

# Resource Misallocation and Aggregate Productivity under Progressive Taxation\*

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## Abstract

This paper quantitatively examines the long-run macroeconomic effects of resource misallocation in an otherwise standard one-sector neoclassical growth model with heterogeneous firms being subject to progressive taxation as well as endogenous entry and exit decisions. Under a progressive fiscal policy rule, capital and labor inputs move from more productive firms to less productive establishments as the latter face a lower or negative tax rate. We find that since low-productivity firms use an inefficiently high level of productive resources when there are no entry and exit decisions, the overall production and aggregate productivity will fall as the tax progressivity rises. By contrast, more progressive taxation may raise the economy's total output and aggregate productivity when endogenous entry and exit decisions are allowed and the household's labor supply is postulated to be fixed. Our analysis therefore shows that the quantitative implications of progressive taxation are sensitive to the variability of hours worked and the presence of entry regulations.

*Keywords:* Resource Misallocation, Aggregate Productivity, Progressive Taxation, Idiosyncratic Distortions.

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# 1 Introduction

There has been a growing literature that explores the effects of resource misallocation on a macroeconomy's output and measured total factor productivity (TFP).<sup>1</sup> Moreover, several recent studies have found that varying entry costs may help explain the substantial cross-country income differences.<sup>2</sup> In the context of a dynamic general equilibrium model with heterogeneous firms, aggregate TFP depends not only on the productivity level of each individual establishment, but also on how productive factors are allocated across these production units. As a result, government policies that distort the relative prices faced by heterogeneous firms will influence the resource allocations and thus generate considerable effects on aggregate economic activity. These policies also affect the expected value of incumbent firms, which in turn will impact the entry decision of potential entrants, as well as the total number of firms in operation and the resulting overall output. Motivated by this strand of previous research, our paper quantitatively examines the long-run effects of resource misallocation on the economy's aggregate variables within a standard one-sector neoclassical growth model in which output is carried out by heterogeneous firms subject to a progressive tax policy *à la* Guo and Lansing (1998) together with endogenous entry and exit decisions.

Given the progressive fiscal policy rule under consideration, below-average productive firms are subsidized whereas above-average counterparts will be taxed. Our nonlinear tax formulation therefore affects macroeconomic aggregates through the channels of both intensive and extensive margins. On the one hand, capital and labor inputs will move from more productive firms to less productive and subsidized establishments. When the tax progressivity rises, resource misallocation exacerbates the overall production as low-productivity firms use an inefficiently high level of productive resources – this is the adjustment along the intensive margin. On the other hand, since firms may freely enter the market upon the payment of an entry cost, progressive taxation that subsidizes below-average productive establishments will increase the expected value of an incumbent firm. This encourages more potential entrants to enter the market, which in turn raises aggregate production – this is the adjustment along the extensive margin.

For the quantitative analyses, we first calibrate firm-level productivities in the model economy to be consistent with the U.S. size distribution of employment across establishments, as in Restuccia and Rogerson (2008); and then postulate the benchmark specification to feature variable labor

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<sup>1</sup>See, for example, Hopenhayn and Rogerson (1993), Lagos (2006), Restuccia and Rogerson (2008), Guner, Ventura and Xu (2008), Hsieh and Klenow (2009), Buera, Kaboski and Shin (2011), Caselli and Gennaioli (2013), and Buera and Shin (2013), among others.

<sup>2</sup>See, for example, Barseghyan (2008), Barseghyan and DiCecio (2011), and Boedo and Mukoyama (2012), among others.

supply together with endogenous entry and exit decisions. We focus on the model's stationary competitive equilibrium and analyze the macroeconomic impacts of changes in the level of tax progressivity. Relative to the "no tax distortion" case, our benchmark model exhibit substantial increases in the numbers of entrants as well as incumbents, ranging from 29 to 91 percent, when the fiscal policy rule becomes more progressive. By contrast, there are significant decreases in both labor (by 11 to 18 percent) and capital (by 26 to 51 percent) inputs, hence total output falls by 14 to 27 percent. This result implies that adjustment effects from the intensive margin due to resource misallocation dominate those along the extensive margin which yield an increase in the total number of producing firms. However, we find that the corresponding Solow residual remains virtually unchanged as the tax progressivity rises, indicating that the above-mentioned positive versus negative effects almost cancel each other out on the economy's aggregate TFP.

To obtain further insights about the proceeding results, we consider an alternative formulation in which adjustments coming only from the intensive margin with the household's hours worked being endogenously determined, while setting the number of firms in operation to be the same as that in the benchmark model under no tax distortion. In this case, an increase in the tax progressivity generates a further leftward shift of the labor demand curve, which leads to relatively larger reductions in equilibrium labor hours and real wage, as well as in capital service and aggregate production (by 31 to 54 percent). Since the total number of firms is postulated to be time invariant, this specification's measured TFP will fall (by 20 to 36 percent) in that productive resources are misallocated across establishments.

