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Financial Frictions and Stimulative Effects of Temporary Corporate Tax Cuts

by William Gbohoui and Rui Castro

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Financial Frictions and Stimulative Effects of Temporary Corporate Tax Cuts[1]

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Abstract

This paper uses an industry equilibrium model where some firms are financially constrained to quantify the effects of a transitory corporate tax cut funded by a future tax increase on the U.S. economy. It finds that by increasing current cash-flows tax cuts alleviate financing frictions, hereby stimulating current investment. Per dollar of tax stimulus, aggregate investment increases by 26 cents on impact, and aggregate output by 3.5 cents. The average effect masks heterogeneity: multipliers are close to 1 for constrained firms, especially new entrants, and negative for larger and unconstrained firms. The output effects extend well past the period the policy is reversed, leading to a cumulative multiplier of 7.2 cents. Multipliers are significantly larger when controlling for the investment crowding-out effect among unconstrained firms.

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Contents Page

Figures

I. Introduction

Policymakers often rely on temporary corporate tax cuts in order to increase business investment in recession times. One motivation for such policies is tied to the idea of a *tax incentive* provision, to the extent that they affect intertemporal investment prices. A much more common motivation, however, is tied to the idea of a *tax relief*. One view consistent with this idea is that firms face financial frictions, and access to credit might be particularly tight during recessions. A reduction in corporate taxation during downturns may help alleviate financial market imperfections by having the government effectively supply external funds. Aggregate investment and output are expected to increase as a result, mitigating the economic slowdown.

Our goal is to quantify the effectiveness of the tax relief role of temporary corporate tax cuts, when firms are subject to financing frictions. Temporary tax cuts are funded by public debt, paid back eventually by future tax increases, so that only the timing of corporate taxation changes. In reality, these measures do not typically target statutory taxation. We are therefore interested in a broad, effective notion of corporate income taxes which is inclusive of all available deductions, namely depreciation allowances (Djankov and others, 2010; Feldstein, Dicks-Mireaux, and Poterba, 1983), which are often changed in times of crisis (e.g. Bush and Obama tax cuts in the U.S., Harper tax cuts in Canada). In short, we are interested in all tax provisions which might directly or indirectly impact firms' cash flows. Hence, we focus on lump-sum taxes to isolate this liquidity effect from the traditional substitution effects of tax policy widely studied in the literature.

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. As the policy reverses and corporate taxation eventually increases, the stimulative effect on investment is also partially reversed. Over the long-run, the cumulative investment multiplier is just 4.6 cents per dollar of tax stimulus. The stimulative effect on output is instead very persistent, as the initial buildup of capital increases future cash-flows and allows firms to relax financial constraints, long after the period of the tax cut reversal. We find a cumulative output multiplier of 7.2 cents per dollar of tax stimulus. These are reasonably large multiplier effects. They are not larger since 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 either very close or equal to one, especially among new entrants. For these firms, the tax cut is entirely 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. To quantify the crowding out effect, we prevent the wage and the interest rate from adjusting, and find that the multipliers could be twice as large for investment, and three times larger for output.

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 face 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. We assume that 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 estimating the expansionary effect of the corporate tax cut policy. We infer these features by requiring the model to match certain properties of the cross-sectional distribution of cash flow and investment rates across U.S. establishments.

The literature has mostly evaluated the tax incentive justification for temporary corporate tax cuts, which relies on intertemporal substitution. The simple intuition is that, when the reduction in taxes is temporary, firms 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. Abel (1982) shows, in a partial equilibrium setting, that temporary investment tax credits are in general more stimulative than permanent ones, except under constant returns to scale technology, when the effect is the same. He also shows that temporary changes in distortionary corporate taxes are stimulative for investment.

Another example is Dotsey (1994), who considers an environment where the government is subject to an intertemporal budget constraint and capital income taxes in any given period are stochastic. In this setting, as in ours, lowering capital taxes today entails higher expected taxes in the future. With distortionary taxation, Dotsey (1994) shows that a temporary tax cut may actually lower investment today, as long as the negative effect of higher future distortions dominates the incentive effect on 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) employ a setting 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 financing policy choice (retained earnings, debt, equity) and how it impacts investment, whereas we consider 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 one, we assume lump-sum corporate taxes. Our setup therefore satisfies a Ricardian proposition, in the sense that absent financial frictions temporary corporate tax cuts produce no aggregate effects. Firm-level investment is insensitive to the additional cash flows generated by the tax cut, which are fully transferred to households in the form of higher dividends. Households then save the additional income in order to pay for the future tax increases and the output and investment multipliers are zero, just like in the more familiar Ricardian proposition setting as shown by Gbohoui (2018).

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 U.S. 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 at different time horizons. Our results show that the expansionary effect is reasonably large. These results are analogous to Heathcote's (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.

II. Model

The model consists of a representative household, a continuum of heterogeneity firms with a unit mass, and a government. Similar general equilibrium setups with heterogeneous firms subject to constraints on the access to external finance include Gomes (2001), Khan and Thomas (2013) and Zetlin-Jones and Shourideh (2017).[1]

A. Firms

Firms face both idiosyncratic productivity shocks, and idiosyncratic entry and exit shocks. The current productivity shock, denoted by z_t, follows a Markov chain with transition probabilities $\pi(z_t, z_{t-1})$ and takes values on the finite set Z.

