Stimulative Effects of Temporary Corporate Tax Cuts *

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Abstract

Policymakers often rely on temporary corporate tax cuts in order to provide incentives for business investment in recession times. A common motivation is that such policies help relax financing frictions, which might bind more during recessions. Our aim is to assess whether this mechanism is effective at raising aggregate investment and output. We consider an industry equilibrium model where some firms are financially constrained, and therefore have high marginal propensities to invest. By increasing current cash flows, corporate tax cuts are effective at stimulating investment. We quantify by how much aggregate investment and output increase, and describe the effects in the cross-section of firms. We find that, on impact, a temporary reduction in corporate taxation increases aggregate investment by 26 cents per dollar of tax stimulus, and aggregate output by 3.5 cents. The cumulative effect multipliers yield increases of investment and output of 4.6 and 7.2 cents, respectively. A major factor preventing larger effects is that this policy tends to significantly crowd out investment among the larger, unconstrained firms.

Keywords: Corporate tax policy, Financing Frictions, Investment dynamics.

JEL Codes: D21, D92, E22, E62, G35, H32.

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1 Introduction

Policymakers often rely on temporary corporate tax cuts in order to provide incentives for business investment in recession times. A common motivation for such policies is the presence of financial frictions. That is, recessions are viewed as periods when firms’ access to credit is particularly tight. A reduction in corporate taxation during downturns may help alleviate financial market imperfections by effectively relaxing access to external funds. Aggregate investment and output are expected to increase as a result, mitigating the economic slowdown.

Our goal is to quantify how effective temporary corporate tax cuts are when firms are subject to financing frictions. We find that, on impact, a temporary reduction in corporate taxation increases aggregate investment by 26 cents per dollar of tax stimulus, and aggregate output by 3.5 cents. The cumulative effects yield increases of investment and output of 4.6 and 7.2 cents, respectively, per dollar of tax stimulus. These are reasonably large multiplier effects. The main reason why they are not larger is that although we find a significant expansion of investment and output among the smallest, constrained firms, this is to a large extent achieved by crowding out the investment of the largest, unconstrained firms.

Among constrained firms, we do find investment multipliers very close to 1, especially among new entrants. For these firms, the entirety of the tax cut is therefore channelled to investment, and the policy achieves full effectiveness. However, the increased aggregate demand for capital puts upward pressure on the interest rate, which discourages investment among the large, unconstrained firms.

Our approach is to concentrate on a simple general equilibrium model which integrates a representative household, a government, and a production sector featuring heterogeneous firms potentially subject to financing frictions. Firms are subject to idiosyncratic productivity and entry/exit shocks, and we abstract from aggregate uncertainty. The firm’s optimal investment decisions in response to shocks may require funds from the household sector, in addition to retained earnings. However, we assume there is an upper bound on the amount of external funds a firm has access to. The industry equilibrium features some firms which are financially constrained. The number of constrained firms, as well as the extent of investment
distortions, are key for the expansionary effect of the corporate tax cut policy.

The literature has mostly considered a different justification for temporary corporate tax cuts, which relies on intertemporal substitution. That is, when the reduction in taxes is temporary, firms may have an incentive to concentrate investment and production activities in the periods of lower taxation. Related policy interventions may also rely, for instance, on temporary investment tax credits (Abel, 1982). These policies have in common their distortionary nature, and therefore their impact on intertemporal marginal costs and benefits from investing. The literature has provided a number of analysis of this channel. One example is Dotsey (1994), who considers an environment where the government is subject to an intertemporal budget constraint and capital taxes in any given period are stochastic. In this setting, lowering capital taxes today entails higher expected taxes in the future. This may actually lower investment today when taxation is distortionary and if the effect of higher future distortions dominates the firms’ investment decisions. Another recent example is Gourio and Miao (2011). These authors study the 2003 dividend and capital gain tax cuts in the U.S., under the assumption that they were unexpected and temporary. They conclude that the capital gain tax cut alone would temporarily increase investment by nearly 10 percent, in accordance with the intertemporal substitution effect. However, when combined with the dividend tax cut, investment actually declines by slightly more than 10 percent. The reason is that firms choose to cut investment expenditures in order to pay more dividends when the dividend tax is temporarily low, an effect large enough to overturn the capital gain tax one. Gourio and Miao (2011) use a setting which is related to ours, in the sense that they also rely on a general equilibrium model with firm heterogeneity. However, they concentrate on the firm’s choice of how to fund investment expenditures (retained earnings, debt, or equity), whereas our focus is on the presence of an overall external financing constraint.

Missing from the literature is precisely an assessment of the role of temporary tax relief policies in alleviating financial frictions. In order to separate this channel from the intertemporal substitution channel, we assume corporate taxes are non-distortionary. Our setup satisfies a Ricardian proposition, in the sense that absent financial frictions temporary corporate tax cuts produce no aggregate effects. We start the economy from the stationary equilibrium, and consider a surprise temporary reduction in corporate tax rates when firms
are subject to financial frictions. Our calibration ensures that the extent of financial frictions allows the model to replicate salient features of the firm-level data at steady-state. We solve for the model’s transition back to the initial steady-state, and compute the investment and output effects of the policy on impact. Our results show that the expansionary effect of these policies is reasonably large. These results are consistent with Heathcote (2005), who shows that temporary income tax cuts when consumers (instead of firms) face borrowing constraints generate increases in aggregate consumption of 11.4 cents per dollar of lost tax revenue with lump-sum taxes (like here), and of 29 cents with proportional taxes. Financing constraints therefore generate significant departures from Ricardian equivalence, both among firms and among consumers.

2 Model

The model consists of a representative household, a continuum of firms with a unit mass, and a government. There is no aggregate uncertainty. Time is discrete and is indexed by $t = 1, 2, \ldots$.

2.1 Firms

Firms face idiosyncratic productivity shocks. By a law of large numbers, all aggregate quantities and prices are deterministic over time, although each firm still faces idiosyncratic uncertainty.

In addition to idiosyncratic productivity shocks, we also assume firms receive exogenous entry and exit shocks. In particular, each firm faces a per period exit probability of $\eta \in (0, 1)$, following production. In every period, this mass of exiters is replaced by an equal mass of entrants. This assumption is entertained by several papers, more recently by Khan and Thomas (2013). Entry and exit allows for a nontrivial equilibrium firm distribution and ensures some firms will always be financially constrained. Figure 1 displays the timing of firm’s decisions.
There are two types of firms in the economy at each point in time, incumbents and prospective entrants. At the beginning of each period $t$, incumbents observe their current productivity shock, hire labor, produce, pay corporate taxes, invest in physical capital, and pay dividends to its shareholders. At the end of the period, they observe the exit shock. This shock can take on two values, 1 for exiting, or 0 for staying. Upon receiving an exit shock, we assume the incumbent sells its capital stock and forever ceases production.

We assume there is a new entrant drawn from the entrant pool for each firm that exits the industry. Potential entrants are ex-ante identical. Upon entering the industry at time $t$, each new entrant invests in order to begin producing next period. At period $t + 1$, new entrants at time $t$ become incumbent firms.