Next, we weaken the adjustment mechanism along the intensive margin by postulating the household's labor hours to be a constant. Under the presence of endogenous entry and exit decisions, more progressive taxation generates smaller decreases in capital (by 17.5 to 39 percent) and output (by 3.9 to 11.3 percent) than those in our benchmark model without tax distortions. In addition, the total numbers of new entrants and operating incumbents both increase substantially, ranging from 43 to 133 percent, as the degree of tax progressivity rises. We also find that the measured aggregate TFP becomes higher (by 1 to 3 percent) because of the stronger (positive) effect from the extensive margin. Finally, for the specification with fixed labor supply and no endogenous entry/exit decisions, decreases in the economy's steady-state levels of capital input and total output are lower compared to those in the benchmark model; and the resulting aggregate TFP will fall as well since adjustments along the extensive margin are now completely shut down.

This paper is closely related to Restuccia and Rogerson (2008) who also quantitatively investigate the effects of firm-level distortions on aggregate production and productivity. Our analyses

differ from theirs in three aspects. First, we allow the household’s labor supply decision to be endogenous, which turns out to exert a significant impact on the adjustment strength along the intensive margin. Second, we consider the firm-level distortions with a progressive feature that is commonly observed in industrialized countries. As a result, the fraction of taxed over subsidized firms is endogenously determined in our model. Finally, we take into account the dynamic changes of factor prices and their corresponding general equilibrium effects as the tax progressivity changes, whereas Restuccia and Rogerson’s study focuses on the case in which the relative prices remain unchanged.<sup>3</sup>

The remainder of the paper is organized as follows. Section 2 describes our benchmark model in which production is carried out by heterogeneous firms, and the household’s labor supply as well as firms’ entry and exit decisions are endogenously determined. We then derive the optimal conditions that characterize the economy’s stationary equilibrium prices and allocations. Section 3 quantitatively compares and contrasts the model’s steady states under alternative specifications. Section 4 concludes.

## 2 The Economy

We examine a one-sector dynamic general equilibrium model that builds upon the work of Hopenhayn (1992) and Hopenhayn and Rogerson (1993) with two important departures: (i) introduction of progressive taxation on incumbent firms’ output, and (ii) abstraction of establishment-level productivity dynamics, as in Restuccia and Rogerson (2008), such that each operating firm’s productivity remains constant over time. Our model economy consist of a representative household, heterogeneous firms with different levels of total factor productivity (TFP) and the government. Households live forever, and derive utilities from consumption and leisure. Establishment firms produce the unique consumption good with a decreasing returns-to-scale technology that is subject to a progressive fiscal policy rule whereby more productive firms face a relatively higher tax rate. The government balances its budget each period by returning all its tax revenue to the representative household as a lump-sum transfer.

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<sup>3</sup>Restuccia and Rogerson (2008) consider various combinations of idiosyncratic distortions that do not affect the steady-state level of aggregate capital stock. Since labor supply is fixed in their setting, this is equivalent to setting equilibrium prices constant.

## 2.1 Households

The economy is populated by a unit measure of identical infinitely-lived households. Each household is endowed with one unit of time and maximizes its present discounted lifetime utility

$$\max_{\{C_t, N_t, K_{t+1}\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \beta^t U(C_t, N_t), \quad 0 < N_t < 1, \quad (1)$$

where  $E_0(\cdot)$  is the conditional expectation operator,  $\beta \in (0, 1)$  is the discount factor,  $C_t$  is consumption at date  $t$ , and  $N_t$  is the labor hours supplied to the market. The budget constraint faced by the representative household is given by

$$C_t + K_{t+1} - (1 - \delta)K_t + T_t = r_t K_t + w_t N_t + \Pi_t, \quad K_0 > 0 \text{ given}, \quad (2)$$

where  $K_t$  is capital stock,  $\delta \in (0, 1)$  is the capital depreciation rate,  $r_t$  is the capital rental rate,  $w_t$  is the real wage,  $\Pi_t$  represents total profits from the household's ownership of all operating firms, and  $T_t$  is a lump-sum transfer payment made by the government. The first-order conditions for the household's dynamic optimization problem are

$$-\frac{U_N(C_t, N_t)}{U_C(C_t, N_t)} = w_t, \quad (3)$$

$$U_C(C_t, N_t) = \beta E_t \{U_C(C_{t+1}, N_{t+1})[1 - \delta + r_{t+1}]\}, \quad (4)$$

$$\lim_{t \rightarrow \infty} \beta^t U_C(C_t, N_t) K_{t+1} = 0, \quad (5)$$

where  $U_C(\cdot) > 0$  is the marginal utility of consumption and  $U_N(\cdot) < 0$  is the marginal disutility of hours worked. In addition, (3) equates the slope of the household's indifference curve to the real wage rate, (4) is the standard Euler equation for intertemporal consumption choices, and equation (5) is the transversality condition.

## 2.2 Firms

There are two types of firms in the economy: operating incumbents and potential entrants. Upon payment of a fixed entrance cost  $c_e > 0$ , a potential entrant will become an establishment firm  $i$  with access to the following Cobb-Douglas production function that exhibits decreasing return-to-scale:

$$y_{it} = s_i k_{it}^{\alpha} n_{it}^{\gamma}, \quad 0 < \alpha, \gamma < 1 \quad \text{and} \quad \alpha + \gamma < 1, \quad (6)$$

where  $k_{it}$  and  $n_{it}$  are the capital and labor inputs, respectively, and  $s_i$  represents the firm-level total factor productivity that is randomly drawn from an exogenously specified distribution. Since our objective is to analyze the cross-sectoral heterogeneity among incumbent firms, we follow Restuccia and Rogerson (2008) and postulate that the value of  $s_i$  is constant over time for a given establishment.