The entry and exit shock follows a Bernoulli process. Each incumbent firm faces a per period exit probability of $\eta \in (0,1)$, after investment but before production takes place. In every period, the total mass η of exiters is replaced by an equal mass of entrants, each drawn from an homogenous pool of potential entrants. The total mass of active firms in every period is normalized to 1.

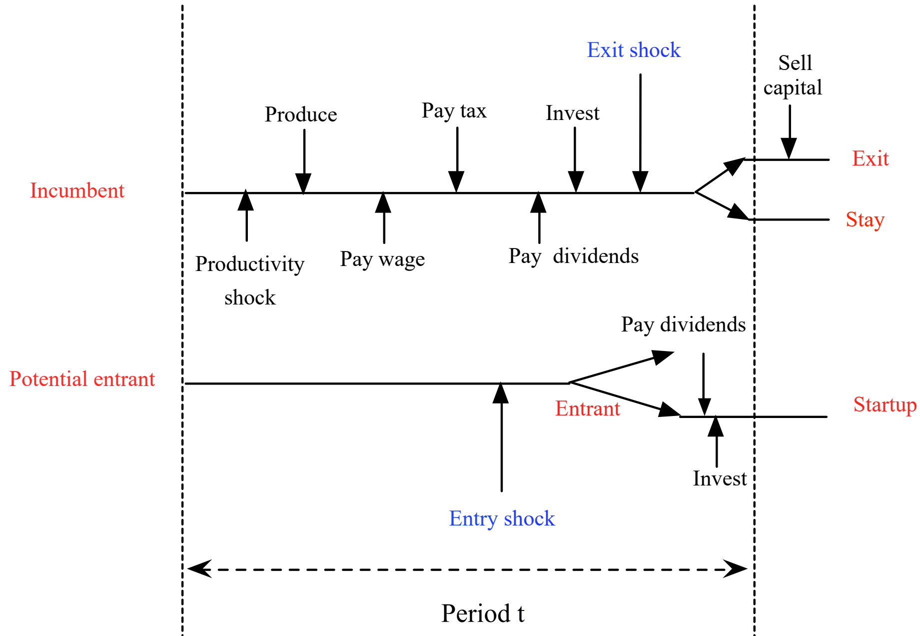
Our modelling of entry and exit is similar to the existing literature, see for example Khan and Thomas (2013). Entry and exit allows for a nontrivial equilibrium firm distribution and ensures some firms will always be financially constrained. We assume a law of large numbers holds so that aggregate quantities and prices are deterministic for given government policy.

Figure 1 illustrates the timing of the model. At the beginning of period t, incumbents draw a productivity shock, and then hire labor, produce, pay corporate taxes, invest in physical capital, and pay dividends to their shareholders. An exit shock is drawn at the end of the period. If an incumbent is to exit, it sells its capital stock at the beginning of next period, and permanently leaves the industry.

Potential entrants are ex-ante identical, and they all start with no initial capital. Upon entering the industry at time t, a new entrant needs to raise funds and invest in order to begin producing

[1]Other related papers include Jermann and Quadrini (2012), who consider a business cycle model of a representative firm subject to financial frictions, and Bassetto, Cagetti, and De Nardi (2015), who consider a business cycle model of heterogeneous entrepreneurs subject to financial frictions.

Figure 1. Timing of the model



next period. These new entrants become incumbent firms at time $t + 1$, and they all begin production with the same initial level of capital.

Firms are owned by the representative consumer. We simplify our analysis by assuming firms are all-equity, and by abstracting from variation in the amount of equity (equity issuance or repurchases).[2] Upon entry, the representative household is endowed with one unit of equity shares in the firm. Each share entitles the household to a stream of dividends, starting from the current period. In our environment, firms require negative dividends in order to raise external funding.[3]

[2]Abstracting from access to the bond market is without loss of generality in the present setting, where taxation is lump-sum. This is an instance of the Modigliani-Miller proposition, only the level of external funding matters, not the capital structure. Further, working with equity simplifies the analysis since we don't need to carry the current debt level as a state variable in the firm's problem. Gourio and Miao (2011) also consider an all-equity baseline model. Differently from us, in their case firms may raise unlimited amounts of external funding through new equity issuance. Their focus is on the implications of distortionary taxation for payout policies (dividend vs stock repurchases).

[3]In the context of all-equity firms, this formulation is isomorphic to one where dividends are non-negative but firms may either issue new equity or make equity repurchases. Positive dividends in the simplified formulation should therefore be interpreted as net firm payouts (dividends plus net equity repurchases), and negative dividends as instances of new equity issuance.

1. Incumbent Firm

We formalize the problem of the firm when government policy follows a deterministic path, likewise for aggregate prices. Denote by $V_t(k_t, z_t)$ the value of a firm at time t, with capital stock k_t and productivity shock z_t. The Bellman equation is:

$$V_t(k_t, z_t) \quad = \quad \max_{n_t, k_{t+1}, d_t} \left\{ d_t + \frac{1}{1+r_{t+1}} \left[\eta k_{t+1} + (1-\eta) \sum_{z_{t+1}} \pi(z_{t+1}, z_t) V_{t+1}(k_{t+1}, z_{t+1}) \right] \right\}$$

subject to

$$d_t \quad = \quad y_t + (1-\delta)k_t - w_t n_t - \tau_t - k_{t+1} \tag{1a}$$

$$d_t \quad \geq \quad -\bar{d} + \zeta k_t, \tag{1b}$$

for $t = 0, 1, \ldots$, where output is $y_t = z_t \left({k_t}^{\alpha} n_t^{1-\alpha} \right)^{\nu}$, with $0 < \alpha, \nu < 1$, and $\delta \in (0,1)$ is the depreciation rate. A decreasing returns to scale technology ensures that firm size is always well-defined.