In order to write the firm’s problem, we first derive the equity valuation equation. In our model, the firm is neither allowed to issue new equity nor to make repurchases. Hence, the only way the firm may have access to external equity financing is by paying negative dividends. Denoting by $P_t$ the ex-dividend equity value at date $t$, the following no-arbitrage
condition must hold in equilibrium:

\[ 1 + r_{t+1} = \frac{1}{\mathbb{E}_t} \mathbb{E}_t (d_{t+1} + P_{t+1}) \]  

(1)

implying

\[ P_t = \frac{\mathbb{E}_t (d_{t+1} + P_{t+1})}{1 + r_{t+1}} \]

where \( \mathbb{E}_t \) is the expectation operator conditional on the productivity shocks, \( r_{t+1} \) is the required return rate to equity, and \( d_{t+1} \) is the firm’s dividend payments.

The cum-dividend equity value \( V_{t+1} \) at period \( t+1 \) is:

\[ V_{t+1} = d_{t+1} + P_{t+1}. \]

(2)

Using (1) we can then derive the equity value of firm:

\[ V_t = d_t + \frac{1}{1 + r_{t+1}} \mathbb{E}_t V_{t+1}. \]

(3)

2.1.1 Incumbent Firm

Denote by \( V(k_t, \varepsilon_t; \mu_t) \) the equity value of a firm that begins period \( t \) with capital stock \( k_t \) and productivity shock \( \varepsilon_t \), when the cross-sectional distribution of firms is characterized by \( \mu_t \). From (3), it satisfies the following Bellman equation:

\[
V(k_t, \varepsilon_t; \mu_t) = \max_{n_t, k_{t+1}, d_t} \left\{ d_t + \frac{1}{1 + r_{t+1}} \left[ \eta k_{t+1} + (1 - \eta) \sum_{\varepsilon_{t+1} \in \mathbb{E}} \psi(\varepsilon_{t+1}, \varepsilon_t) V(k_{t+1}, \varepsilon_{t+1}; \mu_{t+1}) \right] \right\}
\]

subject to

\[
\mu_{t+1} = \Gamma(\mu_t) \]

\[
\varepsilon_t F(k_t, n_t) + (1 - \delta) k_t = d_t + w_t n_t + \tau_t + k_{t+1}
\]

\[
d_t \geq -\bar{d} + \zeta k_t,
\]

where \( \delta \in (0, 1) \) is the depreciation rate of capital, and \( \bar{d} \geq 0 \).
\( \Gamma \) describes the law motion of the aggregate state of the economy. It is jointly determined by the entry-exit process, the tax policy, the transition matrix of the markov process, and the distribution of incumbents. \( \mu \) is the distribution of continuers, which includes one-year old firms.

Equation (4b) describes the flow of funds condition for the firm. Cash inflows consist of output and undepreciated capital, while cash outflows include investment expenditures, tax liabilities, wage and dividend payments.

Financial frictions in our model are described by equation (4c). The analysis of the effects of temporary tax cuts on firm decisions requires a model that departs from the Modigliani-Miller theorem. Our model considers a simple way to achieve this by imposing an upper bound \( \bar{d} \) on the amount of external funds a firm has access to. In addition, we follow Bianchi (2013) and impose a minimum dividend payout policy. While Bianchi (2013) imposes a constant lower limit on dividend payments, we assume that firms are subject to a collateral constraint that limits the minimum amount of dividend payments to an increasing function \( (\zeta > 0) \) of their capital holdings. A special case is the restriction that dividends need to be non-negative when \( \zeta = 0 \) and \( \bar{d} = 0 \). This constraint reflects the notion that dividend payments are required to reduce agency problems and information asymmetries between shareholders and managers. A possible interpretation is that the firm has an established dividend practice that leads stockholders to expect a minimum dividend distribution after each operating year. In the U.S., Poterba et al. (1987) presented evidence of remarkable stability of dividend payouts throughout periods of extensive tax changes. In studying the dividend policies in U.S., Lintner (1956) argued that more than 95% of firms covered by his sample have an established dividend distribution rate in line with their currents net earnings. In the absence of real frictions, current earnings are proportional to the capital stock in our economy. Thus, we impose the minimum dividend payment to be a constant share of the installed capital stock.

Let \( \lambda_t \) be the Lagrange multiplier associated to the constraints (4c). Using equation (4b) to eliminate \( d_t \), we obtain the labor demand and the investment Euler equation:

\[
 w_t = \varepsilon_t F_2(k_t, n_t)
\]
\[ 1 + \lambda_t = \frac{1}{1 + r_{t+1}} \{ \eta + (1 - \eta)E_t \left[ -\zeta \lambda_{t+1} + (1 + \lambda_{t+1})(1 - \delta + \varepsilon_t F_1(k_{t+1}, n_{t+1})) \right] \} \]  \hspace{1cm} (5)

The left-hand-side of (5) represents the marginal cost of investment, while the right-hand-side represents the marginal benefit from investment. The marginal gain from investment consists of the un-depreciated value of the installed capital and its marginal product net of taxes. It comes from (5) that the lump sum tax affects the investment decision of the firm only through alleviating the liquidity constraints. Thus, temporary tax cuts affect investment only because it allows firms to have access to more external funds. In contrast, the existing literature relies mostly on the intertemporal substitution effects of tax cuts.

### 2.1.2 New Entrant

A new entrant is like an incumbent entering the period with a zero capital stock. It invests in order to start operating in the following period, financed by the household sector. Denote by \( V_e \) the value of a new entrant. Then

\[
V_e(\mu_t) = \max_{k_{t+1},d_t} \left\{ -k_{t+1} + \frac{1}{1 + r_{t+1}} \sum_{\varepsilon \in E} \bar{\pi}(\varepsilon_{t+1})V(k_{t+1}, \varepsilon_{t+1}; \mu_{t+1}) \right\}
\]

s.t.

\[
d_t = -k_{t+1}
\]
\[
d_t \geq -\bar{d}.
\]

The initial productivity of new entrants is drawn from the stationary distribution associated to the markov process. As new entrants are identical in all dimensions, they choose the same level of capital to start with. In equilibrium, the optimal decisions of a new entrant are:

\[
d^e_t = -\bar{d}
\]
\[
k^e_{t+1} = \bar{d}.
\]
2.2 Aggregation

The solution to the incumbent’s problem consists of a value function \( V \) as well as policy rules for labor demand, capital, dividends and output which we denote, respectively, by:

\[
    n = n(k, \varepsilon; \mu); k' = k'(k, \varepsilon; \mu); d = d(k, \varepsilon; \mu); y = y(k, \varepsilon; \mu) \tag{6}
\]

The solution to the new entrant’s problem consists of a value function \( V^e \) as well as policy rules for capital, and dividends which we denote, respectively, by:

\[
    k^e = k'(\mu); d^e = d(\mu) \tag{7}
\]

With the description of individual agent behavior completed, we can now characterize the aggregate variables for this economy. Each firm is fully described by its current individual state \( s \equiv (k, \varepsilon) \). Let \( S \equiv K \times E \) denote the set of all possible firm’s states where \( K \) is the set of capital, and \( E \) is the set of possible values of the idiosyncratic shocks. Let \( \Omega_S \) denote the product \( \sigma-algebra \) on \( S \) with typical subset \( S \). We can summarize the aggregate distribution of firms with a measure defined over the state space \( S \). Formally we define the measure \( \mu \) as follows:

\[
    \mu : \Omega_S \to \mathbb{R}_+ \\
    A \mapsto \mu(A)
\]

where at any period \( t \), \( \mu_t(A) \) is the mass of firms that are at a state \( s = (k, \varepsilon) \) such that \( (k, \varepsilon) \in A \subseteq S \).