### 2.2.1 Incumbent Firms

The optimal decision of an establishment firm  $i$  is hiring capital and labor services to maximize its current profit<sup>4</sup>

$$\max \pi_{it}(s_i) = (1 - \tau_{it})y_{it} - w_t n_{it} - r_t k_{it} - c_f, \quad (7)$$

where  $\tau_{it}$  the output tax/subsidy rate,  $y_{it}$  is given by (6) and  $c_f > 0$  is the real quantity of operational costs needed to remain in existence. Similar to Guo and Lansing (1998), we postulate that  $\tau_{it}$  takes the functional form

$$\tau_{it} = 1 - \left(\frac{\bar{y}_t}{y_{it}}\right)^\phi, \quad \phi \geq 0, \quad (8)$$

where  $\bar{y}_t$  is the average level of output produced by all establishments at period  $t$ , and the parameter  $\phi$  governs the “slope” of the tax schedule. Using (8), we obtain the expression for the marginal tax rate  $\tau_{it}^m$ , which is defined as the change in taxes paid by an incumbent firm divided by the change in its output level, as follows:

$$\tau_{it}^m \equiv \frac{\partial(\tau_{it}y_{it})}{\partial y_{it}} = 1 - (1 - \phi) \left(\frac{\bar{y}_t}{y_{it}}\right)^\phi. \quad (9)$$

It is then immediately clear that when  $\phi$  is positive, the marginal tax rate (9) is higher than the average tax rate given by (8). In this case, the tax schedule is said to be “progressive”, which is an empirically realistic feature in U.S. and many industrialized countries. Moreover, establishments with output higher (lower) than  $\bar{y}_t$  will face a positive (negative) tax rate when  $\phi > 0$ . It follows that in contrast to Restuccia and Rogerson (2008), the fractions of incumbent firms being taxed or subsidized in our model economy are endogenously determined. As the baseline case for comparisons in the subsequent quantitative analyses, we also consider the “no tax distortion” specification with  $\phi = 0$ . Therefore, the parametric constraint of  $\phi \geq 0$  is imposed in (8).

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<sup>4</sup>Since an establishment firm’s productivity  $s_i$  remains unchanged over time, the decision to maximize its current profit is equivalent to maximizing its life-time profits.

Establishments are postulated to take into account the way in which the tax schedule affects their production levels when they decide the amount of capital and labor inputs to employ. Consequently, it is the marginal tax rate that governs an incumbent firm's economic decisions. Under the assumption that factor markets are perfectly competitive, the optimal decisions for establishment  $i$ 's choices of capital  $\hat{k}_{it}$  and labor  $\hat{n}_{it}$  are

$$\hat{k}_{it}(s_i) = \left[ \left( \frac{\alpha}{r_t} \right)^{1-\gamma(1-\phi)} \left( \frac{\gamma}{w_t} \right)^{\gamma(1-\phi)} (1-\phi) s_i^{1-\phi} \bar{y}_t^\phi \right]^{\frac{1}{1-(\alpha+\gamma)(1-\phi)}}, \quad (10)$$

$$\hat{n}_{it}(s_i) = \frac{\gamma}{\alpha} \frac{r_t}{w_t} \hat{k}_{it}(s_i). \quad (11)$$

Finally, we assume that all incumbents face the same constant probability of exit  $\lambda \in (0, 1)$  each period. It follows that the discounted life-time value of an establishment firm  $i$  can be expressed as

$$W_{it}(s_i) = \pi_{it}(s_i) + \frac{1-\lambda}{1+R} W_{it+1}(s_i), \quad (12)$$

where  $\pi_{it}(s_i)$  is given by (7) and  $R \left( = \frac{1}{\beta} - 1 \right)$  is the real interest rate.

### 2.2.2 Entering Firms

A potential entrant makes its entry decision based on the comparison of the entrance cost  $c_e$  versus the expected post-entry value after becoming an incumbent firm with the randomly-drawn total factor productivity  $s_i$ . As a result, the present discounted value of a potential entrant  $W_{et}$  is

$$W_{et} = -c_e + \int \max_{\bar{\chi}_t \in \{0,1\}} \{ \bar{\chi}_t(s_i) W_{it}(s_i) h(s_i) ds_i \}, \quad (13)$$

where  $W_{it}(s_i)$  is given by (12),  $h(s_i)$  is the probability density function of  $s_i$ , and  $\bar{\chi}(s_i)$  denotes the optimal decision rule for an entering firm about whether to engage in production or not. Specifically,  $\bar{\chi}_t(s_i) = 1$  means that establishment  $i$  enters the market at period  $t$  and remains in operation. Firms will continue to enter as long as  $W_{et}$  is strictly positive, which in turn implies that the free-entry condition  $W_{et} = 0$  will hold in equilibrium.