Equation (1a) describes the flow of funds condition for the firm. Output is the only cash inflow, while cash outflows include gross investment expenditures, plus tax liabilities, plus wage and dividend payments. Upon exit, the firm's capital stock shows up as a payout to the household. Incumbents cannot issue new equity nor make equity repurchases.

Without any constraint on dividend payments, temporary (lump-sum) tax cuts do not affect firms' decisions. Firms simply distribute the higher cash flows to the household in the form of higher dividend payouts. The household then behaves according to the standard permanent income hypothesis, and saves the additional income in order to pay for the future tax increases. The policy change produces no aggregate investment or output effects.

Our departure from the Ricardian benchmark stems from the presence of (1b).[4] This constraint simultaneously captures two types of restrictions on net payouts. First, we impose an upper bound on the access to external funds $-\bar{d} < 0$, which is unconditional on firm size as measured by the stock of capital. Second, we also impose a minimum dividend payout requirement, which is increasing in firm size for $\zeta > 0$.[5]

[4] Notice that, in addition to lump-sum taxation, our assumption of exogenous entry and exit is also important to deliver a Ricardian benchmark. In general, entry and exit decisions won't be neutral to changes in lump-sum taxes.

[5] Let $d_t^p \geq 0$ be the total amount of dividend payouts. Let $d_t^b \geq 0$ denote the total amount of borrowing from the household sector. As explained previously, we assume this borrowing takes the form of negative dividends. We impose $-d_t^b \geq -\bar{d}$, i.e. $d_t^b \leq \bar{d}$, and $d_t^p \geq \zeta k_t$. Since we model net dividend payouts $d_t \equiv -d_t^b + d_t^p$, the

The first restriction is our key friction governing firms' access to external funds. Our second restriction can be justified by appealing to the notion that minimum dividend payments may help mitigate agency problems between shareholders and managers and work as signaling device (see Allen and Michaely, 2003, for a review). The fact that they're increasing with firm size is also consistent with evidence that large corporations tend to pay out a larger fraction of their earnings (Allen and Michaely, 2003). Bianchi (2016) adopts a similar dividend payout policy, although we allow it to vary with firm size.

Our main motivation for adopting this flexible specification is for calibration purposes. Having $\zeta > 0$ effectively tightens the financial constraints faced by larger firms.[6] This parameter affords us better control in matching the average size of entrants relative to the average size of incumbents.

Let λ_t be the Khun-Tucker multiplier associated with (1b). The optimality conditions for labor is standard one, since it is not distorted by the dividend constraint. The one for capital is:

$$1+\lambda_t = \frac{1}{1+r_{t+1}}\left\{\eta + (1-\eta)\mathrm{E}_t\left[-\zeta\lambda_{t+1} + (1+\lambda_{t+1})\left(1-\delta+\frac{\partial y_{t+1}}{\partial k_{t+1}}\right)\right]\right\}. \tag{2}$$

One important point stemming from (2) is that lump-sum corporate taxation affects the firm's investment behavior when the dividend constraint (1b) binds. This effect is summarized in the value of the multipliers $\lambda_t, \lambda_{t+1} > 0$. If the dividend constraint is instead slack, then lump-sum corporate taxes do not impact investment decisions. This sets our paper apart from the related literature emphasizing the intertemporal substitution effects of tax cuts (Abel, 1982; Dotsey, 1994; Gourio and Miao, 2011).

When (1b) binds today ($\lambda_t > 0$), we see from (2) that the expected discounted marginal gain from investing an additional unit on the right-hand-side exceeds the marginal cost on the left-hand-side, which equals one unit less of dividend payouts today. Relaxing the dividend constraint today therefore reduces the shadow marginal cost 1+λ_t relative to the marginal gain, and the firm invests more.

When (1b) doesn't bind tomorrow ($\lambda_{t+1} = 0$) we obtain the familiar terms for the discounted marginal gain of investing. That is, either the value of undepreciated capital plus the marginal product of capital if the firm survives, or the value of the investment if the firm exits. When

overall constraint on this variable is therefore as in (1b). Whenever (1b) binds in our model, then $-d_t^b = -\bar{d}$ and $d_t^p = \zeta k_t$. Otherwise, d_t is split arbitrarily between d_t^b and d_t^p, subject to $-d_t^b \geq -\bar{d}$ and $d_t^p \geq \zeta k_t$.

[6] Financial constraints are still overall tighter for smaller firms in the model, since these tend to be farther away from their unconstrained optimal size. See the discussion surrounding Figure 2.

$\lambda_{t+1} > 0$, and conditional on survival, the value of future cash flows is higher, since they help fund future investment: a larger firm tomorrow generates more cash-flows, which relaxes tomorrow's dividend constraint. A larger firm size tomorrow, however, also tightens the dividend constraint tomorrow through the dividend payout requirement, which lowers the marginal gain from investing. This is the term associated with ζ in (2).