The law of motion of the aggregate state of the economy is jointly determined by the entry-exit process, the tax policy and the transition function \( Q \) of firms across states. This transition function \( Q \) is induced by the investment decision rules of firms and the transition matrix of the productivity shock. \( Q \) can be derived as follows:

\[
    Q : S \times \Omega_S \to [0, 1] \\
    ((k, \varepsilon), K \times E) \mapsto Q((k, \varepsilon), K \times E) = \sum_{\varepsilon' \in E} \pi(\varepsilon', \varepsilon)1_{k' \in K} \tag{8}
\]

where \( 1_K \) is the indicator function on the set \( K \).
In particular, for $A \subseteq \mathbb{K}$ and $B \subseteq \mathbb{E}$:

$$Q((k, \varepsilon), A \times B) = \begin{cases} \psi(\varepsilon, B) & \text{if } k'(k, \varepsilon) \in A \\ 0 & \text{otherwise} \end{cases}$$  \hspace{1cm} (9)$$

where $\psi(\varepsilon, B)$ is the probability of moving from the shock $\varepsilon$ to any shock in $B$ in one period, $\psi(\varepsilon, B) = \sum_{\varepsilon' \in B} \pi(\varepsilon', \varepsilon)$.

$Q$ is a well defined transition function for a Markov process with the interpretation that $Q((k, \varepsilon), A \times B)$ is the probability of moving from the state $(k, \varepsilon)$ to a state $(k', \varepsilon')$ which lies in $(A \times B)$ in one period.

Under the assumption of time-invariant tax rates, the entry exit rule together with the optimal decisions of firms imply an evolution for the aggregate state $\mu$ of the economy. For any borel set $A \in \mathcal{O}_S$, the law motion of the aggregate state of the economy can be derived as:

$$\mu_{t+1}(A) = (1 - \eta) \int S Q(s, A) \mu_t(s) ds + \eta \Psi(A)$$ \hspace{1cm} (10)$$

where $\Psi$ is the initial distribution of new entrants over productivity shock and capital stock, and $\eta$ is the exit probability.

If the capital stock $k$ and the productivity shock $\varepsilon$ are restricted to a finite number of values, $\mu$ and $\Psi$ can be represented as vectors which length equals the total number of all possible combinations of $k$ and $\varepsilon$. The $i^{th}$ element of $\mu$ will be interpreted as the mass of firms at the state $s_i$. Using (9), a convenient expression for (10) can be obtained as follows:

$$\mu_{t+1} = \mu_t(1 - \eta)Q + \eta \Psi \equiv \Gamma(\mu_t)$$ \hspace{1cm} (11)$$

In anticipation of a stationary equilibrium, we expect that there exists a stationary distribution $\mu^*$ of continuing firms (excluding new entrants but including one year old firms) which satisfies:

$$\mu^* = \mu^*(1 - \eta)Q + \eta \Psi$$ \hspace{1cm} (12)$$

Then, no matter which distribution $\mu$ the economy starts at, the economy will converge asymptotically to $\mu^*$. In this case, aggregate prices become numbers instead of functions of
the aggregate state.

Next, we can define the aggregate quantities that will be used to state the market clearing conditions.

- Aggregate output: \( Y_t = \int_S y_t(s)d\mu_t(s) \).
- Aggregate labor demand: \( N_t^d = \int_S n_t(s)d\mu_t(s) \).
- Aggregate investment:

\[
I_t = \underbrace{\eta k_t^e}_{\text{New Entrants}} + (1 - \eta) \underbrace{\left[ \int k_{t+1}(s)d\mu_t(s) - (1 - \delta) \int k_t(s)d\mu_{t-1}(s) \right]}_{\text{Continuers (Incumbents older than 1 year)}}
+ \underbrace{\eta \left[ \int k_{t+1}(s)d\mu_t(s) - (1 - \delta) k_t^e \right]}_{\text{1 year old Incumbents}} - \underbrace{\eta \int k_t(s)d\mu_{t-1}(s)}_{\text{Exiters}}.
\]

2.3 Household

The representative household derives utility uniquely from consumption according to a standard time-additive utility function \( U \) which satisfies \( U' > 0, U'' < 0 \) and the Inada conditions. The household owns all firms and trades firms’ shares. In addition, it also trades a risk-free bond in zero net supply. Thus, the household’s problem is to choose consumption, and savings decision to maximize its utility. Let \( W(\omega) \) denote the indirect utility of the household where \( \omega \) denotes its total revenue. The household’s maximization program is as follows:

\[
W_t(\omega_t) = \max_{C_t, b_{t+1}, \theta_{t+1}, \theta_{t+1}^e} \{ U(C_t) + \beta W_{t+1}(\omega_{t+1}) \} \quad (13)
\]

s.t.

\[
C_t + b_{t+1} + \eta p_t^e \theta_{t+1} + \int p_t(s)\theta_{t+1}(s)d\mu_t(s) = \omega_t \quad (14a)
\]

\[
\omega_t \equiv w_t + (1 + r_t)b_t + \eta \int k_t(s)\theta_t(s)d\mu_{t-1}(s) + \int [p_t(s) + d_t(s)]\theta_t(s)d\mu_t(s) \quad (14b)
\]
The left-hand-side of equation (14a) represents the current expenditures of the household. It consists of consumption, and investment in government bonds and firms’ shares (incumbents \( \theta \), and new entrants \( \theta^e \)). The right-hand-side of equation (14b) is the current revenue of the household. Current resources are wage, and return on investment in bonds and in firms’ shares. Return on investment in equity consists of dividend paid by exiting firms, and return on investment in continuing firms.

In the stationary equilibrium, the household problem is static and its optimal decisions provide the asset pricing equations:

\[
1 = \beta (1 + r) \tag{15}
\]

\[
1 + r = \frac{E_s P(s') + d(s')}{P(s)} \tag{16}
\]

### 2.4 Government

Government spending is assumed exogenous and time-invariant. At any period \( t \), government finances its expenditure \( G \) by raising lump sum tax \( \tau_t \) on corporate profits or issuing one period debt \( b_{t+1} \). Thus, it faces the budget constraint:

\[
(1 + r_t) b_t + G = \tau_t + b_{t+1} \tag{17}
\]

Accordingly, the government can run a high deficit in the short to medium term, but in the long run it is not allowed to play a Ponzi game with consumers. To ensure this condition, the government debt has to satisfy the following condition:

\[
\lim_{T \to \infty} \prod_{t=0}^{T} (1 + r_t)^{-1} b_{T+1} \leq 0 \tag{18}
\]

This condition implies that the government can not succeed forever in paying off interest on old bonds by floating new bonds. In equilibrium, as the government does not waste resources, this constraint must hold with equality implying the transversality condition on government
debt. That is the present value of the government debt must equal to zero.

\[
\lim_{T \to \infty} \prod_{t=0}^{T} (1 + r_t)^{-1} b_{T+1} = 0
\]  

(19)

Solving the government budget constraint forward and using (19) to rule out Ponzi-schemes gives the intertemporal constraint:

\[
b_0 + G \sum_{t=0}^{+\infty} \prod_{i=0}^{t} (1 + r_i)^{-1} = \sum_{t=0}^{+\infty} \prod_{i=0}^{t} (1 + r_i)^{-1} \tau_t
\]

(20)

According to the intertemporal budget constraint (20), the sum of the present value of government expenditures and its initial debt level determine the present value of government tax receipts.

