concentration when all firms face the same tax rate. Tax avoidance reduces allocative efficiency and results in a deadweight loss. We find that policies to limit tax avoidance may actually exacerbate misallocation.

References

Albertus, J. F., Glover, B., Levine, O., 2019a. Foreign investment of us multinationals: The effect of tax policy and agency conflicts. Available at SSRN 3172468 .

Albertus, J. F., Glover, B., Levine, O., 2019b. Heads I win, tails you lose: Asymmetric taxes, risk taking, and innovation. Journal of Monetary Economics 105, 24–40.

Autor, D., Dorn, D., Katz, L. F., Patterson, C., Van Reenen, J., 2020. The fall of the labor share and the rise of superstar firms. The Quarterly Journal of Economics 135, 645–709.

Baker, S. R., Sun, S. T., Yannelis, C., 2020. Corporate Taxes and Retail Prices. National Bureau of Economic Research .

Barro, R. J., Furman, J., 2018. Macroeconomic Effects of the 2017 Tax Reform. Brookings Papers on Economic Activity pp. 257–313.

Chen, S., Chen, X., Cheng, Q., Shevlin, T., 2010. Are family firms more tax aggressive than non-family firms? Journal of Financial Economics 95, 41–61.

Clausing, K. A., et al., 2016. The effect of profit shifting on the corporate tax base in the united states and beyond. National Tax Journal 69, 905–934.

Clementi, G. L., Hopenhayn, H. A., 2006. A theory of financing constraints and firm dynamics. The Quarterly Journal of Economics 121, 229–265.

Clementi, G. L., Palazzo, B., 2016. Entry, exit, firm dynamics, and aggregate fluctuations. American Economic Journal: Macroeconomics 8, 1–41.

Cooley, T. F., Quadrini, V., 2001. Financial markets and firm dynamics. American economic review 91, 1286–1310.

De Loecker, J., Eeckhout, J., Unger, G., 2020. The rise of market power and the macroeconomic implications. The Quarterly Journal of Economics 135, 561–644.

Desai, M. A., Dharmapala, D., 2006. Corporate tax avoidance and high-powered incentives. Journal of financial Economics 79, 145–179.

Desai, M. A., Dharmapala, D., 2009. Corporate tax avoidance and firm value. The review of Economics and Statistics 91, 537–546.

Desai, M. A., Dyck, A., Zingales, L., 2007. Theft and taxes. Journal of Financial Economics 84, 591–623.

Dimopoulos, T., Sacchetto, S., 2017. Merger activity in industry equilibrium. Journal of Financial Economics 126, 200–226.

Dixit, A. K., Pindyck, R. S., 1994. Investment under uncertainty. Princeton university press.

Dyreng, S. D., Hanlon, M., Maydew, E. L., 2008. Long-run corporate tax avoidance. The accounting review 83, 61–82.

Dyreng, S. D., Hanlon, M., Maydew, E. L., Thornock, J. R., 2017. Changes in corporate effective tax rates over the past 25 years. Journal of Financial Economics 124, 441–463.

Ericson, R., Pakes, A., 1995. Markov-perfect industry dynamics: A framework for empirical work. The Review of economic studies 62, 53–82.

Fair Tax Mark, 2019. The silicon six and their $100 billion global tax gap. https://fairtaxmark.net/wp-content/uploads/2019/12/Silicon-Six-Report-5-12-19.pdf .

Fuest, C., Peichl, A., Siegloch, S., 2018. Do Higher Corporate Taxes Reduce Wages? Micro Evidence from Germany. American Economic Review 108, 393–418.

Gourio, F., Miao, J., 2010. Firm heterogeneity and the long-run effects of dividend tax reform. American Economic Journal: Macroeconomics 2, 131–68.

Gourio, F., Roys, N., 2014. Size-dependent regulations, firm size distribution, and reallocation. Quantitative Economics 5, 377–416.

Graham, J. R., 2003. Taxes and corporate finance: A review. The Review of Financial Studies 16, 1075–1129.

Grullon, G., Larkin, Y., Michaely, R., 2019. Are us industries becoming more concentrated? Review of Finance 23, 697–743.

Gupta, Newberry, 1997. Determinants of the variability in corporate effective tax rates: Evidence from longitudinal data. Journal of Accounting and Public Policy 16, 1–34.

Gutiérrez, G., Philippon, T., 2017. Declining competition and investment in the us. Tech. rep., National Bureau of Economic Research.

Hall, R. E., Jorgenson, D. W., 1967. Tax Policy and Investment Behavior. The American Economic Review 57, 391–414.

Hanlon, M., Heitzman, S., 2010. A review of tax research. Journal of accounting and Economics 50, 127–178.

Harberger, A. C., 1962. The Incidence of the Corporation Income Tax. Journal of Political Economy 70, 215–240.

Hartman-Glaser, B., Lustig, H., Xiaolan, M. Z., 2019. Capital share dynamics when firms insure workers. The Journal of Finance 74, 1707–1751.

Hassett, K. A., Hubbard, R. G., 2002. Tax policy and business investment. In: *Handbook of public economics*, Elsevier, vol. 3, pp. 1293–1343.

Hayashi, F., 1982. Tobin's marginal q and average q: A neoclassical interpretation. Econometrica: Journal of the Econometric Society pp. 213–224.

Hennessy, C. A., Whited, T. M., 2005. Debt dynamics. The journal of finance 60, 1129–1165.

Henry, E., Sansing, R., 2018. Corporate tax avoidance: data truncation and loss firms. Review of Accounting Studies 23, 1042–1070.

Hopenhayn, H., Rogerson, R., 1993. Job turnover and policy evaluation: A general equilibrium analysis. Journal of political Economy 101, 915–938.

Hopenhayn, H. A., 1992a. Entry, exit, and firm dynamics in long run equilibrium. Econometrica: Journal of the Econometric Society pp. 1127–1150.

Hopenhayn, H. A., 1992b. Exit, selection, and the value of firms. Journal of Economic Dynamics and Control 16, 621–653.

House, C. L., Shapiro, M. D., 2008. Temporary Investment Tax Incentives: Theory with Evidence from Bonus Depreciation. American Economic Review 98, 737–768.

Jovanovic, B., 1982. Selection and the evolution of industry. Econometrica: Journal of the Econometric Society pp. 649–670.

Kocieniewski, D., 2011. Ge's strategies let it avoid taxes altogether. New York Times 24, 10.

Luttmer, E. G., 2007. Selection, growth, and the size distribution of firms. The Quarterly Journal of Economics 122, 1103–1144.

McClure, C., 2020. How costly is tax avoidance? evidence from structural estimation. Evidence from Structural Estimation (July 17, 2020). Chicago Booth Research Paper .

Miao, J., 2005. Optimal capital structure and industry dynamics. The Journal of finance 60, 2621–2659.

Omer, T. C., Molloy, K. H., Ziebart, D. A., 1993. An Investigation of the Firm Size—Effective Tax Rate Relation in the 1980s. Journal of Accounting, Auditing & Finance 8, 167–182.

Phillips, G. M., 1995. Increased debt and industry product markets an empirical analysis. Journal of financial Economics 37, 189–238.

Rego, S. O., 2003. Tax-Avoidance Activities of U.S. Multinational Corporations*. Contemporary Accounting Research 20, 805–833.

Shackelford, D. A., Shevlin, T., 2001. Empirical tax research in accounting. Journal of Accounting and Economics 31, 321–387.

Summers, L. H., 1981. Taxation and Corporate Investment: A q-Theory Approach. Brookings Papers on Economic Activity 1981, 67–140.

Yagan, D., 2015. Capital Tax Reform and the Real Economy: The Effects of the 2003 Dividend Tax Cut. American Economic Review 105, 3531–3563.

Zimmerman, J., 1983. Taxes and firm size. Journal of Accounting and Economics 5, 119–149.

Zwick, E., Mahon, J., 2017. Tax Policy and Heterogeneous Investment Behavior. American Economic Review 107, 217–248.

Table I: **Effective Tax Rates.** Reports statistics on cash effective tax rates (ETRs) with each column using an alternative measurement approach. The N-year cash ETR is calculated for each firm and year as the sum of cash taxes paid (TXPD) over the previous N years divided by the sum of pre-tax income (PI) over that same period. See Section 2 for details of construction. The top four rows report summary statistics of the ETRs for the full sample. In the second panel, each year firms are sorted into deciles based on either the average market value of assets over the N-year period (columns 1, 3, 4, and 5), or the average book value of assets (column 2), and the means are reported within each decile. The average ETR for the top 1% of firms by asset value is also reported. The last two columns report the ETR difference between the tenth and first decile, and the top 1% and first decile, respectively. The "ETR horizon" indicates the number of years used to construct the tax rate measure. Column 3 uses pretax profits minus special items as the denominator in the ETR estimate.