Equation (2) illustrates the static and the dynamic effects that changes in corporate taxation produce on the current investment decision. Suppose, as we shall consider later, that the government decides to defer corporate taxation. Specifically, suppose today's taxes are lower, and tomorrow's higher. This produces strong investment incentives today, since not only λ_t decreases but also λ_{t+1} increases in expectation. The firm decides to concentrate its investment activity today since (i) the additional cash-flows afforded by the tax cut help overcome today's financial constraint (static effect), and (ii) investing today generates additional cash-flows tomorrow which are now more likely to relax the tighter financial constraint tomorrow (dynamic effect). The dynamic effect is operative for firms which are not constrained today following the tax cut, but may be so in the future. Their investment increase today is for precautionary reasons.

What happens to investment tomorrow, as corporate taxation increases? Higher investment today generates higher cash-flows tomorrow, which partially counteract the effect of higher corporate taxes. As a result, we don't expect aggregate investment to be as sensitive to the tax increase compared to the tax cut.

2. New Entrant

A new entrant is like an incumbent with a zero capital stock, and no corporate tax liability. Its main decision is to invest to start operating next period. In order to invest, the new entrant requires a negative dividend payout from the household in the current period. In line with (1b), and given that $k^e_t = 0$, this negative payout is limited only by $\bar{d}$.

The new entrant solves

$$V^e_t = \max_{k^e_{t+1}, d^e_t} \left\{ d^e_t + \frac{1}{1+r_{t+1}} \sum_{z_{t+1}} \bar{\pi}(z_{t+1}) V_{t+1}(k^e_{t+1}, z_{t+1}) \right\}$$

subject to

$$\begin{aligned} 0 &= k^e_{t+1} + d^e_t && (3) \\ d^e_t &\geq -\bar{d}, && (4) \end{aligned}$$

where $\bar{\pi}(z_{t+1})$ is the long-run probability of state z_{t+1}, and V_{t+1} is the incumbent's value function defined previously. The initial productivity of new entrants is therefore drawn from the stationary distribution of the Markov chain.

Equation (3) is the cash-flow constraint of the firm, and (4) the constraint on the net payout. Since they don't produce, new entrants do not pay corporate income taxes.[7] And since they are homogeneous, they all choose the same initial level of capital. In addition, our parameterization is such that $\bar{d}$ is sufficiently low compared to the unconditional mean of the productivity shocks, so that new entrants will always find themselves constrained. The solution to their problem is:

$$\begin{aligned} d_t^e &= -\bar{d} \\ k_{t+1}^e &= k^e = \bar{d}. \end{aligned}$$

B. Aggregation

Denote the incumbent's decision rule for investment by $k_{t+1}(s_t)$, where $s_t \equiv (k_t, z_t)$ is the individual state. Let $S \equiv K \times Z$ denote the set of individual states, where K is the set of capital stock levels. Let Ω_S denote the product $\sigma - algebra$ on S with typical subset $\mathcal{A}$.

We can summarize the aggregate distribution of firms with a measure defined over the state space S by $\mu_t(\mathcal{A})$, which is the mass of firms engaged in production at time t, with state $s_t \in \mathcal{A} \subseteq S$. This includes incumbents as of $t-1$ which survive into t, and the new entrants replacing the exiters as of $t-1$.

Now define the transition function Q_t of incumbents across states:

$$\begin{array}{rcccl} Q_t & : & S \times \Omega_S & \to & [0,1] \\ & & (s_t, K \times Z) & \mapsto & Q_t(s_t, K \times Z) = \sum_{z_{t+1} \in Z} \pi(z_{t+1}, z_t) \mathbb{1}_{k_{t+1}(s_t) \in K}, \end{array}$$

where $\mathbb{1}_K$ is the indicator function on the set K.

For any Borel set $\mathcal{A} \in \Omega_S$, the law motion of the aggregate state of the economy is:

$$\mu_{t+1}(\mathcal{A}) = (1-\eta) \int_S Q_t(s, \mathcal{A}) \mu_t(s) ds + \eta \psi(\mathcal{A}), \tag{5}$$

[7] We make this assumption to partially deal with the fact that, with lump-sum taxation, small firms pay a proportionally high amount of taxes.

where ψ is the distribution of new entrants,

$$\psi(K \times Z) = \sum_{z_{t+1} \in Z} \bar{\pi}(z_{t+1}) \mathbb{1}_{k^e \in K}. \tag{6}$$

It is useful to define gross aggregate investment at this point:

$$i_t = \int_S k_{t+1}(s) d\mu_t(s) - (1-\delta)\left[(1-\eta)\int_S k_t(s) d\mu_{t-1}(s) + \eta k^e\right] + \eta\left[k^e - \int_S k_t(s) d\mu_{t-1}(s)\right], \tag{7}$$

where the first two terms correspond to the total gross investment of incumbent firms as of time t (which includes the fraction $1-\eta$ of those that were already operating at $t-1$, plus the fraction η of new entrants at $t-1$), and the last term corresponds to the investment of new entrants as of time t, net of the disinvestment of exiters.

C. Household

A representative household with unit measure derives utility from consumption alone, according to a standard time-additive utility function $u(c) = \log c$, with future utility discounted at rate $0 < \beta < 1$. A time endowment of 1 is supplied inelastically every period.