2.5 Stationary Equilibrium

Given the transition matrix \( \psi \), the government policy \((\tau, G)\), a recursive stationary equilibrium consists of a stationary distribution \( \mu^* \), a law motion \( \Gamma \), prices \( w, P \) and \( P^e \), decision rules for firms \((n, k', d, k^e, d^e)\), and households, \( \theta^e, \theta', b', C \) as well as associated value functions for firms \((V, V^e)\) and for household, \( W \), such that:

1. Given prices, \( \theta^e, \theta', b', C \) and \( W \) solve the household problem.

2. Given prices and the government policy, \((n, k', d)\) and \( V \) solve the incumbent dynamic problem in (4).

3. Given prices and the government policy, \((k^e, d^e)\) and \( V^e \) solve the new entrant problem.

4. Given prices, the government budget constraint in (17) holds.

5. All markets clear:

   - Labor market: \( N^d = 1 \).
• Equity market:
  Incumbents: $\theta(s) = 1, \forall s$.
  New Entrants: $\theta^e = 1$.

• Final good: $Y = I + C + G$.

6. $\mu^*$ is consistent with the law of motion in (12).

3 Model Solution

We solve our model by numerical methods. The algorithm consists of two parts. First, we compute the steady-state, which characterizes the economy before the tax cut, and in the long-run and after the tax cut (the tax rate reverts back to its initial level). We use a backward induction algorithm to compute the transition of the economy following the tax cut back to the initial steady-state. The details of the numerical algorithm are in the Appendix.

4 Calibration

The data on establishment-level investment dynamics are reported annually. We thus assume one model period corresponds to one calendar year. Our parameters can be classified into two groups. The first group includes parameters we set a priori and are reported in Table 1.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return to scale $v$</td>
<td>0.85</td>
<td>Atkeson and Kehoe (JPE, 2005)</td>
</tr>
<tr>
<td>Capital elasticity $\alpha$</td>
<td>$1/3$</td>
<td>Capital income share</td>
</tr>
<tr>
<td>Discount factor $\beta$</td>
<td>0.96</td>
<td>Interest rate of 4%</td>
</tr>
<tr>
<td>Exit probability $\eta$</td>
<td>0.05</td>
<td>Evans (JIE, 1987)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lee and Mukoyama (EER, 2012)</td>
</tr>
</tbody>
</table>

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Preferences. We consider a logarithmic utility function:

\[ U(C) = \ln(C), \]

and target a pre-tax real interest rate of 4 percent, implying \( \beta = 0.96. \)

Technology. We choose the Cobb-Douglas production function with decreasing return to scale, \( F(k, n, \varepsilon) = \varepsilon (k^\alpha n^{1-\alpha})^\nu, \) where \( 0 < \alpha, \nu < 1. \) We fix the return to scale parameter, \( \nu, \) equal to 0.85 to be consistent with the direct estimates of establishment-level production functions and different calibration procedures in the literature.\(^1\) The income share of capital, \( \alpha, \) is fixed to 1/3. The exit rate is exogenous and is equal to 5%. This is standard in the literature, and is in the range of the estimates by Evans (1987) and Lee and Mukoyama (2012) who report, 4.5% and 5.5%, respectively.

The second set of parameters are calibrated internally and presented in Table 2.

Tax system. As there is a single lump sum corporate tax in the model, the appropriate empirical counterpart is the average corporate tax revenue to GDP. From the IRS data, capital gains and dividend taxes represent in average 1% of GDP over the period 2000-2005. In average, S-corporations taxes account for around 1% of GDP over the period 2004-2007. The corporate profits tax represents in average 2% of GDP over the period 2000-2007. We target 4% as the average corporate tax revenue to GDP.

Productivity shocks. The process for firm level productivity shocks is estimated by fitting an \( AR(1) \) process:

\[ \ln \varepsilon_t = (1 - \rho) \gamma + \rho \ln \varepsilon_{t-1} + \varsigma_t \quad (21) \]

where \( \varsigma_t \) is i.i.d. and normally distributed with mean zero and variance \( \sigma^2. \) This process is approximated using a 5-state Markov chain obtained by applying the method of Tauchen (1986).

\(^1\)Restuccia and Rogerson (2008), Atkeson and Kehoe (2005), Pavcnik (2002), Veracierto (2001), and Atkenson et al. (1996), among others
The parameters governing the extent of financial frictions are key. We infer them by requiring that the presence of financial constraints in the model is capable of delivering the firm level dynamics observed for U.S plants. In particular, we calibrate our model to match (i) the average relative size of new entrants of 6% with respect to survivors as reported by Lee and Mukoyama (2012),\(^2\) (ii) the aggregate cash-to-asset ratio to the Compustat (2006) value of 0.102 reported by Khan and Thomas (2013), (iii) the average mean and standard deviation of investment rates as reported by Cooper and Haltiwanger (2006), and (iv) the cross-sectional variation in cash-to-asset ratios from the Compustat over 1954-2011 reported by Khan and Thomas (2013). The depreciation rate, $\delta$, is calibrated to deliver an average investment-to-capital ratio of roughly 0.069, which corresponds to the average value for the private capital stock between 1954 and 2002 in the U.S. Fixed Asset Tables, controlling for growth (Khan and Thomas (2013)).

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\(^2\)Lee and Mukoyama (2012)’s data come from the Annual Survey of Manufactures (ASM) of the Longitudinal Research Database (LRD), which is constructed by the U.S. Census Bureau 1972-1997. The model counterpart is obtained by dividing the average size of new entrant by the average size of Incumbents
5 Steady-State Implications

5.1 Implications of the Dividend Constraint

Let us call by *desired investment*, the amount of investment a given firm would have made in the absence of the dividend constraint. We measure the tightness of the constraint for this firm by the ratio of its realized investment to its desired investment. A smaller ratio means that the constraint is tighter. For unconstrained firms, the tightness index is equal to 1. Figure 2 plots the tightness of the borrowing constraint against firm size for two different values of productivity shocks.