	(1)	(2)	(3)	(4)	(5)
ETR horizon:	10-year	10-year	10-year	5-year	1-year
Size measure:	Market assets	Book assets	Market assets	Market assets	Market assets
Special items:	Include	Include	Exclude	Include	Include
Mean	0.351	0.351	0.295	0.336	0.295
Median	0.319	0.319	0.281	0.310	0.275
Std dev.	0.201	0.201	0.169	0.211	0.225
Obs	23,927	23,927	21,601	39,108	58,436
Size Decile					
(Small) 1	0.414	0.394	0.362	0.392	0.301
2	0.392	0.386	0.330	0.359	0.294
3	0.384	0.368	0.328	0.354	0.297
4	0.377	0.368	0.303	0.357	0.295
5	0.347	0.367	0.283	0.344	0.298
6	0.342	0.345	0.285	0.333	0.297
7	0.325	0.318	0.278	0.313	0.293
8	0.317	0.327	0.266	0.320	0.290
9	0.327	0.330	0.263	0.310	0.295
(Large) 10	0.306	0.318	0.260	0.306	0.295
Top 1%	0.269	0.304	0.223	0.284	0.290
(10)−(1)	−0.108	−0.077	−0.102	−0.086	−0.005
Top 1%−(1)	−0.144	−0.090	−0.139	−0.108	−0.010

Table II: **Model parameters** The table displays the parameter values for the baseline model calibration with tax avoidance. Where applicable, parameter values are at an annual frequency. See Section 4.1 for a discussion of the calibration approach.

Parameter	Value
μ	-0.0003
σ	0.085
λ	0.038
α	0.22
β	0.44
γ	0.036
r	0.05
δ	0.1
w	1
c_f	0.2
c_E	0.8
z_0	1
ϵ	0.75
$b \times 1000$	28.2
$\overline{\tau}$	0.414
τ_0	0.414
τ_L^{ETR}	0.261

Table III: **Targeted moments** The table displays the moments that we target in our calibration. The first three moments are used to target μ, σ, λ. The remaining moments are the ETRs by size percentile, which are used to calibrate b and γ. The first column of the table reports the moment in the calibrated model and the second column is the value in the data. See Table II for the parameter values and Section 4.1 for a discussion of the calibration approach.

	Model	Data
Mean of earnings growth	0.026	0.026
Volatility of earnings growth	0.278	0.278
Pareto tail, firm size	1.300	1.300
ETR of Size Percentile:		
5	0.398	0.414
15	0.387	0.392
25	0.379	0.383
35	0.372	0.377
45	0.364	0.348
55	0.355	0.343
65	0.343	0.325
75	0.326	0.317
85	0.299	0.328
95	0.261	0.310
99.5	0.261	0.270

Table IV: **Tax outcomes in the baseline model.** The table reports variable outcomes from the baseline model related to taxes and tax avoidance. Aggregate ETR is aggregate taxes paid over aggregate pretax income. Average ETR is the firm average effective tax rate. Aggregate tax avoidance costs are the direct costs ($bh_{i,t}$) of tax avoidance aggregated across all firms.

			Agg. tax avoidance costs over		
Agg. ETR	Avg. ETR	Agg. taxes paid/revenue	taxes paid	profits	revenue
0.294	0.348	0.116	0.083	0.067	0.010

Table V: **The effect of tax avoidance.** The table reports the percent increase in aggregates and firm-level averages due to tax avoidance; negative numbers indicate a decrease due to tax avoidance. These are constructed by comparing the baseline model steady state equilibrium with the counterfactual steady state equilibrium where tax avoidance has been shut down. Aggregate values are shown in Panel A and firm average values are shown in Panel B. Average cost is defined as operating costs ($wL + (\delta + r)K$) over output (Y). The gross (pretax) profit margin is gross profits ($pY - \omega L - (\delta + r)K$) over revenue ($pY$). The net (after-tax) profit margin is after-tax profits (Π) over revenue. The productivity exit threshold is z_D. The marginal product of capital (MPK) and labor (MPL) are $\alpha y_{i,t}/k_{i,t}$ and $\beta y_{i,t}/\ell_{i,t}$, respectively. The marginal revenue product of capital (MRPK) and labor (MRPL) are MPK and MPL times the equilibrium price p_t.

Panel A: Aggregates		Panel B: Firm averages	
Percent increase due to tax avoidance			
Firm value	8.95	Firm value	16.90
Output	2.51	Output	9.99
Revenue	−0.82	Revenue	6.41
Capital	7.23	Capital	15.06
Labor	7.23	Labor	15.06
Profit	6.94	Profit	14.74
Taxes		*Taxes*	
Taxes paid	−36.85	Taxes paid	−32.24
Taxes paid/Revenue	−36.32	Taxes paid/Revenue	−20.36
Taxes paid/Cash flow	−40.94	ETR	
ETR		p.p.	−6.55
p.p.	−12.02	percent	−15.82
percent	−29.03		
		Productivity	
Productivity		MRPK	−4.29
Average cost	4.61	MRPL	−4.29
Gross (pretax) profit margin		MPK	−1.08
p.p.	−5.02	MPL	−1.08
percent	−13.14		
Net (after-tax) profit margin			
p.p.	1.05		
percent	7.83		
Industry			
Price (p)	−3.25		
Mass of firms (Q)	−6.80		
Entry flow (N)	−4.04		
Exit threshold (z_D)	0.96		

Table VI: **Effect of tax avoidance on size and concentration.** The table reports the percent increase in each variable due to tax avoidance; negative values represent a decrease due to tax avoidance. These are constructed by comparing the baseline model steady state equilibrium with the counterfactual steady state equilibrium where tax avoidance has been shut down. Panel A reports the percent increase in the percentiles of the size distribution where size is measured as firm value, revenue, capital, or output. Panel B reports the percent increase in industry concentration. Panel B also reports the level of industry concentration for each variable in the baseline model. Concentration is defined as the fraction or share of a given variable coming from the top X% of firms. For example, 62.3% of all capital is employed by the top 10% of firms, a 5.4% increase relative to the case without tax avoidance.

Panel A: Effect of tax avoidance on the size distribution

Percent increase in firm quantities at given percentile							
	Percentile						
	10	30	50	70	90	95	99
Value	1.0	2.7	5.4	8.6	14.3	17.0	20.1
Revenue	−4.7	−3.3	−1.4	1.7	8.5	10.3	10.3
Capital	−3.1	−0.6	2.4	7.3	18.4	21.4	21.4
Output	−1.5	−0.1	1.9	5.1	12.2	14.0	14.0

Panel B: Effect of tax avoidance on industry concentration

		Share of firms in the...			
		Top 20%	Top 10%	Top 5%	Top 1%
Value	Level	0.847	0.750	0.655	0.462
	% increase	1.71	2.45	2.98	3.57
Capital	Level	0.725	0.623	0.531	0.366
	% increase	4.56	5.40	5.48	5.48
Revenue	Level	0.715	0.612	0.522	0.360
	% increase	3.04	3.59	3.64	3.64
Profit	Level	0.960	0.864	0.760	0.541
	% increase	2.51	3.76	4.62	5.44
Taxes Paid	Level	0.634	0.531	0.451	0.311
	% increase	−8.56	−10.22	−10.37	−10.37
TAC	Level	0.585	0.374	0.193	0.039

Table VII: **Welfare effects of tax avoidance.** This table reports the aggregate welfare effects due to tax avoidance as a percent of aggregate firm revenue in the baseline model. These are constructed by taking the baseline model steady state equilibrium outcome minus that same outcome in the counterfactual steady state equilibrium where tax avoidance has been shut down. For each quantity, the numerator is the change in the dollar flow going to the stated group. The denominator is the aggregate flow of firm revenue in the baseline model. The first row is the increase in aggregate firm profits minus aggregate entry costs. The second row is the increase in consumer surplus due to changes in price and supply: $\frac{\epsilon}{\epsilon-1}\left(Y_B^{\frac{\epsilon-1}{\epsilon}} - Y_{NA}^{\frac{\epsilon-1}{\epsilon}}\right) + Y_{NA}p_{NA} - Y_B p_B$. The third row is the increase in tax revenue. The fourth row is the increase in the total surplus across firms, consumers, and taxpayers, which is the sum of the first three rows. The fifth row is direct costs of tax avoidance, or $bh_{i,t}$, aggregated across all firms. The sixth row is the sum of the total surplus and the direct costs of tax avoidance which gives the increase in productive efficiency.

Panel A: Effect of tax avoidance

Increase as % of aggregate firm revenue	
Firm profits	1.02
+ Consumer surplus	3.31
+ Tax revenue	−6.79
= Total surplus	−2.45
+ Tax avoidance costs	0.97
= Productive efficiency	−1.49

Panel B: Effect of NA tax cut

Increase as % of aggregate firm revenue	
Firm profits	2.43
+ Consumer surplus	9.44
+ Tax revenue	−6.93
= Total surplus	4.94
+ Tax avoidance costs	0.00
= Productive efficiency	4.94

Table VIII: **Varying the cost of tax avoidance** The table presents the percent increase in each variable under an alternative policy. Each quantity is constructed as the percent change in the given variable from the baseline model steady state equilibrium to the counterfactual steady state equilibrium. TAC refers to the direct costs of tax avoidance, or $bh_{i,t}$, aggregated across all firms. The last six rows present the welfare effects of the new policy as defined in Table VII. The first (second) column is for a lower (higher) input cost of tax avoidance, b, such that aggregate ETR decreases (increases) by approximately 1 p.p.