The household trades equity shares in the firms, as well as a government bond. Let $\theta_t(s)$ denote the shareholding of type $s \in S$ firms at the start of period t (θ_t^e for new entrants), valued at price $p_t(s)$ (p_t^e for new entrants), and b_t the government bondholding, paying interest rate r_t.

Let W_t denote the household's value function, which solves the Bellman equation:

$$W_t(\omega_t) = \max_{c_t, b_{t+1}, \theta_{t+1}^e, \{\theta_{t+1}(s)\}_{s \in S}} \{\log c_t + \beta W_{t+1}(\omega_{t+1})\} \tag{8}$$

subject to

$$c_t + b_{t+1} + \eta(p_t^e - d_t^e)\theta_{t+1}^e + \int_S p_t(s)\theta_{t+1}(s) d\mu_t(s) = \omega_t \tag{9a}$$

$$\omega_{t+1} \equiv w_{t+1} + (1+r_{t+1})b_{t+1} + \eta\int_S k_{t+1}(s)\theta_{t+1}(s) d\mu_t(s) + \int_S [p_{t+1}(s) + d_{t+1}(s)]\left[(1-\eta)\theta_{t+1}(s) + \eta\theta_{t+1}^e\right] d\mu_{t+1}(s). \tag{9b}$$

Equation (9a) is the household's budget constraint. The consumer spends his resources ω_t on consumption, government bonds, and equity sales of new entrants, net of current dividend payouts, plus equity purchases of incumbents at time t. Income from (9b) equals labor earnings, plus the income from government bondholdings, plus the income from physical capital sales of exiting firms, plus shareholding income. The latter equals the dividend plus share value of new entrants at time t and surviving incumbents from t to $t+1$.

The sole outcome from the household's problem which is relevant for our analysis is the real interest rate determination. From the first-order condition for government bonds

$$\frac{c_{t+1}}{c_t} = \beta(1+r_{t+1}),$$

and in steady-state we obtain $1 = \beta(1+r)$.

D. Government

Government spends a constant amount of resources $g > 0$ at each time t, funded either by lump sum corporate taxation, providing total revenue equal to τ_t, or by issuing one period debt b_{t+1}, held by the representative consumer.[8] The government's budget constraint is

$$(1+r_t)b_t + g = \tau_t + b_{t+1},$$

together with the no Ponzi game condition:

$$\lim_{T\to\infty} \prod_{t=0}^{T} (1+r_t)^{-1} b_{T+1} \leq 0.$$

Requiring that the government wastes no resources and therefore satisfies the no Ponzi game condition with equality, we obtain the present value budget constraint:

$$b_0 + g\sum_{t=0}^{\infty}\prod_{i=0}^{t}(1+r_i)^{-1} = \sum_{t=0}^{\infty}\prod_{i=0}^{t}(1+r_i)^{-1}\tau_t, \tag{10}$$

where we assume $b_0 = 0$.

The government's policy will be a sequence $\{\tau_t, b_{t+1}\}_{t=0}^{\infty}$ of tax rates and debt issuance which satisfies (10).

[8] We also assume g is small enough relative to average productivity, so that government spending does not necessarily exhaust aggregate production.

E. Stationary Equilibrium

We now provide a formal definition of the equilibrium, focusing on the steady-state. Given a stationary government policy $(\tau_t, b_{t+1}) = (\tau, b)$, a stationary recursive competitive equilibrium is a value function $V(s_t)$, with $s_t \equiv (k_t, z_t)$, and a set of decision rules for incumbents, $n(s_t)$, $k(s_t)$, $y(s_t)$ and $d(s_t)$, a decision rule for new entrants k_e, a value function W and a set of decisions for the representative household c, b, θ^e and $\{\theta(s_t)\}_{s_t \in S}$, time-invariant cross-sectional distributions of new entrants and incumbents, respectively μ and ψ, and prices r, w, $\{p(s_t)\}_{s_t \in S}$ and p^e such that:

1. Given prices, each agent's value function and decision rules solve their corresponding problem.

2. Given prices, the government's policy satisfies the present value budget constraint (10).

3. Markets clear:

   - Labor market: $\int_S n(s) d\mu(s) = 1$.
   - Equity market:
     new entrants: $\theta^e = 1$.
     incumbents: $\theta(s) = 1$, for all $s \in S$.
   - Final good: $\int_S y(s) d\mu(s) = i + c + g$, where i is defined in (7).

4. μ is the fixed point of (5), and ψ is defined in (6).

III. 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 both before and in the long-run following the tax cut. This requires first solving for the industry equilibrium given wages (the real interest rate is pinned-down by β), and then computing wages to clear the labor market. As part of the solution, we obtain aggregate consumption from the economy's resource constraint, with aggregate production and investment being the outcome of the industry equilibrium.

Second, for the transition of the economy following the transitory tax cut, we use a backward induction algorithm. We guess a transition length and a sequence of wages and real interest rates along the transition, and solve for the industry equilibrium and household consumption at each point in time. We then ensure that prices clear the labor and the final good markets at each point along the transition. The details of the numerical algorithm are in the Appendix.