![Figure 2: Tightness of the Dividend Constraint](image)

The red curve plots the tightness index for the lowest productivity shock. It has an upward slope for small firms implying that the constraint weakens as the firm grows. When the firm grows beyond a certain size, the tightness index is equal to 1 independently from the firm size. In this case, the constraint is inactive, and the curve becomes an horizontal line. Firms, which size falls in this region are unconstrained. Consequently, they are able to invest up to their desired level. Overall, both curves show that the smallest firms are
most constrained. These results are consistent with the findings by Beck et al. (2005), and Angelini and Generale (2008) using direct measures of financial constraints from firm-level survey data. In our model, two reasons explain this slope. Firstly, as the production function is increasing in its inputs, firms with smaller stock of capital generates less cash flows and are more likely to be constrained for a given value of the productivity shock. Secondly, smaller firms are more likely to be in their expansion phase. As a result, they need more resources to finance their investment.

Now let us consider two firms with the same level of capital and different levels of productivity. The blue dashed-curve plots the tightness index for a highest productivity value. Figure 2 shows that for a given level of capital, the blue curve is above the red curve for constrained firms. This result implies that the constraint is tighter for high productivity firms than low productivity ones. The intuition behind the result is that highly productive firms are willing to investment more because they have higher marginal productivity of capital.

5.2 Firm Size Distribution

Figure 3 plots the firm size distribution that obtains in stationary equilibrium when we consider capital as a measure of firm-size. On the horizontal axis, we have capital stock and the area of each bar represents the share of firms which size fall in this interval of capital stock. The constrained and unconstrained start-ups are in blue and red, respectively. These one year old firms are the smallest firms in the economy. In cyan and magenta, we have the constrained and unconstrained older incumbents, respectively. From Figure 3, we can make two remarks.

Firstly, the figure reveals that constrained firms are of all size. This result suggests that the level of productivity is the most important driver of the number of constrained firms in our model. Especially, it is more likely that constrained firms are the most productive. This intuition is supported by Table 3, which displays the output share of each category of firms in our economy.
Table 3 reports that startups own only 2.3 per cent of the capital stock and contributes to around 3 per cent of the aggregate output. Old and unconstrained firms own nearly 50 per cent of the capital in the economy and contribute only to one third of the output. However, old and constrained own similar stock of capital, but contribute up to two-thirds of output. The larger contribution of constrained firms to production is explained by their productivity. Consistent with the facts presented in Figure 3, these statistics confirm that constrained firms are the most productive.
Table 3: **Stationary Distribution of Firms**

<table>
<thead>
<tr>
<th>Firm-type</th>
<th>Frequencies (%)</th>
<th>Capital Share</th>
<th>Output Share</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Startups</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constrained</td>
<td>3.4</td>
<td>1.6</td>
<td>2.5</td>
</tr>
<tr>
<td>Unconstrained</td>
<td>1.6</td>
<td>0.7</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Continuers</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constrained</td>
<td>46.9</td>
<td>47.8</td>
<td>63.7</td>
</tr>
<tr>
<td>Unconstrained</td>
<td>48.1</td>
<td>49.9</td>
<td>33.3</td>
</tr>
</tbody>
</table>

Secondly, Figure 3 shows that the distribution of firm by capital decision is skewed to the right. This result holds true even when we measure size with employment rather than capital as illustrated by Figure 4. In fact, Figure 4 draws the distribution of firms by employment level. Overall, it displays a positive skewness. This implies that in stationary equilibrium we have a big mass of small firms and a small mass of larger firms. These implications are consistent with the evidence gathered by Cabral and Mata (2003) from a comprehensive data set of Portuguese manufacturing firms.

### 5.3 Firm Dynamics

While we have not targeted employment dynamics in our calibration, our model implications have some interesting features consistent with the data. Table 4 reports the job creation and job destruction in stationary equilibrium.

The empirical counterparts are computed by Lee and Mukoyama (2012) using the job

---

3Angelini and Generale (2008) reach the same conclusions using Italian firm-level survey data
flows data published by Davis et al. (1998). From the table, one can see that our model matches most firm-level employment dynamics moments. Especially, the model exactly replicates the relative contribution of continuers and exiters to job destruction. In addition, it matches almost exactly the relative contribution of startups and continuers to job creation. However the model is unable to deliver the overall job creation and job destruction rate. This is not surprising because entry and exit are exogenous in our model.

Figure 5 plots the average employment growth by firm employment distribution. Our model implications are consistent with the empirical evidence that firm growth is uncon-
ditionally negatively correlated with size as reported by Dunne et al. (1988). Hopenhayn (1992) is also consistent with this fact but the mechanism underlining our result is richer than the intuition behind Hopenhayn (1992). Indeed in Hopenhayn (1992), idiosyncratic productivity is a sufficient statistic for firm growth and size. Small firms grow faster because larger firms are those which have accumulated high productivity. They are more likely to see a decline in their productivity because the stochastic process is mean-reverting. To illustrate this, let us assume there is no financial frictions, no capital, and the productivity shocks can only take two values $z$ and $\bar{z}$, $z < \bar{z}$. In this case, only two types of surviving firms will be changing their employment: small firms with current shock $\bar{z}$ and large firms with current shock $z$.

Figure 5: Average Employment Growth by Firm-Size (Employment)

Ignoring the possibility of exit, small firms will only grow while large firms will only shrink. Moreover, small firms will never destroy jobs while large firms will never create jobs. This result also holds when the shock $z$ takes more than two values and the transition probability matrix is symmetric with decreasing probability of changing the current $z$ to more distant values. In our model, the same mechanism is at work and it is still the case that employment growth declines with size because larger firms have accumulated higher productivity in average.
However, an additional mechanism contributes to generating the right unconditional correlation between growth and size. In our context, we have two states variables: productivity and capital. Consider now all the firms with the same employment. In Hopenhayn (1992), they will behave identically. In our model they may behave differently depending on their current capital stock and productivity shock. Since financial constraints prevent the instantaneous adjustment of capital to the first-best implied by productivity, some of these firms are characterized by a relatively low capital and high shock, and others by a relatively high capital and low shock. The former will grow faster because investment and capital are catching up the optimal size induced by productivity. The latter will shrink as the scale of production is adjusted to the new lower level of productivity. It is worth emphasizing that, no matter the definition of size (capital or employment), the negative unconditional relationship between growth and size holds true.

6 Temporary Cut in Corporate Tax

To quantitatively assess the effects of temporary tax cuts, we undertake the following experiment. We assume that, prior to period 1, the economy is initially in the steady-state described in section 5. At period 1, the government reduces unexpectedly the corporate tax rate to zero while maintaining spending unchanged. Once the tax rate occurs, agents have perfect foresight about the future path of tax rates and government debt levels. Accordingly, the government issues one-period debt to finance the deficit implied by the tax cut. At period 2, the government increases the tax to fully repay the outstanding debt plus interest, and there is no further public debt issuance. From period 2 onwards, the tax rate reverts back to its steady-state level. The economy goes through a transition following the tax cut which brings it back to the initial steady state. Figures 6 and 7 display the transitional dynamics of the economy.

6.1 Transitional Dynamics After The Tax-Cut

Figure 6 plots the tax policy as well as the transitional dynamics of investment and output. Figure 7 illustrates the responses of interest rate, wage, dividend and consumption in response
to the tax cut. In period 0, the economy is in the steady-state. The economy takes 10 periods to converge back to the steady-state after the tax cut. In period 1, aggregate output is determined by the predetermined level of aggregate capital but investment jumps up. As the tax rate is increased above the steady-level in period 2, investment decreases at period 2 and then gradually rises to the steady-state. Higher investment in period 1 leads to a higher aggregate capital stock in period 2 implying an increase in output. Afterwards, output decreases monotonically to the steady-state. This reflects the fact that the tax increase in period 2 is expected.