	Decrease b	Increase b
Percent increase under new policy		
Aggregates		
Firm value	−0.30	0.19
Output	0.77	−0.53
Revenue	−0.25	0.18
Capital	0.33	−0.34
Profit	−0.02	−0.01
Average cost	−0.44	0.19
Taxes paid	−4.66	4.14
ETR (p.p.)	−1.05	0.92
TAC/Profit	−1.73	−3.33
Firm averages		
Firm value	−1.74	0.86
Output	−0.69	0.13
Revenue	−1.69	0.85
Capital	−1.12	0.32
Profit	−1.46	0.66
Taxes paid	−6.03	4.83
ETR (p.p.)	−2.28	1.76
MPK	−0.35	0.46
MPL	−0.35	0.46
Industry		
Price (p)	−1.01	0.71
Mass of firms (Q)	1.46	−0.66
Entry flow (N)	1.71	−1.15
Exit threshold (z_D)	0.08	−0.16
Top 10% share of		
Revenue	−1.15	0.85
Profit	−0.60	0.35
Top 1% share of		
Revenue	−1.20	1.11
Profit	−1.30	1.13
50th percentile of value	0.34	−0.69
90th percentile of value	−0.56	−0.34
99th percentile of value	−2.43	1.40
Increase under new policy as percent of revenue		
Welfare		
Firm profits	−0.04	0.02
Consumer surplus	1.02	−0.71
Tax revenue	−0.54	0.48
Total surplus	0.44	−0.21
Tax avoidance costs	−0.02	−0.03
Productive efficiency	0.42	−0.24

Table IX: **Tax policy experiments.** The table presents the percent increase in each variable under an alternative policy with a lower statutory tax rate. With the exception of column 2, each quantity is constructed as the percent change in the given variable from the baseline model steady state equilibrium to the counterfactual steady state equilibrium. TAC refers to the direct costs of tax avoidance, or $bh_{i,t}$, aggregated across all firms. The last six rows present the welfare effects of the new policy as defined in Table VII. The counterfactual in column 1 is with tax avoidance shut down and the tax rate set to $\tau_0 = 0.274$, the tax revenue-neutral level. Column 2 reports the effect of a 5 p.p. tax cut in world without tax avoidance. Columns 3 and 4 are a 5 p.p. cut in τ_0 where the tax avoidance function is truncated or shifted, respectively. Column 5 is a tax cut of 14 p.p. as specified in the TCJA where the the tax avoidance function is shifted.

	(1)	(2)	(3)	(4)	(5)
Tax cut:	Revenue neutral	5 p.p.	5 p.p.	5 p.p.	TCJA
Benchmark:	Baseline	No avoidance	Baseline	Baseline	Baseline
New policy:	No avoidance	No avoidance	Truncation	Shifting	Shifting
		Percent increase under new policy			
Aggregates					
Firm value	11.09	7.57	4.79	6.36	16.16
Output	4.62	2.73	1.21	1.33	4.89
Revenue	−1.50	−0.89	−0.40	−0.44	−1.58
Capital	−0.02	2.83	−0.03	0.87	2.58
Profit	13.18	7.57	5.17	6.33	16.89
Average cost	−10.47	−2.48	−3.77	−3.01	−8.39
Taxes paid	−0.30	−13.74	3.07	−4.08	−20.41
ETR (p.p.)	−1.98	−5.00	−0.09	−1.74	−6.68
TAC/Profit	−100.00	–	−37.60	−26.00	−62.76
Firm averages					
Firm value	−14.46	0.02	−4.12	−1.37	−6.77
Output	−19.43	−4.48	−7.40	−6.04	−15.81
Revenue	−24.15	−7.85	−8.87	−7.68	−21.01
Capital	−23.01	−4.39	−8.53	−6.46	−17.67
Profit	−12.84	0.02	−3.77	−1.40	−6.18
Taxes paid	−23.23	−19.80	−5.70	−11.05	−36.12
ETR (p.p.)	−7.45	−5.00	−0.66	−0.82	−7.81
MPK	1.12	−0.10	0.92	1.01	1.27
MPL	10.98	3.65	4.71	4.80	11.14
Industry					
Price (p)	−5.85	−3.53	−1.59	−1.74	−6.17
Mass of firms (Q)	29.86	7.55	9.29	7.84	24.59
Entry flow (N)	26.12	7.53	7.48	6.22	21.40
Exit threshold (z_D)	−0.96	−0.01	−0.54	−0.49	−0.85
Top 10% share of					
Revenue	−3.46	0.00	0.01	1.10	−3.46
Profit	−3.63	−0.01	−0.59	0.06	−3.63
Top 1% share of					
Revenue	−3.51	0.00	0.04	1.54	1.96
Profit	−5.16	−0.01	−0.53	1.24	0.97
50th percentile of value	−5.11	0.03	−2.71	−2.47	−4.46
90th percentile of value	−12.47	0.02	−4.35	−3.20	−9.83
99th percentile of value	−16.73	0.01	−4.31	−0.78	−7.33
		Increase under new policy as percent of revenue			
Welfare					
Firm profits	1.39	0.86	0.60	0.79	2.03
Consumer surplus	6.07	3.60	1.60	1.76	6.42
Tax revenue	−0.04	−2.53	0.36	−0.48	−2.41
Total surplus	7.43	1.93	2.56	2.08	6.04
Tax avoidance costs	−0.98	0.00	−0.33	−0.21	−0.56
Productive efficiency	6.45	1.93	2.22	1.87	5.49

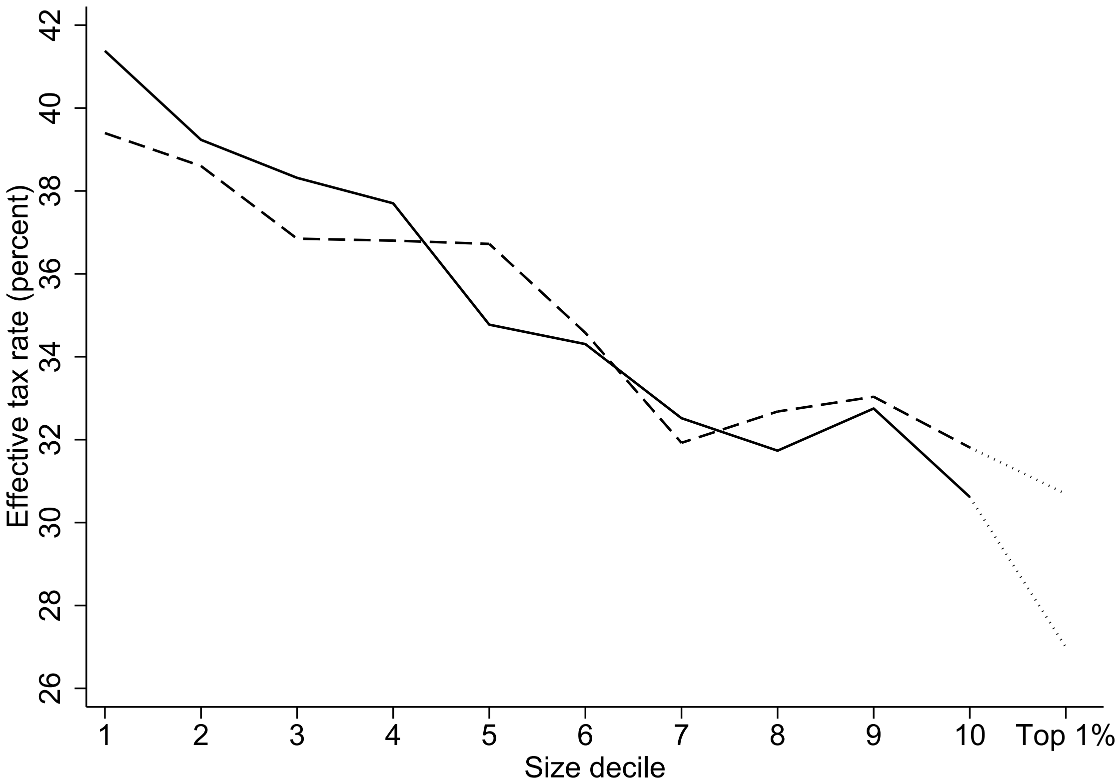

Fig. 1. **Effective tax rate by size.** Plots the average ten-year cash effective tax rate by firm size decile. Size is measured as either the market value of assets (solid line) or the book value of assets (dashed line). The 10-year cash ETR is calculated for each firm and year as the sum of cash taxes paid (TXPD) over the previous 10 years divided by the sum of pre-tax income (PI) over that same period. See Section 2 for details of construction. Each year, firms are sorted into deciles based on the average market or book value of assets over the ten-year period. The average ETR of firms in the top 1% of the size distribution is reported with a dotted line.