IV. Calibration

The steady-state of the model is calibrated to U.S. data for establishment-level investment dynamics, and firm-level cash flow dynamics.[9] This data is reported annually, thus 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 1. Parameters Selected A Priori

Parameter		Value	Source
Returns to scale	υ	0.85	Atkeson and Kehoe (2005) and others
Capital elasticity	α	$1/3$	income share data
Discount factor	β	0.96	interest rate of 4%
Entry probability	η	0.05	(Evans, 1987; Lee and Mukoyama, 2015)

The return to scale parameter $\nu = 0.85$ has a standard value in the literature employing the same production function specification as ours (Atkenson, Khan, and Ohanian, 1996; Atkeson and Kehoe, 2005; Clementi and Palazzo, 2016; Gomes, 2001), as is the capital share parameter $\alpha = 1/3$.[10] This parameter is also consistent with several empirical studies estimating a degree of returns to scale just under 1 (Basu and Fernald, 1997; Burnside, 1996; Lee, 2007). The entry rate is exogenous and set to 5%. This value is standard in the literature and is in the range of the estimates by Evans (1987); Lee and Mukoyama (2015)who report 4.5% and 5.5%, respectively.

The parameters calibrated internally, by requiring the model to match a set of moments, are presented in Table 2. The corporate tax in the model delivers a value for the GDP share of corporate tax revenue as in the postwar period.[11] A challenge we face is that a large component of corporate income is nowadays taxed at the personal rather than at the corporate level, including

[9] Although we calibrate our model to establishment-level observations, we still refer to production units in our model as firms.

[10] In order to arrive at a 1/3 capital share in our model, we assume that the profits firms generate after incurring investment expenditures and making payments to labor are attributed to capital and labor according to the shares α and $1-\alpha$.

[11] The source is the White House Historical Tables. The tax revenue is reported on a domestic basis and therefore includes foreign corporations operating in the U.S.

both corporate profits of pass-through corporations (sole proprietorships, S corporations, partnerships, limited liability corporations) and capital gains and dividends subject to double taxation, both at the corporate and at the personal level. The corporate tax in the model delivers a value for the share of corporate tax revenue of GDP as in the data. From IRS (Internal Revenue Service) data, capital gains and dividend taxes represent roughly 1% of GDP on average for the 2000-2005 period. Taxes on S corporations (whose income is taxed at the shareholder rather than at the corporation level) account for around 1% of GDP over the 2004-2007 period. Corporate profits taxes represent about 2% of GDP on average over the 2000-2007 period. We therefore target a value of 4%.[12]

Table 2. Internal Calibration

Parameter		Value	Target	Data	Model
Tax rate, gov spending	τ, g	0.057	Corp tax revenue/GDP	0.040	0.041
Depreciation rate	δ	0.069	$avg(i)/avg(k)$	0.069	0.069
Productivity	$\bar{z}$	1.7	$sd\,(i/k)$	0.337	0.300
	σ	0.253	$avg\,(i/k)$	0.122	0.151
	ρ	0.618	$sd\,(cf/k)$	0.161	0.152
Borrowing limit	$\bar{d}$	1.574	$avg(cf)/avg(k)$	0.102	0.127
	ζ	0.382	Rel size entrants	0.52	0.585

The depreciation rate δ is calibrated to deliver an aggregate investment-to-capital ratio of 0.069. This is the same value targeted by Khan and Thomas (2013), and is based on private capital stock estimates from the Fixed Asset Tables, controlling for growth, for the 1954-2002 period.

Firm level productivity follows the discretized version of the $AR(1)$ process:

$$\ln z_t = (1-\rho)\ln \bar{z} + \rho \ln z_{t-1} + \sigma \varepsilon_t, \tag{11}$$

where ε_t follows an i.i.d. standard normal distribution. We discretize this process into a 5-state Markov chain using Tauchen's (1986) procedure. The three parameters of the AR(1) process are selected to match three cross-sectional moments: (i) a standard deviation of investment rates (as a fraction of capital) of 0.337, and (ii) an average investment rate of 0.122, both as reported by Cooper and Haltiwanger (2006) and used by Khan and Thomas (2013), (iii)

[12]Notice that the only important role g plays in the analysis is in ensuring a constant target for government revenue in our tax experiments.

a standard deviation of the cash-to-assets ratio of 0.161, as reported by Khan and Thomas (2013) using Compustat data for the 1954-2011 period.[13] Our autocorrelation coefficient (0.618) and the standard deviation of productivity shocks (0.253) are close to the values obtained in Khan and Thomas's (2013) and Clementi and Palazzo's (2016) calibrations.

The parameters governing the extent of financial frictions are key. We infer them by requiring that the model matches two additional moments relating to the plant-level dynamics: (i) an average employment size of new entrants (firms in their first production year) of 52% of the average size of incumbents, as reported by Moreira (2017), based upon establishment-level data spanning all sectors of activity from the U.S. Census Business Dynamics Statistics (BDS) 1978-2012;[14] (ii) an aggregate cash-to-asset ratio of 0.102, as reported by Khan and Thomas (2013) for Compustat data.

Our calibration leads to $\bar{d} > 0$ and $\zeta > 0$. As pointed out previously, this implies binding borrowing constraints, which are overall tighter for smaller firms. To illustrate this point, Figure 2 plots the ratio of actual to unconstrained investment levels in the model as a function of current capital (firm size).[15] Two lines are plotted, one for a high and the other for a low value of current (hence expected future) productivity. A value of one means the firm is operating at the unconstrained level, and the lower the ratio the tighter the borrowing constraint is. The parameter ζ allows us to control how fast this ratio increases with firm size. As the figure illustrates, the magnitude we obtain for ζ is still consistent with smaller firms, which generate less cash flows, being the most constrained. See Beck, Demirguc-Kunt, and Maksimovic (2005) and Angelini and Generale (2008) for some evidence consistent with this model prediction.