Using  $\mu_t(s_i)$  to denote the distribution of incumbent firms over establishment-level productivity  $s_i$  in the current period, it is straightforward to derive the law of motion of producing firms as

$$\mu_{t+1}(s_i) = (1-\lambda)\mu_t(s_i) + \bar{\chi}_t(s_i)h(s_i)E_t. \quad (14)$$

where  $E_t$  is the mass of potential entrants at period  $t$ .

## 2.3 Government

The government is postulated to balance its budget every period. Since a given distribution of establishment-level taxes and subsidies do not necessarily lead to a balanced budget, we assume that the government either levies lump-sum transfers or taxation  $T_t$  on the representative household. Hence, its period budget constraint is given by

$$T_t + \int \tau_{it}(s_i) \hat{y}_{it}(s_i) \mu_t(s_i) ds_i = 0, \quad (15)$$

where  $\hat{y}_{it}(s_i)$  is the optimal level of output that establishment  $i$  produces with  $\hat{k}_{it}(s_i)$  and  $\hat{n}_{it}(s_i)$  *a la* (10)-(11) as factor inputs.

## 2.4 Market Clearing

The equalities of demand by establishment firms and supply by households in the capital and labor markets are

$$K_t = \int \hat{k}_{it}(s_i) \mu_t(s_i) ds_i, \quad (16)$$

$$N_t = \int \hat{n}_{it}(s_i) \mu_t(s_i) ds_i. \quad (17)$$

Next, the economy's total output  $Y_t$  is defined as

$$Y_t = \int \hat{y}_{it}(s_i) \mu_t(s_i) ds_i, \quad (18)$$

and the aggregate resource constraint is given by

$$C_t + X_t + c_e E_t + c_f M_t = Y_t, \quad (19)$$

where  $M_t$  is the mass of producing firms, and  $X_t$  is gross investment that is governed by the following aggregate law of motion for capital stock:

$$K_{t+1} = (1 - \delta)K_t + X_t. \quad (20)$$

## 2.5 Stationary Equilibrium

As in Restuccia and Rogerson (2008), our analysis is focused on the model's stationary competitive equilibrium with a time-invariant distribution of productivity levels across different incumbent



firms. Variables without time subscripts are used to denote their steady-state values. Per the consumption Euler equation (4), the steady-state rental rate for capital services is

$$r = \frac{1}{\beta} - (1 - \delta) = R + \delta, \quad (21)$$

where  $R$  represents the real interest rate (see equation 12). Given the consumption Euler equation (4), the zero-profit equilibrium condition for entrants  $W_e = 0$  will determine the corresponding real wage rate  $w$ . From the law of motion (14), the resulting invariant distribution for the producing establishments is given by

$$\mu(s) = \frac{1}{\lambda} \bar{\chi}(s) h(s) E. \quad (22)$$

Substituting (22) into the stationary equilibrium version of the labor-market clearing condition (17) yields

$$E = \frac{\lambda N}{\int \hat{n}(s) \bar{\chi}(s) h(s) ds}, \quad (23)$$

where  $N$  is the steady-state level of aggregate labor supply. Since the establishment-level productivity is constant over time, the discounted present value of an incumbent producer at the stationary equilibrium is

$$W(s) = \frac{\pi(s)}{1 - \rho}, \quad (24)$$

where  $\rho = \frac{1-\lambda}{1+R}$  is the effective discount rate for establishments. Finally, the steady-state level of aggregate consumption is given by

$$C = Y - c_f M - \delta K - c_e E. \quad (25)$$

### 3 Quantitative Results

This section quantitatively examines the long-run macroeconomic effects of fiscal policy distortions in our model economy under parameter values that are consistent with post Korean-war U.S. time series data. As is commonly adopted in the real business cycle literature, the household's period utility function is given by

$$U(C_t, N_t) = \log C_t - \psi N_t, \quad \psi > 0, \quad (26)$$

where the linearity in hours worked draws on the formulation of indivisible labor *à la* Hansen (1985) and Rogerson (1988). With the exception of the tax progressivity parameter  $\phi$ , we take

on Restuccia and Rogerson’s (2008, Table 1) baseline calibration. Specifically, each period in the model is taken to be one year with the discount factor  $\beta$  set to be 0.96; the capital depreciation rate  $\delta$  fixed at 0.08; and the exit probability  $\lambda$  chosen to be 0.1. In addition, the degree of decreasing return-to-scale in the production function (6) is equal to 0.85, which is divided according to the observed national income shares of capital ( $\alpha = 0.283$ ) and labor ( $\gamma = 0.567$ ). We also set the establishment’s operational cost  $c_f = 0$ , and normalize the entrance-cost parameter  $c_e = 1$ . Finally, we reproduce Restuccia and Rogerson’s Figure 1 to approximate the probability density function  $h(\cdot)$  over firm-level productivities  $s_i \in [1, 3.98]$  such that the resulting invariant distribution for the number of employees at the establishment level matches with the U.S. data.

Our analyses begin with the benchmark specification, described in section 2, that exhibits variable labor supply coupled with endogenous entry and exit decisions. We obtain the stationary equilibrium under “no tax distortion” with  $\phi = 0$  as the basis for all subsequent comparisons, and then consider positive levels of tax progressivity by setting  $\phi = 0.1, 0.2$  and  $0.3$ . To explore how adjustments along the intensive and extensive margins respectively affect the macroeconomy, we also examine alternative formulations with fixed labor supply and/or no endogenous entry and exit decisions.