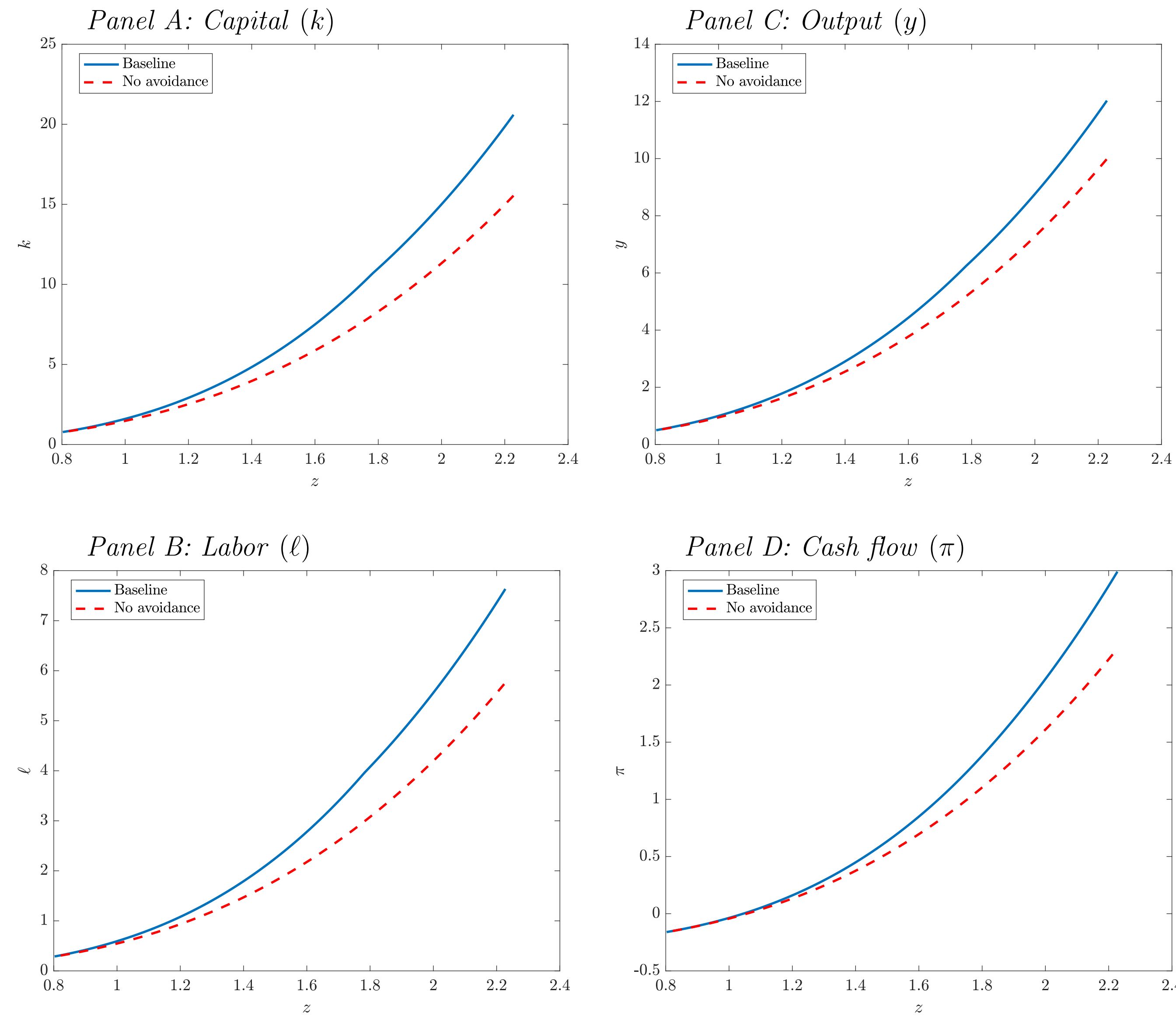

Fig. 2. **Policy functions: production** The figure plots the policy functions for the firm's optimal choice of capital (Panel A), labor (Panel B), output (Panel C), and cash flow (Panel D) as a function of the underlying productivity shock, z. In each panel we plot the policy function for the baseline case with tax avoidance (solid blue line) and the no avoidance case (dashed red line). The price is held fixed across these two cases and values are normalized by the firm's output in the baseline case with $z = z_0$.

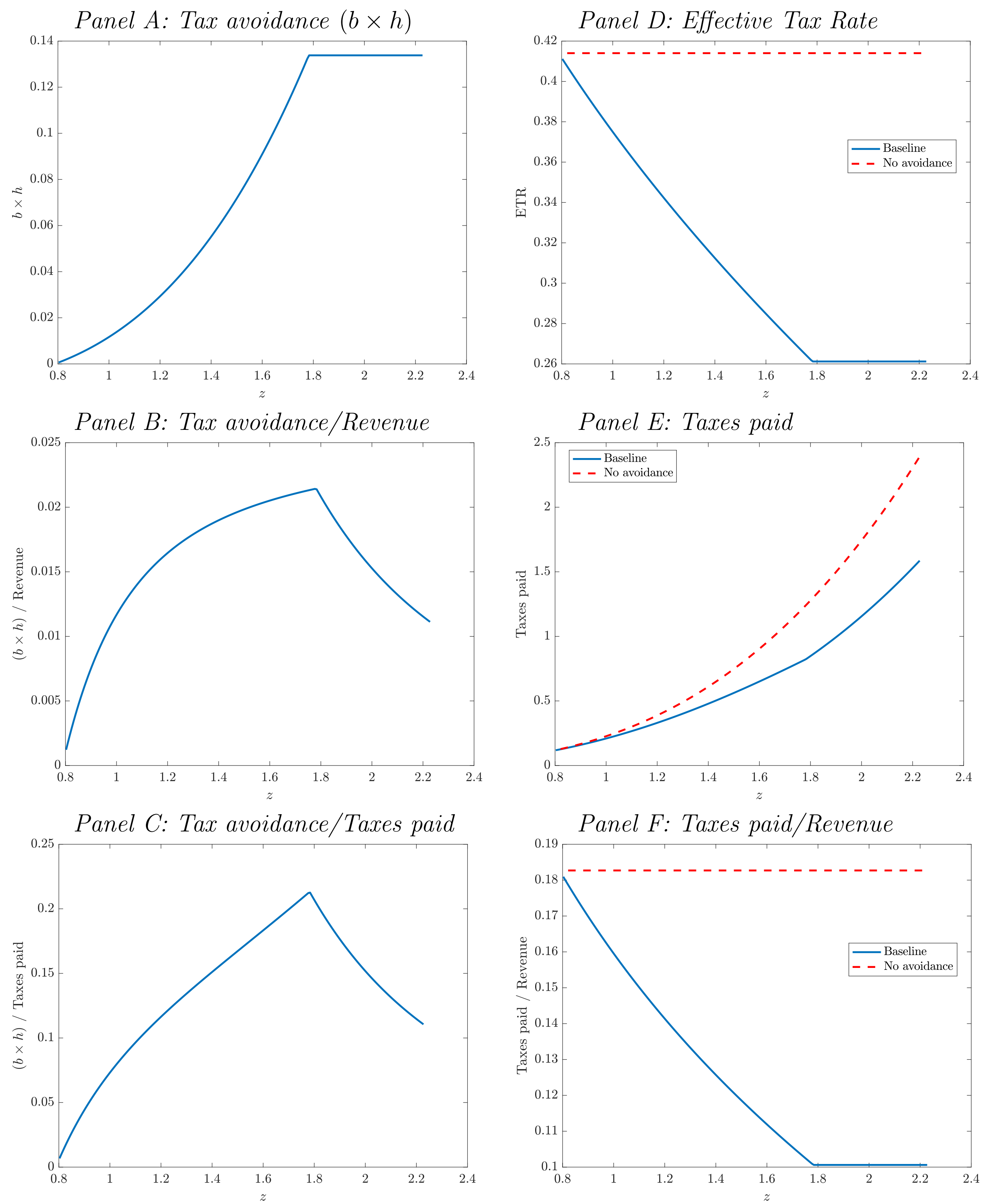

Fig. 3. **Policy functions: Taxes** The figure shows firm-level tax measures as a function of the underlying level of productivity, z. In the left column, we plot the firm's optimal tax avoidance expense (Panel A), avoidance expense divided by firm revenue, (Panel B) and avoidance expense divided by taxes paid (Panel C). In Panel D, we plot the effective tax rate, measured as taxes paid divided by taxable income. In Panel E we plot the taxes paid and in Panel F the taxes paid divided by firm revenue. In all three panels in the right column, the plots show the baseline model with avoidance (solid blue line) and the model with no avoidance (dashed red line). The parameter values are listed in Table II.