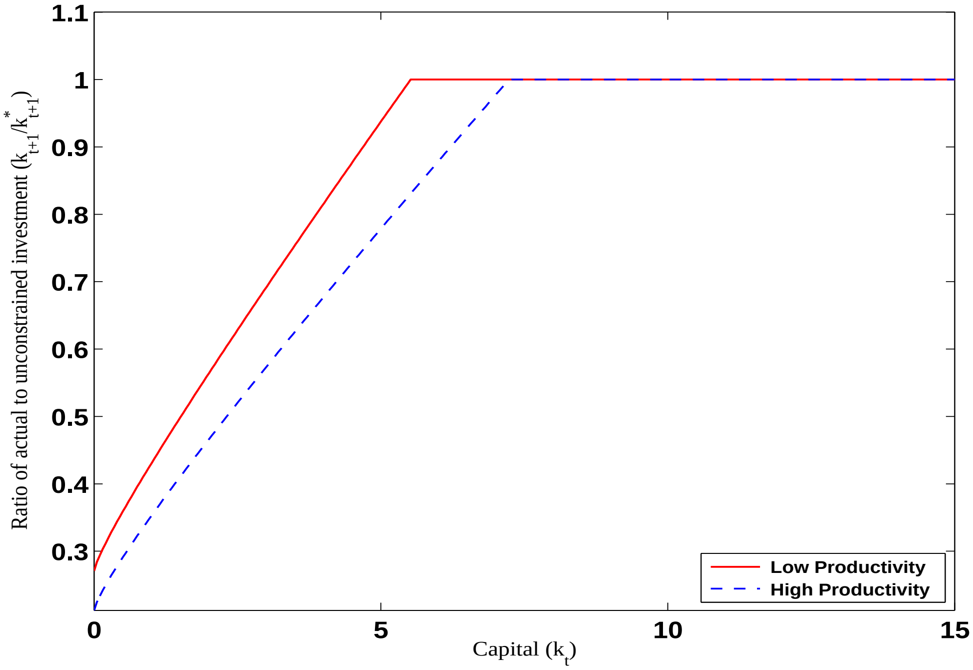
The figure also shows that high productivity firms are more constrained, given their higher unconstrained optimal level of investment. Our calibration, namely the degree of persistence of the productivity shocks, is such that this effect always dominates the effect of higher current cash-flows due to higher current productivity.

[13] In the data, "cash" corresponds to cash and equivalent assets with short maturity (less than 3 months). As the model counterpart of cash, we choose dividends conditional on them being positive, and zero otherwise.

[14] This figure is a bit lower than the 60% figure reported by Lee and Mukoyama (2015) from the U.S. Census Bureau's Annual Survey of Manufactures (ASM) over the period 1972-1997, but higher than the 10% used by Khan and Thomas (2013)

[15] The unconstrained investment level k^*_{t+1} is the solution to either the new entrant or the incumbent's problem when ignoring the dividend constraint.

Figure 2. Tightness of the Dividend Constraint



V. Steady-State Properties

A. Firm Size Distribution

Figure 3 plots the firm size distribution that obtains in the stationary equilibrium, when size is measured by either employment or capital. Figure 3a displays a right-skewed employment distribution which resembles its empirical counterpart in the U.S. (Henly and Sanchez, 2009; Hsieh and Klenow, 2014).

Since capital is predetermined whereas employment is not, some of the model's properties are more transparent when looking at the capital distribution in Figure 3b. We identify several firm types. Startups, defined as firms in their first year of productive activity, are among the smallest firms in the economy, and are mostly borrowing-constrained. The relatively few which are not, are amongst the least productive. The remaining firms, widely distributed across different sizes, are what we label mature incumbents. Although larger firms do face less tight financial constraints conditional on productivity (Figure 2), unconditionally the fraction of constrained mature incumbents does not decline with firm size according to Figure

3b. This is due to selection effects, as the largest firms in the stationary distribution also tend to be among the most productive, hence more likely to be constrained for this reason.