![Figure 6: Transitional dynamics](image)

Turning to Figure 7, the stimulative effects of the tax cut on investment in period 1 leads firms to increase labor demand in period 2 causing the aggregate demand for labor to rise. As the aggregate labor supply is inelastic, the wage should go up to clear the labor market. Consistent with this intuition, Figure 7 shows that wage increases in period 2 and falls monotonically to steady-state.
Moreover, the investment boom in period 1 generates an increased aggregate demand of capital which puts upward pressures on the interest. Because output does not change instantaneously, the increase in investment crowds out consumption. Specifically, consumption in period 1 is affected by two opposite effects. On the first hand, the increase in interest rate implies a substitution effect which may induce the consumer to consume less and save more for investment. On the other hand, firms distribute more dividends in response to the tax cut. Accordingly, shareholders are wealthier and have incentives to increase consumption. As illustrated by Figure 7, the substitution effect dominates this revenue effect and consumption falls in period 1. In period 2, the government increases taxes forcing firms to cut investment and to distribute less dividends. The implied lower demand for capital puts downward pressure on interest rate. In response, interest rate falls below the steady-state value in period 2 and increases monotonically to steady-state. Lower interest rate encourages the household to consume more. In addition, the household receives the return on investment in government bonds and hence is wealthier. Thus, consumption increases in period 2 and decreases monotonically to the steady-state.
6.2 Quantitative Effect of the Tax Cut

To quantify the effects of the tax cut, we compute the transition of the economy back to the initial steady-state and compare it to the steady-state, when there is no change in taxes.

Denote by \( \{X_t\}_{t=1}^T \) the path for any variable \( X_t \) along the transition. Define the multiplier effect of the tax cut on the variable \( X_t \) at period \( t \) by

\[
m_t \equiv \frac{\hat{X}_t - \bar{X} \Delta \tau}{\Delta \tau}
\]

where \( \bar{X} \) is the steady-state value of \( X_t \) and \( \Delta \tau \) is the change in the tax revenue at the period of the tax cut. We concentrate on impact multipliers, that is \( m_1 \) for all variables except output, for which we equate the impact multiplier to \( m_2 \) to deal with the fact that capital is pre-determined and labor is fixed in the aggregate. We also compute the cumulative multiplier, defined as the discounted cumulative change in \( X_t \) over the transition,

\[
cum \equiv \frac{1+r}{\Delta \tau} \sum_{t=1}^T \frac{\hat{X}_t - \bar{X}}{\prod_{i=1}^T (1+r_i)}
\]

where \( r_i \) is the interest rate between the periods \( i-1 \) and \( i \). Table 5 reports the responses of aggregate and firm-level investment, output, and dividends.

The top panel of Table 5 reveals that per dollar of tax stimulus, aggregate investment, dividend, and output increases by 25.7, 74.3, and 3.5 cents, respectively in the short run. As discussed above, the reported elasticity of output is the period 2 effect of the tax cut because capital is predetermined in this model. Compared with the impact multipliers, the cumulative multipliers are substantially lower for investment and dividend. Especially, the long run investment effects is around four times lower than the impact effect on investment. Aggregate dividend increases only by 1 cent over the long run while it increases by more 70 cents instantaneously after the tax cut. These lower cumulative multipliers are explained by the tax increase in period 2. In fact, as the government raises taxes in period 2 to pay back its debt, it forces firms to substantially cut investment and dividend payments. However, the reduction in investment at period 2 is not high enough to offset the stimulative effects in period 1. Thus, the tax cut has a net positive effect on aggregate capital accumulation and hence on output in period 2. Overall, the cumulative output multiplier is twice the impact multiplier. While the tax cut implies a significant expansion of aggregate investment, individual firms’ responses depend heavily on their characteristics as reported by the bottom panel of Table 5.

Let us start by the response of startups to the tax cut. Table 5 shows that per dollar of
Table 5: Effects of Temporary Tax Cuts

<table>
<thead>
<tr>
<th>Level of aggregation</th>
<th>Average Variation (Cents per dollar of tax stimulus)</th>
<th>Investment</th>
<th>Output</th>
<th>Dividend</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aggregate</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impact multiplier</td>
<td></td>
<td>25.7</td>
<td>3.5</td>
<td>74.3</td>
</tr>
<tr>
<td>Cumulative multiplier</td>
<td></td>
<td>4.6</td>
<td>7.2</td>
<td>1</td>
</tr>
<tr>
<td><strong>Firm-level</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Impact multiplier)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Startups</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constrained</td>
<td></td>
<td>100</td>
<td>24.8</td>
<td>0</td>
</tr>
<tr>
<td>Unconstrained</td>
<td></td>
<td>-0.02</td>
<td>-3.0</td>
<td>100.02</td>
</tr>
<tr>
<td><strong>Continuers</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constrained</td>
<td></td>
<td>82.4</td>
<td>16.5</td>
<td>17.6</td>
</tr>
<tr>
<td>Unconstrained</td>
<td></td>
<td>-34.1</td>
<td>-11.8</td>
<td>134.1</td>
</tr>
</tbody>
</table>
additional revenue obtained through tax cut, one year old firms devote 68 cents to investment and use the remaining to pay dividend. In average, their output increases by around 16 cents. The multiplier is even larger for constrained startups. In fact, constrained one year old firms devote the entirety of the tax cut to investment and the policy achieves full effectiveness. However, the investment elasticity of unconstrained young firms differs qualitatively. They increase dividend payment by more than 1 dollar per dollar of tax stimulus. That is, they use not only all the revenue provided by the tax cut but they also subtract from their investment to increase dividend payments. In average, constrained young firms’ output increases by almost 25 cents while unconstrained young firms reduce output by less than 1 cent per dollar of tax stimulus.

The continuers’ investment responsiveness is qualitatively similar to that of startups. Quantitatively, their multiplier is smaller. In average per dollar of tax stimulus, continuers’ investment and output increase by about 23.4 and 2.2 cents, respectively. Again, within continuers, constrained firms expand while unconstrained ones shrink. Constrained firms increase investment by more than 80 cents while unconstrained firms reduce investment by more than 34 cents. To further explain the firm level behavior, let us focus on Figure 8.

![Figure 8: Investment Decisions Pre versus Post Tax Cuts](image)
Figure 8 plots the investment decision rules for a given value of the productivity shock at period 1 (period of the tax cut) with (in blue) and without (in red) the tax cut. Before explaining the effects of the tax cut on the investment decision of individual firms, let us first focus on the red curve which describes the firm’s investment decision without a change in the tax policy. As one can see, the curve has an upward slope for small firms and becomes horizontal after some level of capital. The rising portion of the curve represents the capital decisions of constrained firms while the horizontal portion refers to the decision rules of unconstrained ones. To understand this, let assume that firms have access to an unlimited borrowing. As there is no adjustment cost in our model, all firms should instantaneously choose their optimal size of investment independently of their initial capital stock. In this case, the investment decision rule should be an horizontal line. This is exactly what happens in our model for unconstrained firms, whose investment jumps instantaneously to their optimal size. However, as constrained firms’ investment is limited by their cash flows, it adjusts gradually toward the optimal level. This explains why the curve shows an upward slope for smaller firms.