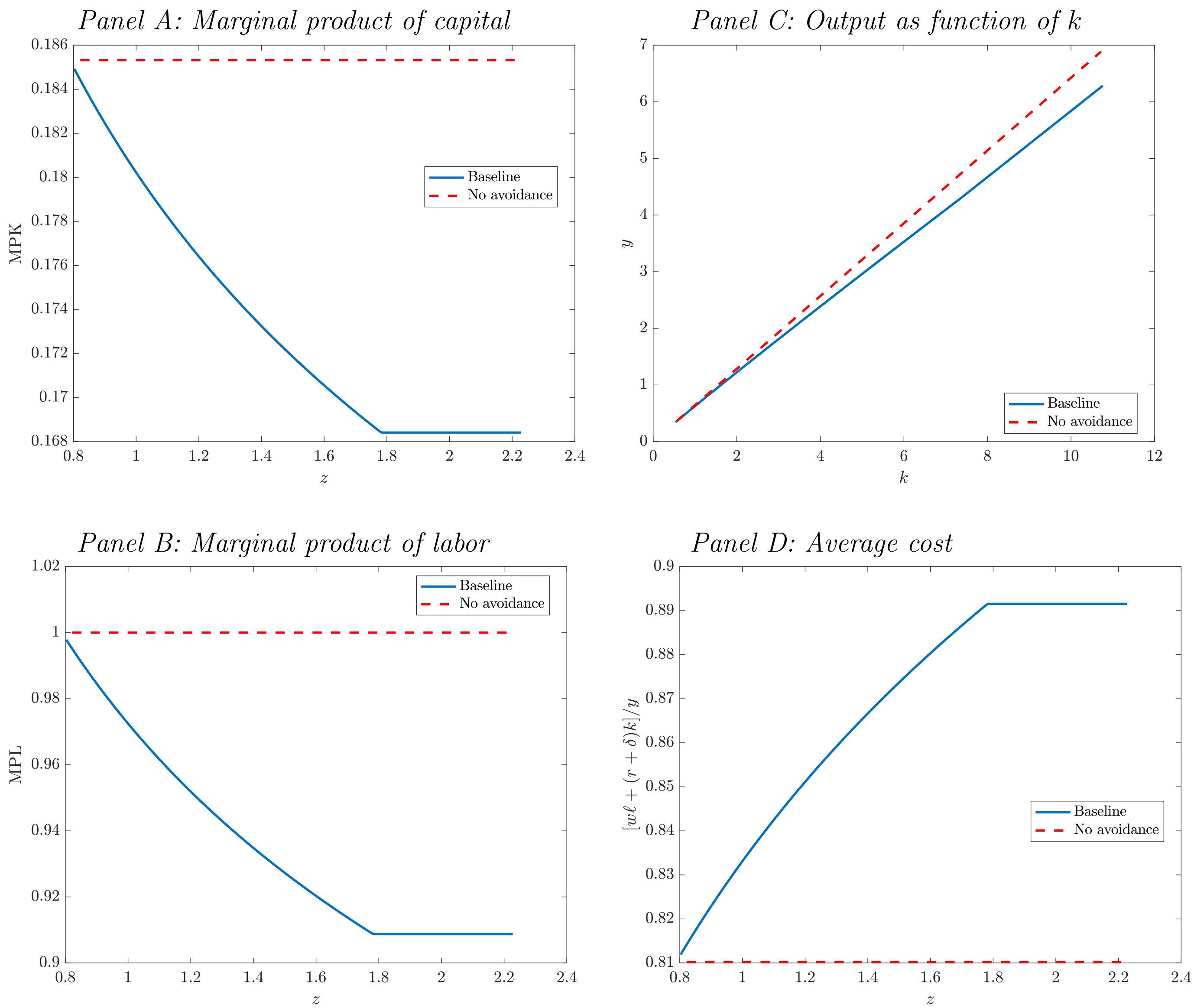

Fig. 4. **Productivity** The figure plots measures of firm-level productivity. In each panel we compare the baseline case with tax avoidance (solid blue line) to the model with no tax avoidance (dashed red line). We hold the product market price, p, fixed between these two cases. In Panels A and B we plot the marginal revenue products of capital and labor, respectively, as functions of the underlying productivity shock z. In Panel C, we plot the firm's output as a function of its optimal capital choice, k. In Panel D we plot the firm's average cost (depreciation and rental expense on capital plus the labor expense) divided by its output as a function of the productivity shock z.

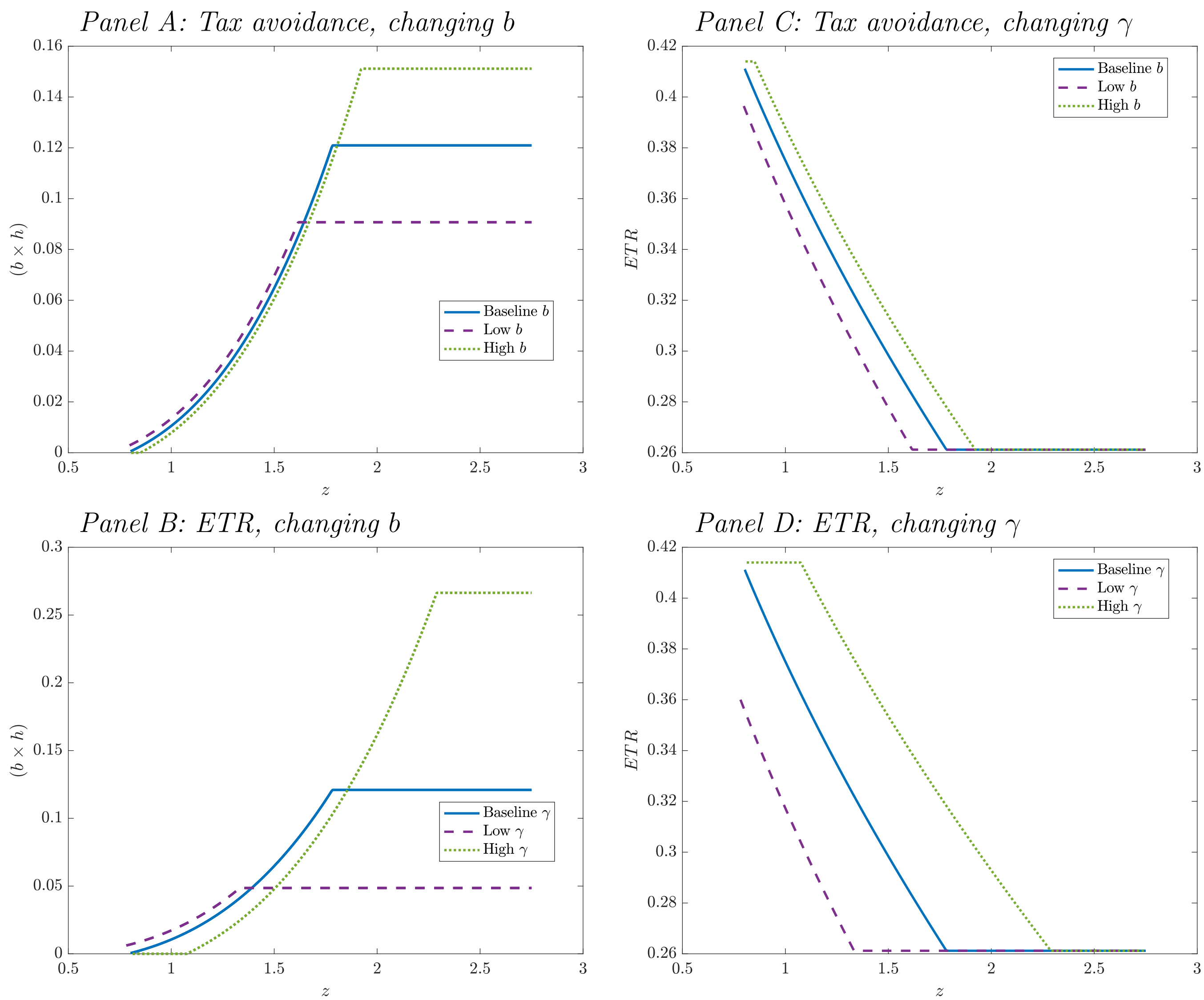

Fig. 5. **Tax avoidance comparative statics** The figure plots the optimal tax avoidance expenditure and the firm's effective tax rate as a function of the productivity shock z. The effective tax rate is computed in the model as

$$ETR = \frac{\tau^* py - \overline{\tau}(\delta k + w\ell)}{py - \delta k - w\ell}.$$

In Panels A and B we vary the parameter b, the marginal cost of tax avoidance. In Panels C and D, we vary the returns to scale of tax avoidance, γ. In each case, the solid blue line represents the firm policy under the baseline model calibration. See Table II for parameter values. The dashed purple line represents a low parameter value (b or γ) and the dotted green line represents a high parameter value.