### 3.1 Variable Labor Supply with Endogenous Entry and Exit

Table 1 summarizes the steady-state effects of progressive taxation within our benchmark model. Its second column presents the stationary equilibrium levels of macroeconomic aggregates when there is no fiscal distortion ( $\phi = 0$ )<sup>5</sup>; and columns 3-5 report the resulting percentage changes, relative to the undistorted counterpart, as the degree of tax progressivity increases. We find that the economy’s total output, consumption, capital stock, labor hours, and real wage all fall under progressive taxation. On the contrary, there are substantial increases in the numbers of entrants and incumbents, ranging between 29 and 91 percent, when  $\phi$  rises from 0.1 to 0.3. These equilibrium outcomes result from adjustments along both the intensive as well as the extensive margins.

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<sup>5</sup>The preference parameter  $\psi$  in (26) is set to be 2.4 such that the steady-state level of hours worked is equal to  $1/3$ .

Table 1. Benchmark Model: Variable Labor Supply with Endogenous Entry and Exit Decisions

$\phi$	0	0.1	0.2	0.3
Relative Y	1.12	-14%	-21%	-27%
Relative TFP	1.59	-0.2%	-0.4%	-0.5%
Relative E	0.12	29%	63%	91%
Relative M	1.24	29%	63%	91%
Relative w	1.90	-17%	-29%	-40%
Relative K	2.61	-26%	-39%	-51%
Relative N	0.33	-11%	-14%	-18%
Relative C	0.79	-17%	-29%	-40%

Note: We report the stationary equilibrium levels when  $\phi = 0$ , and all the remaining entries are in terms of percentage changes when  $\phi = 0.1, 0.2$  and  $0.3$  respectively.

To help understand the preceding quantitative results, Figure 1 plots the tax rates versus firms' productivity levels under different tax progressivities, whereby the horizontal axis corresponds to our distortion-free formulation. Notice that when  $\phi > 0$ , the tax rate increases as the productivity rises. In particular, below-average productive firms are subsidized whereas above-average counterparts are taxed. Under more progressive taxation, the levels of tax and subsidy rates, as well as the proportion of firms that are taxed, all become higher. For example, the fraction of taxed firms increases from 70% when  $\phi = 0.1$  to nearly 80% when  $\phi = 0.3$ .

In terms of adjustments along the intensive margin, we note from Figure 1 that more (less) productive firms face higher (lower) tax rates as the tax progressivity rises. This distorts the relative prices faced by heterogeneous establishments, which in turn leads to resource misallocation that reduces (raises) factor demands for more (less) productive firms. Figure 2 depicts firms' truncated labor demand with different productivity levels under various values of  $\phi$ <sup>6</sup>. It shows that employment will move from more to less productive firms when the fiscal policy rule becomes more progressive. This result can be understood as follows. Consistent with the U.S. data, incumbents with lower (higher) levels of productivity in our model account for a large (small) share in the total number of firms and a small (large) fraction of usage in productive services. It turns out that the decrease in labor demand from more productive firms quantitatively dominate the corresponding increase from less productive establishments. As a result, the economy's aggregate labor, and thus real wage, capital, output and consumption, all fall along the intensive margin.

<sup>6</sup>To visualize the changes in labor demand across different tax progressivities, we have truncated firms' productivity levels up to  $s_i = 2$ . Otherwise, the increase in labor demand would be hardly seen as the scale of the rise in labor demand is relatively small compared to the corresponding decrease.

Next, we examine adjustments along the extensive margin, as shown in Figure 3 with the mass distribution of firms under different values of  $\phi$ . When the tax schedule becomes more progressive, the mass distribution of establishments moves up, which implies that the equilibrium number of firms in operation is higher. Intuitively, our postulated fiscal policy that subsidizes below-average productive firms will raise the expected value of an incumbent firm as the tax progressivity rises. This in turn encourages more potential entrants to enter the market until the free entry condition  $W_{et} = 0$  is satisfied. As a result, the economy's total numbers of entrants and incumbents, as well as aggregate production, all increase along the extensive margin.

Overall, Table 1 shows that in response to a higher tax progressivity, the decreases in capital and labor services from the intensive margin due to resource misallocation dominate the opposite increases in factor demands from the extensive margin due to the expansion of producing firms. It follows that total output and consumption will fall. Table 1 also illustrates that the measured aggregate TFP, represented by the model's Solow residual, remains virtually unchanged when the tax scheme becomes more progressive. Generally speaking, the economy's aggregate productivity is affected by the total number of firms engaging in production as well as how productive factors are allocated across heterogeneous establishments. As it turns out, the negative impacts on the aggregate TFP due to resource misallocation is almost cancelled out by the positive effects from the increase in the total number of operating firms within our benchmark specification.