Now, let us explain how the tax cut affects firm-level investment. To do this we will compare the red curve to the blue one. The two curves plot the capital decision of firms at the period of tax cut for the same value of productivity. Accordingly, the change in the tax rate is the unique fact that should justify any difference between these two curves. The response of the firm to the policy depends on the extent to which its investment is initially distorted. Especially, Figure 8 shows that we can distinguish three types of firms by comparing the two curves. On the left, we have the firms which are initially constrained and remain constrained after the tax cut. On the right, we have the firms which are unconstrained before the tax cut. As expected, these firms remained unconstrained after the tax cut. Between the two dashed-vertical lines, we have initially constrained firms which become unconstrained after the tax cut.
Let us start by the left, that is, the investment response of initially constrained firms. For a given level of installed capital, the blue curve is above the red curve meaning that initially constrained firms increase investment. The intuition behind this result is that the investment of initially constrained firms was limited by their cash flows. By providing additional cash flows, the tax cut releases the constraint and stimulates their investment. Figure 9 shows that those keep their dividend payments almost unchanged meaning that they devote almost the entirety of the tax cut to investment.

Now, let us focus on the firms which were initially unconstrained. Figure 8 shows that they reduce their investment. Their behavior is explained by the effects of the tax cut on interest rate. In fact, the increased aggregate demand for capital by initially constrained firms generates an excess demand of capital. This excess capital demand puts upward pressure on interest rate and induces consumer to consume less and save more for investment. The rise in interest rate discourages the investment of unconstrained firms which reduce their capital demand. Consistent with the investment response, Figure 9 shows that they distribute more dividends.
Finally, let us consider the decisions of firms which were initially constrained but become unconstrained after the tax cut. After the tax cut, the smaller ones remain undersized and expand in order to reach their optimal size. The larger ones appear to be oversized. As response, they reduce their investment to their optimal level. Figure 9 shows that those which are oversized increase their dividend payment.

7 Conclusion

We have assessed the effectiveness of temporary reductions in corporate taxes in raising aggregate investment and output. The mechanism we have focused upon is related to the presence of financing constraints. Temporary tax relief for firms raises investment because credit constrains induce high marginal propensities to invest. Our analysis has traced out the full transition following the tax cut, using a model with heterogeneous firms. Our main finding is that this policy is reasonably effective at raising investment. The effect on impact is an increase in investment by 26 cents per dollar of tax stimulus, and an increase in aggregate output by 3.5 cents. The cumulative effects are increases in investment and output of 4.6 and 7.2 cents, respectively.

There are several ways in which our analysis could be improved. One would ideally study the policy experiment in an environment with aggregate uncertainty, and cyclical variation in the severity of financing frictions. It would also be interesting to endogeneize entry and exit decisions, given that temporary changes in corporate taxation could have potentially important effects along these margins. Finally, the model could be very easily amended to incorporate distortionary taxation, which would allow us to incorporate the intertemporal substitution effects typically considered in the literature into our analysis.

References


Appendix

A Approximation of Stationary Equilibrium

The algorithm used to solve for the stationary equilibrium consists of the following steps.

1. We guess value for wage, and solve for the optimal decision rules of an incumbent firm.

2. Given the value function of incumbent, we compute the optimal decision rules of a new entrant.

3. We compute the stationary distribution by simulate the economy for $T$ periods, starting from an arbitrary initial condition. Especially, we consider one incumbent and track it over time using Incumbents’ decisions rules, new entrants decision rules, exit shock, and productivity shocks until convergence of the distribution.

4. Finally, we check whether the labor market equilibrium condition holds. If not, we adjust the wage and go back to the first step.

We now provide more details about each step.

A.1 Approximation of Incumbent’s Value Function

1. Construct a grid on the capital space $\{k_1, k_2, \cdots, k_n\}$, $k_j < k_{j+1}$, such that $k_1 < k$ and $k_{N} > \bar{k}$ where $k$ (respectively $\bar{k}$) are lower and upper bounds for capital.

2. Guess an initial wage $w^0$ and solve the dynamic program of the incumbent. We consider continuous decision rules using linear interpolation to interpolate value function.

\[
V^{j+1}(k^i, \epsilon_q) = \max_{k' \in [k_1,k_N]} d(k_i, \epsilon_q, k') + \beta \left[ \eta k' + (1 - \eta) W^{j+1}(k^i, \epsilon_q, k') \right]
\]

where $W$ is defined below:
i. Initialize the algorithm with an arbitrary value $V^0$

\[
V^0(\epsilon_1, k'_1) \cdots V^0(\epsilon_1, k'_{nk}) \\
\vdots \quad \vdots \quad \vdots \\
V^0(\epsilon_n, k'_1) \cdots V^0(\epsilon_n, k'_{nk})
\]

ii. For a capital stock $k_i$, compute the expected value function for choosing future capital $k'$, conditional on current shock $\epsilon$:

\[
\text{Futval}_i(\epsilon) = \begin{bmatrix}
p_{11} & \cdots & p_{1n} \\
\vdots & \ddots & \vdots \\
p_{n1} & \cdots & p_{nn}
\end{bmatrix} \begin{bmatrix}
V^0(\epsilon_1, k'_1) & \cdots & V^0(\epsilon_1, k'_{nk}) \\
\vdots & \ddots & \vdots \\
V^0(\epsilon_n, k'_1) & \cdots & V^0(\epsilon_n, k'_{nk})
\end{bmatrix}
\]

\[
= \begin{bmatrix}
EV^0(k'_1|\epsilon_1) & \cdots & EV^0(k'_{nk}|\epsilon_1) \\
\vdots & \ddots & \vdots \\
EV^0(k'_1|\epsilon_n) & \cdots & EV^0(k'_{nk}|\epsilon_n)
\end{bmatrix}
\]

iii. Allow continuous decision rules by using linear interpolation. Especially, compute the expected interpolated function value $W^{j+1}(k^i, \epsilon_q, k')$ as follows:

\[
W^{j+1}(k^i, \epsilon_q, k') = \\
\begin{bmatrix}
A^j_1 EV^j(k'_1|\epsilon_q) + (1 - A^j_1) EV^j(k'_2|\epsilon_q) \\
\vdots \\
A^j_m EV^j(k'_{m+1}|\epsilon_q) + (1 - A^j_m) EV^j(k'_{m+2}|\epsilon_q) \\
\vdots \\
A^j_{nk-1} EV^j(k'_{nk-1}|\epsilon_q) + (1 - A^j_{nk-1}) EV^j(k'_{nk}|\epsilon_q)
\end{bmatrix}
\]

where: $A^j_m = \frac{k'_{m+1} - k'}{k'_{m+1} - k'_{m}}$

iv. Keep iterating on the bellman equation until convergence of the Value Function, i.e. until:

\[\max_{\epsilon} \left\| \frac{V^{j+1}(\epsilon) - V^j(\epsilon)}{10^{-3} + |V^j(\epsilon)|} \right\|_\infty < \zeta\]

where $\zeta$ (in practice $\zeta = 10^{-6}$) is a convergence criterion.
A.2 Approximation of New Entrant’s Value Function