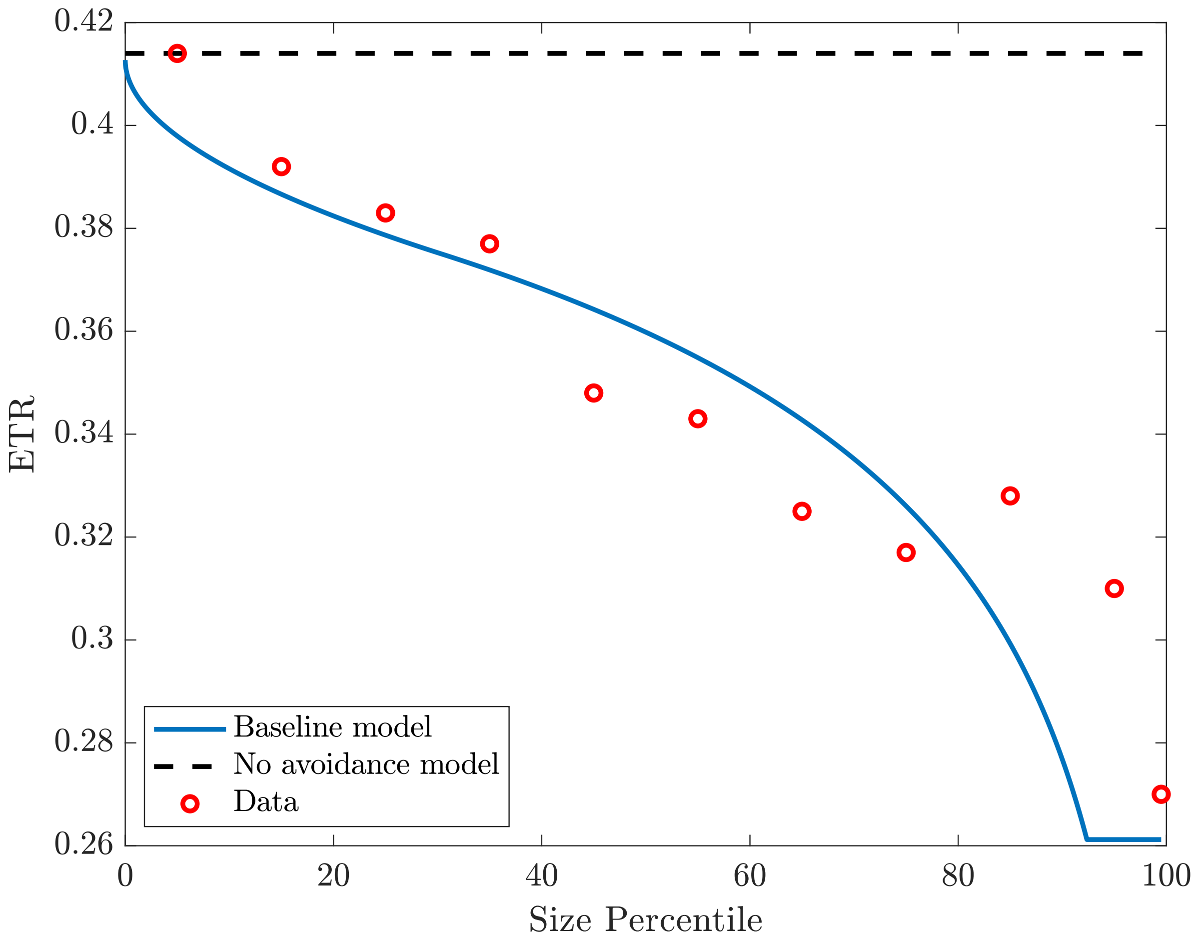

Fig. 6. **Effective tax rate by size: model and data.** The figure shows the effective tax rate (ETR) across firm size percentiles for both the data and the model. The solid blue line shows the model ETR across the firm size distribution for the baseline model with tax avoidance, where the ETR is computed as

$$ETR = \frac{\tau^* py - \overline{\tau}(\delta k + w\ell)}{py - \delta k - w\ell}.$$

The black dashed line shows the ETR in the no avoidance case of the model. The red circles indicate the ETR by firm size decile in the data. See Section 2 for a description of the construction of the ETR measure in the data. See Table II for the parameter values in the calibrated model.

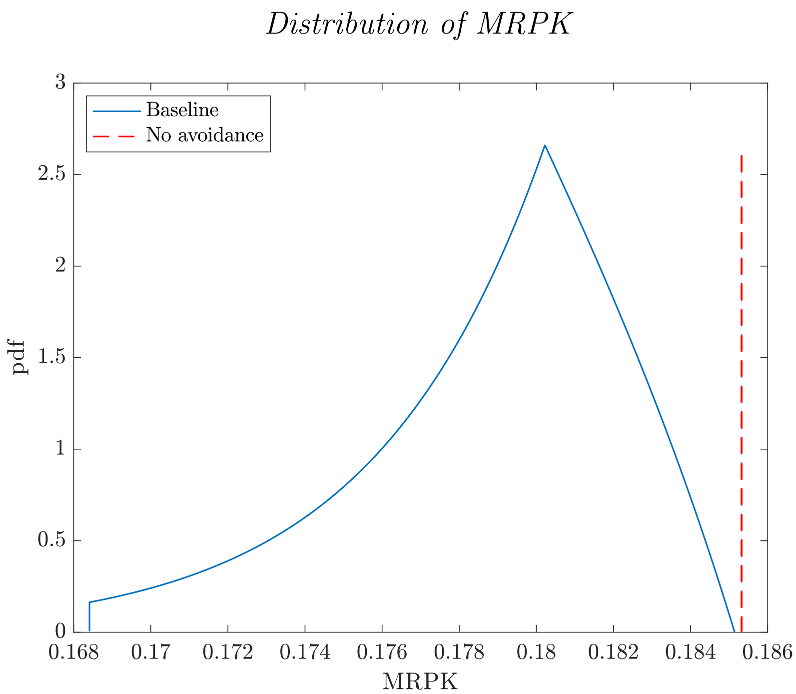

Fig. 7. **Distribution of the marginal revenue product of capital.** The figure plots the cross-sectional stationary distribution of the marginal revenue product of capital for the baseline model with tax avoidance (solid blue line) and the model with no tax avoidance (dashed red line). The model parameter values are given in Table II.

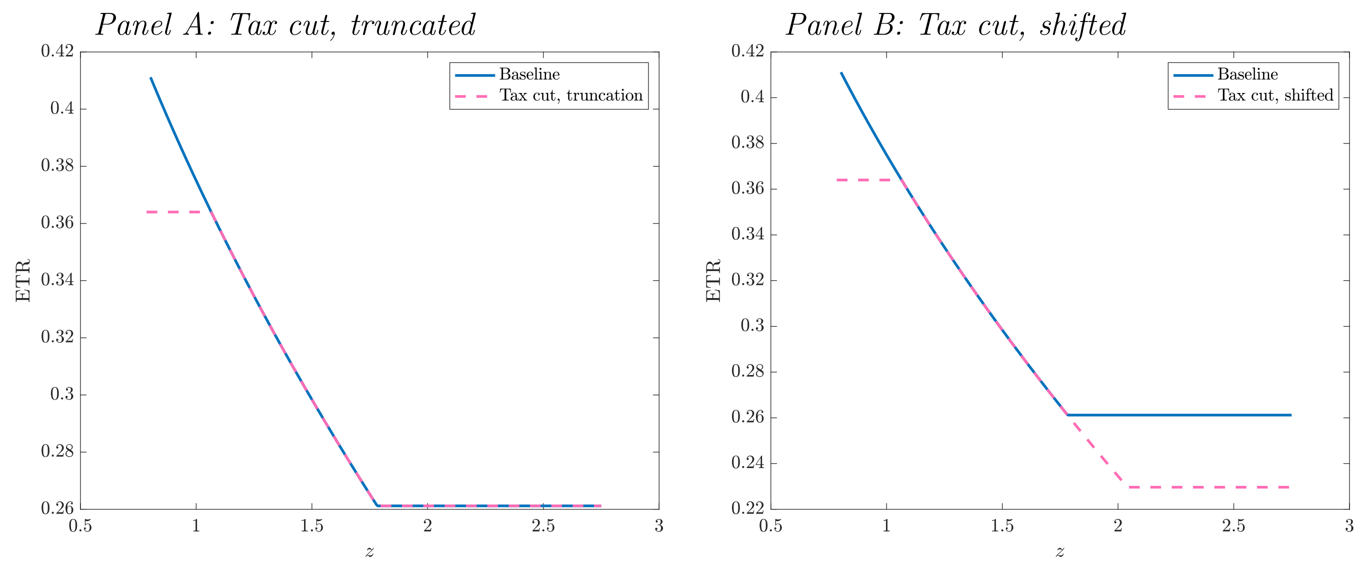

Fig. 8. **Effective tax rates on productivity for truncated and shifted tax cuts** The figure plots the firm's effective tax rate on its productivity. The ETR in the model is computed as

$$ETR = \frac{\tau^{*} py - \overline{\tau}(\delta k + w\ell)}{py - \delta k - w\ell}.$$

In Panel A, we compare the ETR in the baseline calibrated model to the ETR in the case of a tax cut where we truncate the tax rate function. In Panel B, we compare the baseline case ETR to the case of a tax cut where we shift the tax function. In both panels, the solid blue line corresponds to the baseline calibrated model and the dashed pink line corresponds to the case of a 5 p.p. tax cut. See Section 5.3 for further discussion.