### 3.2 Variable Labor Supply without Endogenous Entry and Exit

For the sensitivity analyses, we first shut down the extensive margin by fixing the number of firms in operation the same as that in the steady state of our benchmark model without any fiscal distortion, *i.e.*  $M_t = 1.24$  for all  $t$ , while maintaining variable labor supply and a positive degree of tax progressivity. Therefore, there are no new entrants entering the market and all the adjustments will be made along the intensive margin. Table 2 reports the percentage changes in key macroeconomic aggregates, relative to the baseline distortion-free economy (Table 1, second column), when the tax schedule becomes more progressive and there is no endogenous entry and exit decision.

Table 2. Variable Labor Supply without Endogenous Entry and Exit Decisions

$\phi$	0.1	0.2	0.3
Relative Y	-31%	-44%	-54%
Relative TFP	-20%	-29%	-36%
Relative M	0%	0%	0%
Relative w	-18%	-31%	-43%
Relative K	-41%	-57%	-69%
Relative N	-28%	-37%	-45%
Relative C	-18%	-31%	-43%

Note: We report the percentage changes compared to those in the second column of Table 1 when  $\phi = 0$ .

Compared to the free-entry counterpart, an increase in the tax progressivity  $\phi$  yields a further leftward shift of the labor demand curve through the intensive-margin adjustments alone. It follows that the resulting reductions in the steady-state levels of employment and real wage, as well as in capital service and total output (by 31 to 54 percent), are relatively larger. In addition, since the number of producing firms is postulated to be a constant within this formulation, the measured aggregate TFP will fall (by 20 to 36 percent) in that productive resources are misallocated across establishments. These results imply that allowing firms to freely enter and exit the market can mitigate the negative impacts of idiosyncratic tax distortions imposed on them.

### 3.3 Fixed Labor Supply with Endogenous Entry and Exit

Next, we weaken the adjustment mechanism along the intensive margin by postulating the household's labor supply to be a fixed constant ( $= 1/3$ ), which is equal to the steady-state level of hours worked in our benchmark model without tax distortions. In this case, the labor market equilibrium condition is changed to

$$N_t = \int \hat{n}_{it}(s_i)\mu_t(s_i)ds_i = 1/3, \text{ for all } t \text{ and } \phi \geq 0. \quad (27)$$

Moreover, since productive inputs can move freely across firms and every firm faces identical relative prices, the capital-to-labor ratio will be the same across establishments in each period. It follows that at the model's stationary equilibrium with fixed labor supply and constant interest rate

$$\frac{\hat{n}_i(s_i)}{\hat{k}_i(s_i)} = \frac{r}{w} = \frac{\int \hat{n}_i(s_i)\mu(s_i)ds_i}{\int \hat{k}_i(s_i)\mu(s_i)ds_i} = \frac{1/3}{K}, \quad (28)$$

which in turn implies that the percentage change of real wage will be identical to that in aggregate capital stock.

Given the presence of endogenous entry and exit decisions, Table 3 shows that more progressive taxation leads to a smaller decrease in aggregate capital (by 17.5 to 39 percent) than that in our baseline undistorted specification. As can be seen in Tables 1 and 2 under variable labor supply, the steady-state level of employment falls as the tax progressivity  $\phi$  rises. By contrast, hours worked always remain unchanged within the current formulation, hence they are higher than the corresponding varying-labor counterparts. Since capital and labor are complementary factors in firms' production technology, the reduction in aggregate capital will be relatively lower due to a weaker intensive margin. On the other hand, the total numbers of new entrants and operating incumbents both increase substantially, ranging from 43 to 133 percent, because of adjustments from the extensive margin. As in our benchmark model, the strength along the intensive margin turns out to be quantitatively stronger, thus economy's total output will fall by a smaller (3.9 to 11.3) percentage.

Table 3. Fixed Labor Supply with Endogenous Entry and Exit Decisions

$\phi$	0.1	0.2	0.3
Relative Y	-4%	-8%	-11%
Relative TFP	1%	2%	3%
Relative E	43%	89%	133%
Relative M	43%	89%	133%
Relative K and w	-18%	-29%	-39%
Relative N	0%	0%	0%
Relative C	-8%	-17%	-26%

Note: We report the percentage changes compared to those in the second column of Table 1 when  $\phi = 0$ .

Per our earlier discussion, the measured aggregate TFP depends on the number of firms in operation as well as the resource allocation across establishments with different levels of productivity. Table 3 shows that in the economy with fixed labor supply, the positive impacts from a significantly higher number of producing firms exceeds the negative effects from misallocation of resources. As a result, the model's Solow residual will increase (by 1 to 3 percent) as the tax schedule becomes

more progressive. This finding implies that whether idiosyncratic tax distortions raise aggregate productivity is governed by the variability of hours worked.

### 3.4 Fixed Labor Supply without Endogenous Entry and Exit

Finally, we examine the specification that exhibits fixed labor supply together with no endogenous entry and exit decisions, and report the associated steady-state effects under different degrees of tax progressivity in Table 4. Qualitatively, the economy’s aggregate output, consumption, capital stock, real wage and measured TFP all fall when the tax schedule becomes more progressive. Quantitatively, these decreases are smaller than those shown in Table 2 when the household’s hours worked are endogenously determined. The intuition for this result is the same as that discussed in the preceding subsection. Under a constant level of hours worked which weakens the strength along the intensive margin, the magnitude for the resulting reductions in macroeconomic variables will be relatively lower than the matching formulation with variable labor supply. Since the total number of producing firms remains unchanged (*i.e.* without the extensive margin), we also find that (i) the decreases in aggregate output, capital stock and real wage, shown in Table 4, are larger than those in Table 3 when firms can freely enter the market; and (ii) the measured TFP will fall in that the adjustments only come from the intensive margin.