- Given the value function of Incumbents at all possible states, and the same grid of capital as before, compute the following object $W^e$ defined by:

$$W^e = \begin{cases} 
\sum_{\epsilon_j \in E} \Pr(\epsilon_0 = \epsilon_j) [A^\epsilon_1 V(k^\epsilon_1, \epsilon_0) + (1 - A^\epsilon_1) V(k^\epsilon_2, \epsilon_0)] \text{ for } k^\epsilon \in [k_1, k_2] \\
\vdots \\
\sum_{\epsilon_j \in E} \Pr(\epsilon_0 = \epsilon_j) [A^\epsilon_1 V(k^\epsilon_1, \epsilon_0) + (1 - A^\epsilon_1) V(k^\epsilon_2, \epsilon_0)] \text{ for } k^\epsilon \in [k_m, k_{m+1}] \\
\vdots \\
\sum_{\epsilon_j \in E} \Pr(\epsilon_0 = \epsilon_j) [A^\epsilon_1 V(k^\epsilon_1, \epsilon_0) + (1 - A^\epsilon_1) V(k^\epsilon_2, \epsilon_0)] \text{ for } k^\epsilon \in [k_{n_k-1}, k_{n_k}] 
\end{cases}$$

where $A^j_m = \frac{k^\epsilon_{m+1} - k^\epsilon_m}{k^\epsilon_{m+1} - k^\epsilon_m}$.

- $V^e = \max_{k^\epsilon \in [k_1, k_n]} -k^\epsilon + \beta W^e$

A.3 Model Simulation

1. Start by initializing an incumbent firm with a pair $(k_0, \epsilon_0)$.

2. Simulate exit shocks by drawing random numbers from the Bernoulli distribution with success probability $\eta$.

3. For each period when the firm exits, draw the productivity shock of the following period from the unconditional distribution $\pi$ associated to the transition matrix. Especially, the Initial productivity shocks are generated using the Inverse Transform Sampling Method.

4. Between two exits, use a random number generator to simulate the markov chain.

5. Given the decision rule $k'(k, \epsilon)$, the transition matrix of the markov chain $\pi(\epsilon', \epsilon)$, and the entry-exit shock, construct the transition function of the aggregate state of the economy conditional on the candidate wage, $\Gamma(w^0)$. Then by successive iterations on the cross-section distribution, obtain the fixed point distribution $\mu^*(w^0)$. Especially:
i. From the 1001st realization, compute a set of moments $H^t$ to summarize the distribution of firms for every period. In practice, consider mean and standard deviation of capital stock.

ii. After each 1000 periods, check whether $H^t$ is close enough to $H^{t+1000}$, i.e. $\|H^{t+1000} - H^n\|_\infty < \iota$, where $\iota$ is a convergence criterion. In practice, use $\iota = 10^{-3}$.

A.4 Labor Market Clearing

1. After reaching the fixed point distribution, compute aggregate variables: $Y(w^0), N(w^0), K(w^0)$. For example for $M$ simulations:

$$N^d(w^0) = \frac{\sum_{i=1001}^{M} n^i(w^0)}{M - 1000}$$

2. Compare $N^d(w^0)$ to the target of labor Supply $N^s = 1$ to verify the labor market clearing condition. At iteration $j$, update the guess to $w^{j+1}$ and go back to step 1 until labor market clears:

- $w_t^{j+1} = \left[ N_t^d \geq 1 \right] \left[ \frac{w_t^j + \bar{w}_t^j}{2} \right] + \bar{w}_t^j [N_d \leq 1]$.
- $\bar{w}_t^{j+1} = \left[ N_t^d \leq 1 \right] \left[ \frac{w_t^j + \bar{w}_t^j}{2} \right] + \bar{w}_t^j [N_d \geq 1]$.
- $w_t^{j+1} = \frac{w_t^{j+1} + \bar{w}_t^{j+1}}{2}$.

B Approximation of The Transition Path

Assume that the economy starts in the steady state associated with the initial tax rate $\hat{\tau}$. After the tax cut at period 1, the economy goes into a transition. As the tax is reverted to its initial level from period 3, the economy converges to the initial steady state. Assume that for $t \leq T$, the economy reaches the steady-state. We can then solve for the transitional dynamics from period 0 to $T$ as follows.
1. We compute the stationary equilibrium objects: $\tilde{w}, \tilde{r}, \tilde{C}, \tilde{V}, \tilde{V}^\text{Ent}$, and fix the length of the transition, $T$.

2. We guess paths for consumption $\{C_t\}_{t=1}^T$ and wage $\{w_t\}_{t=1}^T$ such that $C_T = \tilde{C}$ and $w_T = \tilde{w}$.

3. Given the consumption path, we derive the path for interest rate $\{r_{t+1} = \frac{C_{t+1}}{w_{t+1}} - 1\}_{t=1}^{T-1}$; $\tau_1 = \tilde{r} - \Delta \tau; \tau_2 = \tilde{r} + (1 + r_2)\Delta \tau$; and $b_{t+1} = 0, \forall t \in [2, T]$.

4. Given $\{w_t, r_{t+1}\}$, solve the dynamic problem of incumbents by backward induction assuming that $\hat{\tilde{V}}_{T+1}(s) = \tilde{V}(s)$ and derive $\{\hat{\tilde{V}}(s)\}_{t=1}^T$ and the associated policy function $\{\hat{k}_{t+1}(s)\}_{t=1}^T$, $\forall s$.

5. Given the policy and value functions of incumbents, we solve for the value and policy functions of new entrants: $\{\hat{\tilde{V}}^\text{Ent}_t\}_{t=1}^T; \{\hat{k}_{e t+1}\}_{t=1}^T$.

6. Given the policy functions, the entry and exit shocks, and the initial distribution $\mu_1 = \tilde{\mu}$, we simulate histories of length $T$ for $M$ firms drawn from the stationary distribution and compute $\{\hat{I}_t, \hat{\tilde{Y}}_t, \hat{N}_t, \hat{r}_{t+1}\}_{t=1}^T$ using the implied sequence of cross-sectional distribution $\{\mu_t\}_{t=1}^T$. Then, we use the resource constraint, $\hat{\tilde{C}}_t = \hat{\tilde{Y}}_t - \hat{I}_t - G$, to derive the implied path of consumption $\{\hat{\tilde{C}}_t\}_{t=1}^{T-1}$.

7. We check if the implied consumption and employment are consistent with market clearing. More precisely, if $\max \left( \frac{1}{T} \sum_{t=1}^T \left( \frac{\hat{\tilde{C}}_t - C_t}{C} \right)^2, \frac{1}{T} \sum_{t=1}^T \left( \hat{N}_t - 1 \right)^2 \right) \leq \varsigma$, then stop. Otherwise, update both $\{C_t\}_{t=1}^T$ and wage $\{w_t\}_{t=1}^T$, and return to step 2 until convergence.