Appendix A. Model Appendix

A.1. Derivation of optimal firm policies and cash flows

Plugging in $h^*_{i,t}$ from Eq. (7) into the profit function in Eq. (5) and collecting terms gives

$$\pi_{i,t} = \max_{k_{i,t},\ell_{i,t}} \begin{cases} (1-\tau_0)p_t y_{i,t} - (1-\bar{\tau})(\delta k_{i,t} + \omega \ell_{i,t}) - r k_{i,t} - c_f & \text{if } z_{i,t} \leq z_l \\ (1-\gamma)\left(\frac{\gamma}{b}\right)^{\frac{\gamma}{1-\gamma}} (p_t y_{i,t})^{\frac{1}{1-\gamma}} - (1-\bar{\tau})(\delta k_{i,t} + \omega \ell_{i,t}) - r k_{i,t} + b h_0 - c_f & \text{if } z_l < z_{i,t} < z_h \\ (1-\tau_L)p_t y_{i,t} - (1-\bar{\tau})(\delta k_{i,t} + \omega \ell_{i,t}) - r k_{i,t} - b\bar{h} - c_f & \text{if } z_{i,t} \geq z_h. \end{cases} \tag{A-1}$$

Taking first order conditions with respect to capital and labor for each region yields the optimal input choices in terms of $z_{i,t}$:

$$k^*_{i,t} = \begin{cases} \left[\left(\frac{\alpha}{r+\delta(1-\bar{\tau})}\right)^{1-\beta} \left(\frac{\beta}{\omega(1-\bar{\tau})}\right)^{\beta} (1-\tau_0)p_t z_{i,t}\right]^{\frac{1}{1-\alpha-\beta}} & \text{if } z_{i,t} \leq z_l \\ \left[\left(\frac{\alpha}{r+\delta(1-\bar{\tau})}\right)^{1-\beta-\gamma} \left(\frac{\beta}{\omega(1-\bar{\tau})}\right)^{\beta} \left(\frac{\gamma}{b}\right)^{\gamma} p_t z_{i,t}\right]^{\frac{1}{1-\alpha-\beta-\gamma}} & \text{if } z_l < z_{i,t} < z_h \\ \left[\left(\frac{\alpha}{r+\delta(1-\bar{\tau})}\right)^{1-\beta} \left(\frac{\beta}{\omega(1-\bar{\tau})}\right)^{\beta} (1-\tau_L)p_t z_{i,t}\right]^{\frac{1}{1-\alpha-\beta}} & \text{if } z_{i,t} \geq z_h \end{cases} \tag{A-2}$$

$$\ell^*_{i,t} = \begin{cases} \left[\left(\frac{\alpha}{r+\delta(1-\bar{\tau})}\right)^{\alpha} \left(\frac{\beta}{\omega(1-\bar{\tau})}\right)^{1-\alpha} (1-\tau_0)p_t z_{i,t}\right]^{\frac{1}{1-\alpha-\beta}} & \text{if } z_{i,t} \leq z_l \\ \left[\left(\frac{\alpha}{r+\delta(1-\bar{\tau})}\right)^{\alpha} \left(\frac{\beta}{\omega(1-\bar{\tau})}\right)^{1-\alpha-\gamma} \left(\frac{\gamma}{b}\right)^{\gamma} p_t z_{i,t}\right]^{\frac{1}{1-\alpha-\beta-\gamma}} & \text{if } z_l < z_{i,t} < z_h \\ \left[\left(\frac{\alpha}{r+\delta(1-\bar{\tau})}\right)^{\alpha} \left(\frac{\beta}{\omega(1-\bar{\tau})}\right)^{1-\alpha} (1-\tau_L)p_t z_{i,t}\right]^{\frac{1}{1-\alpha-\beta}} & \text{if } z_{i,t} \geq z_h. \end{cases} \tag{A-3}$$

Optimal revenue $p_t y^*_{i,t}$ is then given by the following expression:

$$p_t y^*_{i,t} = \begin{cases} \left[\left(\frac{\alpha}{r+\delta(1-\bar{\tau})}\right)^{\alpha} \left(\frac{\beta}{\omega(1-\bar{\tau})}\right)^{\beta} (1-\tau_0)^{\alpha+\beta} \quad p_t z_{i,t}\right]^{\frac{1}{1-\alpha-\beta}} & \text{if } z_{i,t} \leq z_l \\ \left[\left(\frac{\alpha}{r+\delta(1-\bar{\tau})}\right)^{\alpha(1-\gamma)} \left(\frac{\beta}{\omega(1-\bar{\tau})}\right)^{\beta(1-\gamma)} \left(\frac{\gamma}{b}\right)^{\gamma(\alpha+\beta)} \quad (p_t z_{i,t})^{1-\gamma}\right]^{\frac{1}{1-\alpha-\beta-\gamma}} & \text{if } z_l < z_{i,t} < z_h \\ \left[\left(\frac{\alpha}{r+\delta(1-\bar{\tau})}\right)^{\alpha} \left(\frac{\beta}{\omega(1-\bar{\tau})}\right)^{\beta} (1-\tau_L)^{\alpha+\beta} \quad p_t z_{i,t}\right]^{\frac{1}{1-\alpha-\beta}} & \text{if } z_{i,t} \geq z_h. \end{cases} \tag{A-4}$$

This in turn gives the optimal spending on tax reduction:

$$h^*_{i,t} = \begin{cases} 0 & \text{if } z_{i,t} \leq z_l \\ \left[\left(\frac{\alpha}{r+\delta(1-\bar{\tau})}\right)^{\alpha} \left(\frac{\beta}{\omega(1-\bar{\tau})}\right)^{\beta} \left(\frac{\gamma}{b}\right)^{1-\alpha-\beta} p_t z_{i,t}\right]^{\frac{1}{1-\alpha-\beta-\gamma}} - h_0 & \text{if } z_l < z_{i,t} < z_h \\ \bar{h} & \text{if } z_{i,t} \geq z_h \end{cases} \tag{A-5}$$

and the optimal tax rates:

$$\tau^*_{i,t} = \begin{cases} \tau_0 & \text{if } z_{i,t} \leq z_l \\ 1 - \left[\left(\frac{\alpha}{r+\delta(1-\bar{\tau})}\right)^{\alpha} \left(\frac{\beta}{\omega(1-\bar{\tau})}\right)^{\beta} \left(\frac{\gamma}{b}\right)^{1-\alpha-\beta} p_t z_{i,t}\right]^{\frac{\gamma}{1-\alpha-\beta-\gamma}} & \text{if } z_l < z_{i,t} < z_h \\ \tau_L & \text{if } z_{i,t} \geq z_h. \end{cases} \tag{A-6}$$

Finally, the profit function for the firm at the optimal choice of tax reduction, capital, and labor is

$$\pi^*_{i,t} = \begin{cases} (1-\alpha-\beta) \left[\left(\frac{\alpha}{r+\delta(1-\bar{\tau})}\right)^{\alpha} \left(\frac{\beta}{\omega(1-\bar{\tau})}\right)^{\beta} (1-\tau_0) p_t z_{i,t}\right]^{\frac{1}{1-\alpha-\beta}} - c_f & \text{if } z_{i,t} \leq z_l \\ (1-\alpha-\beta-\gamma) \left[\left(\frac{\alpha}{r+\delta(1-\bar{\tau})}\right)^{\alpha} \left(\frac{\beta}{\omega(1-\bar{\tau})}\right)^{\beta} \left(\frac{\gamma}{b}\right)^{\gamma} \quad p_t z_{i,t}\right]^{\frac{1}{1-\alpha-\beta-\gamma}} + b h_0 - c_f & \text{if } z_l < z_{i,t} < z_h \\ (1-\alpha-\beta) \left[\left(\frac{\alpha}{r+\delta(1-\bar{\tau})}\right)^{\alpha} \left(\frac{\beta}{\omega(1-\bar{\tau})}\right)^{\beta} (1-\tau_L) p_t z_{i,t}\right]^{\frac{1}{1-\alpha-\beta}} - b\bar{h} - c_f & \text{if } z_{i,t} \geq z_h \end{cases} \tag{A-7}$$

We can solve for z_l, the highest $z_{i,t}$ at which the firm optimally chooses $h_{i,t} = 0$, by setting the middle expression for $h^*_{i,t}$ in Eq. (A-5) equal to zero and solving for $z_{i,t}$. This yields

$$z_l = \frac{1}{p_t}\left(\frac{\alpha}{r+\delta(1-\bar{\tau})}\right)^{-\alpha}\left(\frac{\beta}{\omega(1-\bar{\tau})}\right)^{-\beta}\left(\frac{\gamma}{b}\right)^{-(1-\alpha-\beta)} h_0^{1-\alpha-\beta-\gamma} \tag{A-8}$$

$$= \frac{1}{p_t}\left(\frac{\alpha}{r+\delta(1-\bar{\tau})}\right)^{-\alpha}\left(\frac{\beta}{\omega(1-\bar{\tau})}\right)^{-\beta}\left(\frac{\gamma}{b}\right)^{-(1-\alpha-\beta)} (1-\tau_0)^{\frac{1-\alpha-\beta-\gamma}{\gamma}} \tag{A-9}$$