Table 4. Fixed Labor Supply without Endogenous Entry and Exit Decisions

$\phi$	0.1	0.2	0.3
Relative Y	-11%	-19%	-26%
Relative TFP	-4%	-8%	-10%
Relative M	0%	0%	0%
Relative K and w	-24%	-38%	-50%
Relative N	0%	0%	0%
Relative C	6%	-1%	-7%

Note: We report the percentage changes compared to those in the second column of Table 1 when  $\phi = 0$ .

## 4 Conclusion

We have analyzed the long-run general equilibrium effects of progressive taxation in an otherwise standard one-sector neoclassical growth model with heterogeneous firms characterized by different levels of productivity. Our postulated fiscal policy rule affects key macroeconomic variables

through the channels of both intensive and extensive margins. Along the intensive margin, more progressive taxation shifts resources from more productive firms to less productive and subsidized establishments. This in turn decreases the economy's total output, consumption, capital stock, labor hours and real wage. Along the extensive margin, the expected value of an incumbent firm becomes higher as the tax progressivity rises. This encourages more potential entrants to enter the market, thus raises the total number of firms in operation as well as aggregate production. In the benchmark model with variable labor supply together with endogenous entry and exit decisions, we find that the adjustment effects from the intensive margin associated with resource misallocation quantitatively dominate those from the extensive margin due to an expansion of producing firms. On the other hand, the measured aggregate TFP remains virtually unchanged when the tax schedule becomes more progressive. To obtain further insights about these results, we also examine alternative specifications with fixed labor supply and/or no endogenous entry and exit decision. Our analyses show that the quantitative implications of progressive taxation are sensitive to the variability of hours worked and the presence of entry regulations.

This paper can be extended in several directions. For example, progressive taxation may distort firms' technology adoption decisions, and thus reduce the aggregate productivity. In addition, financial frictions might as well affect resource misallocation and the entry decisions of potential firms. Hence, the interplay between different distortions and their consequent impacts on macroeconomic aggregates would be worth exploring. Finally, while this paper analyzes the effects of within-sector distortions at the firm's level, cross-sector frictions may also play an important role within a macroeconomy. We plan to pursue these research projects in the future.



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Figure 1. Tax Rates versus Firms' Productivity