Similarly, we can solve for z_h, the lowest $z_{i,t}$ at which the firm optimally chooses $h_{i,t} = \bar{h}$, by setting the same expression equal to $\bar{h}$ and solving for $z_{i,t}$. This gives

$$z_h = \frac{1}{p_t}\left(\frac{\alpha}{r+\delta(1-\bar{\tau})}\right)^{-\alpha}\left(\frac{\beta}{\omega(1-\bar{\tau})}\right)^{-\beta}\left(\frac{\gamma}{b}\right)^{-(1-\alpha-\beta)} (\bar{h}+h_0)^{1-\alpha-\beta-\gamma} \tag{A-10}$$

$$= \frac{1}{p_t}\left(\frac{\alpha}{r+\delta(1-\bar{\tau})}\right)^{-\alpha}\left(\frac{\beta}{\omega(1-\bar{\tau})}\right)^{-\beta}\left(\frac{\gamma}{b}\right)^{-(1-\alpha-\beta)} (1-\tau_L)^{\frac{1-\alpha-\beta-\gamma}{\gamma}} \tag{A-11}$$

A.2. Firm valuation (Proof of Proposition 1)

Define $\eta = 1-\alpha-\beta$ and

$$A_1 = \eta\left[\left(\frac{\alpha}{r+\delta(1-\bar{\tau})}\right)^{\alpha}\left(\frac{\beta}{\omega(1-\bar{\tau})}\right)^{\beta}(1-\tau_0)p_t\right]^{\frac{1}{\eta}} \tag{A-12}$$

$$A_2 = (\eta-\gamma)\left[\left(\frac{\alpha}{r+\delta(1-\bar{\tau})}\right)^{\alpha}\left(\frac{\beta}{\omega(1-\bar{\tau})}\right)^{\beta}\left(\frac{\gamma}{b}\right)^{\gamma}p_t\right]^{\frac{1}{\eta-\gamma}} \tag{A-13}$$

$$A_3 = \eta\left[\left(\frac{\alpha}{r+\delta(1-\bar{\tau})}\right)^{\alpha}\left(\frac{\beta}{\omega(1-\bar{\tau})}\right)^{\beta}(1-\tau_L)p_t\right]^{\frac{1}{\eta}} \tag{A-14}$$

Then we can write the cash flows, $\pi(z;p)$ as

$$\pi(z;p) = \begin{cases} A_1 z^{1/\eta} - c_f & \text{if } z_{i,t} \le z_l \\ A_2 z^{\frac{1}{\eta-\gamma}} + bh_0 - c_f & \text{if } z_l < z_{i,t} < z_h \\ A_3 z^{1/\eta} - b\bar{h} - c_f & \text{if } z_{i,t} \ge z_h \end{cases} \tag{A-15}$$

Firm value is given by

$$v(z;p) = \sup_{\{k_t,\ell_t,h_t\}_{t\ge 0},T_D} \int_0^{T_D} e^{-(r+\lambda)t}\pi(z_t;p)dt. \tag{A-16}$$

The firm's optimal stopping time can be expressed as a threshold, z_D, such that the firm exits when its productivity $z = z_D$. Given this endogenous exit threshold, we divide the productivity space into three regions: $(z_D, z_L], (z_L, z_H], (z_H, \infty)$.

Region 1: $z_D < z \leq z_L$

Define $\eta = 1 - \alpha - \beta$. The value of the firm in this region satisfies the ordinary differential equation (ODE):

$$(r+\lambda)v(z;p) = \mu z v_z(z;p) + \frac{\sigma^2}{2} z^2 v_{zz}(z;p) + A_1 z^{1/\eta} - c_f \tag{A-17}$$

The solution in this region takes the form

$$v(z;p) = B_1 z^{\xi_1} + B_2 z^{\xi_2} + \frac{A_1 z^{1/\eta}}{r + \lambda - \frac{\mu}{\eta} - \frac{\sigma^2}{2}(1/\eta)(1/\eta - 1)} - \frac{c_f}{r+\lambda}, \tag{A-18}$$

where ξ_1, ξ_2 are the roots of the fundamental quadratic, given by

$$\xi_1 = \frac{1}{2} - \frac{\mu}{\sigma^2} + \sqrt{\left(\frac{\mu}{\sigma^2} - \frac{1}{2}\right)^2 + \frac{2(r+\lambda)}{\sigma^2}}, \quad \xi_2 = \frac{1}{2} - \frac{\mu}{\sigma^2} - \sqrt{\left(\frac{\mu}{\sigma^2} - \frac{1}{2}\right)^2 + \frac{2(r+\lambda)}{\sigma^2}}, \tag{A-19}$$

with $\xi_1 > 1$ and $\xi_2 < 0$. The coefficients B_1 and B_2 are determined by solving the boundary conditions, which are shown below.

Region 2: $z_L < z < z_H$

The value of the firm in this region satisfies the ODE:

$$(r+\lambda)v(z;p) = \mu z v_z(z;p) + \frac{\sigma^2}{2} z^2 v_{zz}(z;p) + A_2 z^{\frac{1}{\eta-\gamma}} + bh_0 - c_f \tag{A-20}$$

The solution in this region takes the form

$$v(z;p) = C_1 z^{\xi_1} + C_2 z^{\xi_2} + \frac{A_2 z^{\frac{1}{\eta-\gamma}}}{r + \lambda - \frac{\mu}{\eta-\gamma} - \frac{\sigma^2}{2}(\frac{1}{\eta-\gamma})(\frac{1}{\eta-\gamma} - 1)} + \frac{bh_0 - c_f}{r+\lambda} \tag{A-21}$$

where C_1 and C_2 are determined by the boundary conditions given below.

Region 3: $z_H \leq z < \infty$

The value of the firm in this region satisfies the ODE:

$$(r+\lambda)v(z;p) = \mu z v_z(z;p) + \frac{\sigma^2}{2} z^2 v_{zz}(z;p) + A_3 z^{1/\eta} - b\bar{h} - c_f \tag{A-22}$$

The solution in this region takes the form

$$v(z;p) = D_1 z^{\xi_1} + D_2 z^{\xi_2} + \frac{A_3 z^{\frac{1}{\eta}}}{r + \lambda - \frac{\mu}{\eta} - \frac{\sigma^2}{2}(1/\eta)(1/\eta - 1)} - \frac{b\bar{h} + c_f}{r + \lambda}, \tag{A-23}$$

where again the coefficients D_1 and D_2 are determined by the boundary conditions.

We need to solve for the coefficients $B_1, B_2, C_1, C_2, D_1, D_2$ and the optimal exit threshold z_D. First, note that to ensure that firm value is finite, we require that $D_1 = 0$. The five remaining coefficients and the optimal exit threshold solve the following system of equations:

$$v(z_D;p) = 0 \tag{A-24}$$

$$\frac{\partial v(z_D;p)}{\partial z} = 0 \tag{A-25}$$

$$\lim_{z \uparrow z_L} v(z;p) = \lim_{z \downarrow z_L} v(z;p) \tag{A-26}$$

$$\lim_{z \uparrow z_L} \frac{\partial v(z;p)}{\partial z} = \lim_{z \downarrow z_L} \frac{\partial v(z;p)}{\partial z} \tag{A-27}$$

$$\lim_{z \uparrow z_H} v(z;p) = \lim_{z \downarrow z_H} v(z;p) \tag{A-28}$$

$$\lim_{z \uparrow z_H} \frac{\partial v(z;p)}{\partial z} = \lim_{z \downarrow z_H} \frac{\partial v(z;p)}{\partial z} \tag{A-29}$$

The first pair of equations are the value-matching and smooth-pasting conditions, respectively, for the optimal exit threshold z_D. These reflect our assumption that firms have zero recovery at exit. The four remaining equations impose that the firm value is continuously differentiable at z_L and z_H.

A.3. Firm distribution (Proof of Proposition 2)

Firms optimally choose to exit when their productivity falls to the level z_D, which implies the stationary distribution of firms has support on $[z_D, \infty)$. The stationary distribution of firms satisfies the Kolmogorov forward equation

$$-\frac{\partial}{\partial z}\left[\mu z \phi(z)\right] + \frac{\partial^2}{\partial z^2}\left[\frac{1}{2}\sigma^2 z^2 \phi(z)\right] - \lambda \phi(z) = 0, \tag{A-30}$$

for all $z \neq z_0$. At z_0, new firms enter. We solve the Kolmogorov forward equation separate over two regions: $[z_D, z_0)$ and (z_0, ∞). The ODE can be rewritten as

$$\frac{1}{2}\sigma^2 x^2 \phi''(z) - (\mu - 2\sigma^2)x\phi'(x) - (\mu - \sigma^2 + \lambda)\phi(x) = 0. \tag{A-31}$$

This ODE has a general solution

$$\phi(x) = \begin{cases} H_1 z^{\zeta_1 - 1} + H_2 z^{\zeta_2 - 1} & \text{if } z_D < z < z_0 \\ J_2 z^{\zeta_2 - 1} & \text{if } z > z_0 \end{cases} \tag{A-32}$$