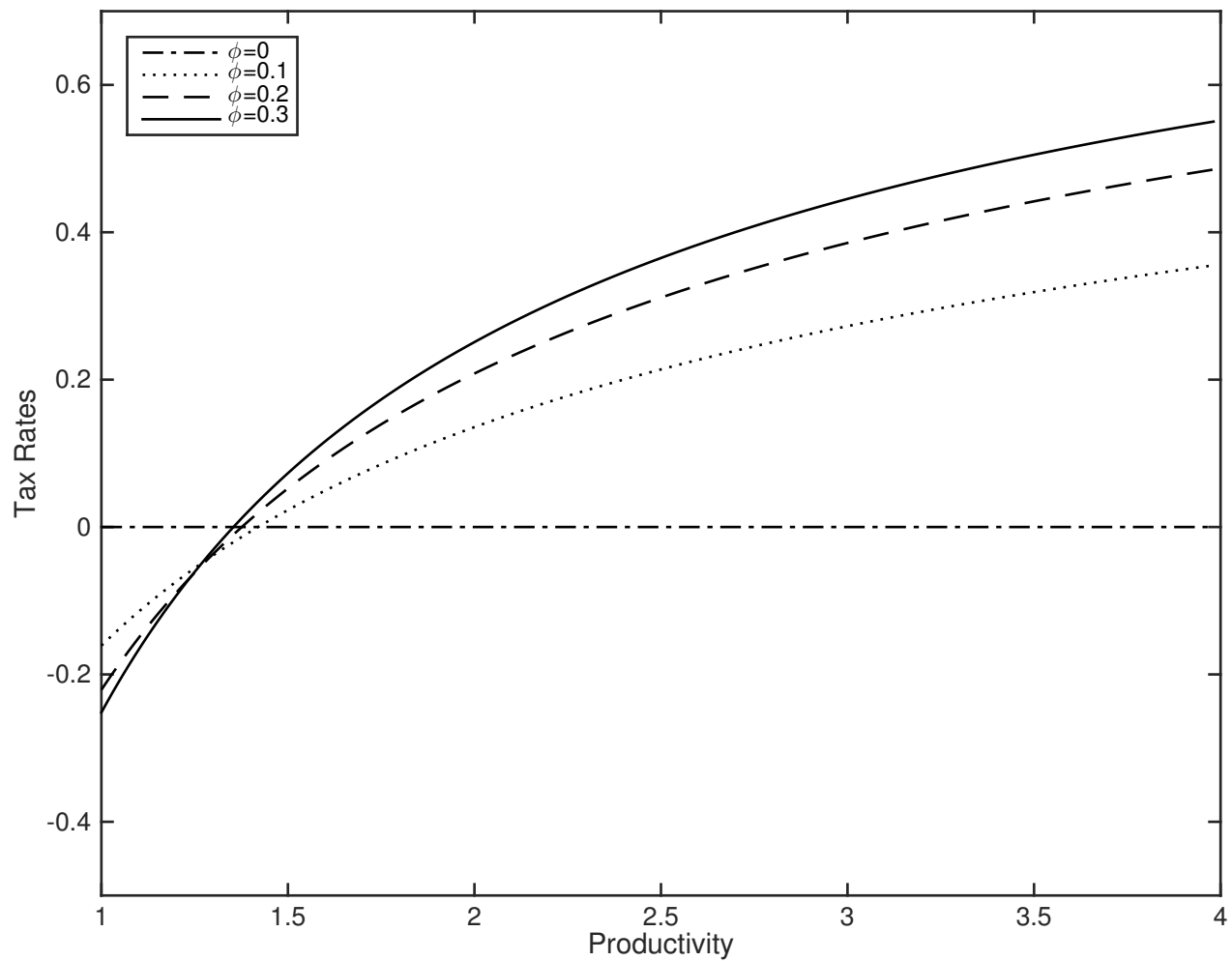


Figure 2. Intensive Margin: Truncated Labor Demand

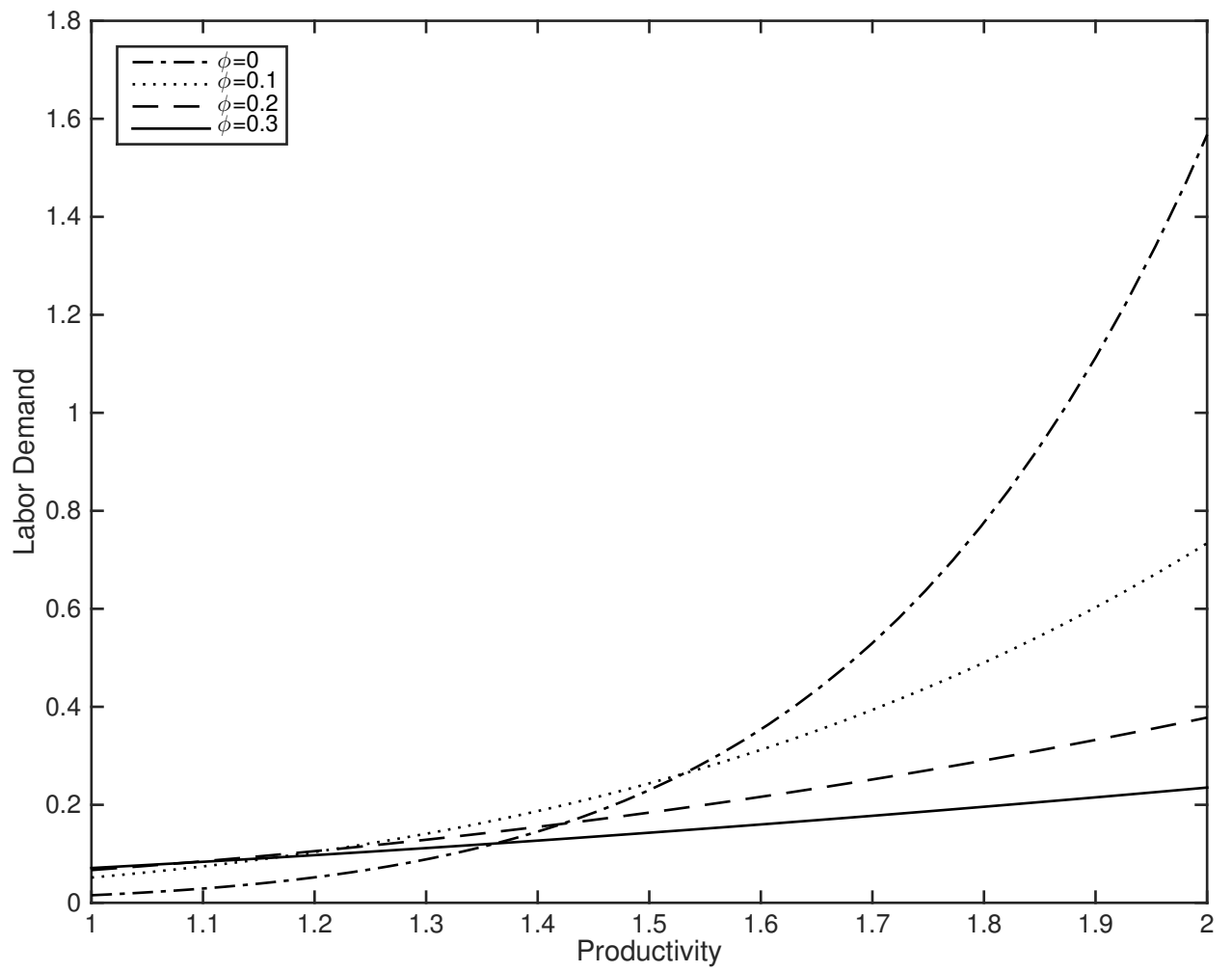


Figure 3. Extensive Margin: Mass Distribution of Producing Firms