Figure 3. Stationary Firm Size Distribution

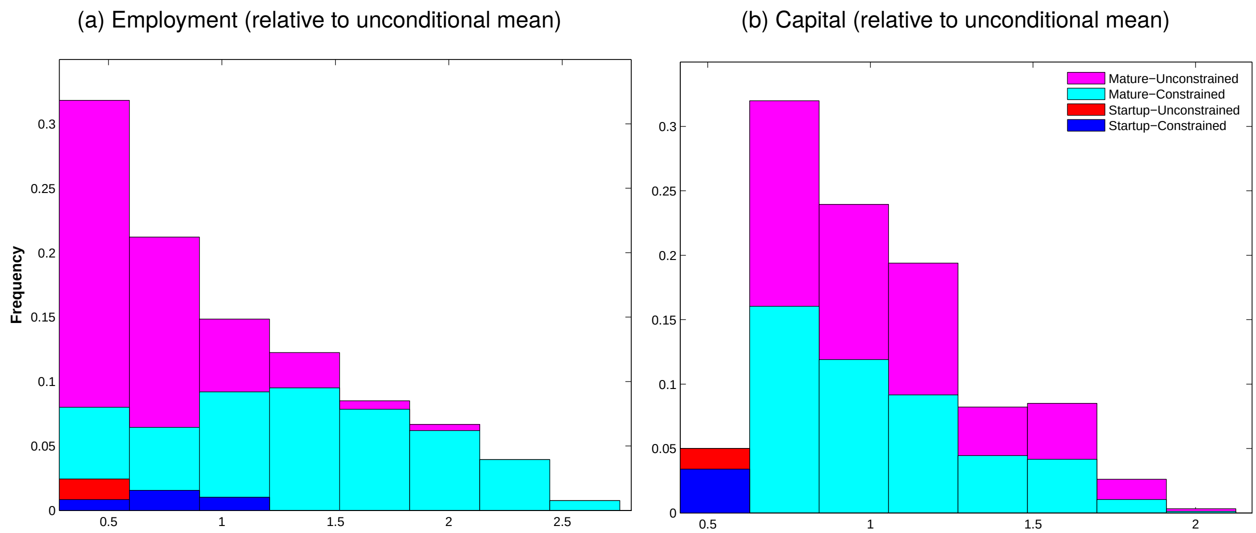


Table 3 provides some quantitative information about the steady-state distribution of firms. Startups are only 5 percent of the total number of firms, given by the exogenous entry probability, and since they tend to be constrained and small, they contribute to an even lower percentage of about 3 percent of aggregate output. Most of aggregate output is therefore produced by mature incumbents. An important feature is that although constrained firms are only about half of all mature incumbents, they contribute to almost 2/3 of total output. This is again explained by the fact that these firms tend to be very productive in the model.

B. Firm Dynamics

Table 4 reports the job creation and job destruction rates in the stationary equilibrium and in the data (Lee and Mukoyama, 2015). The job creation rate is defined in the usual way, as the total employment change among expanding firms, relative to the initial employment size across all firms.[16] The job destruction rate is defined in an analogous way for shrinking firms.

[16]In the empirical counterpart, initial employment size is defined as $(n_t + n_{t-1})/2$, where n_t is aggregate employment at time t. In our model, $n_t = 1$ for all t.

Table 3. Relative Importance of Startups and Mature Incumbents

	Share of total (in %)		
	firms	capital	output
Startups	5	2.3	3
constrained	3.4	1.6	2.5
unconstrained	1.6	0.7	0.5
Mature	95	97.7	97
constrained	46.9	47.8	63.7
unconstrained	48.1	49.9	33.3

Table 4. Job Creation and Job Destruction Rates

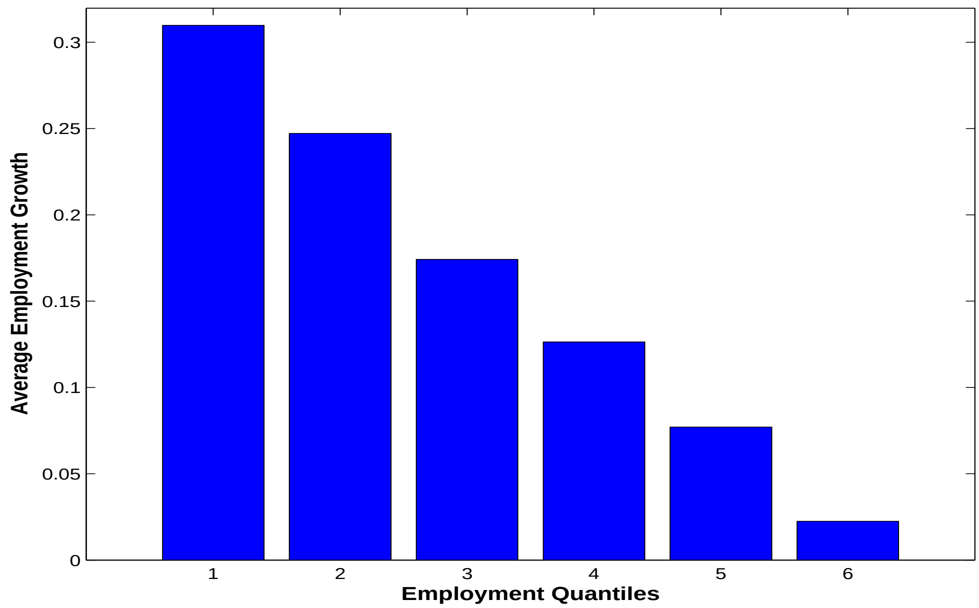
	Job Creation		Job Destruction	
	Model	Data	Model	Data
	20.7	9	20.7	10
Relative Contribution				
startups	14	17	0	0
mature	86	83	76	76
exiters	0	0	24	24

The table shows that, in the aggregate, the job creation and destruction rates in the model are twice as high compared to the data. This is in part due to the way we model entry (initial productivity drawn from the unconditional distribution, rather than from a distribution with lower mean), and exit (random across all incumbents, rather than higher among smaller firms).

The relative contribution of the different firm types, however, is totally in line with the data, in spite of this not being a calibration target. Mature incumbents are responsible for most job creation and destruction in the economy.

Figure 4 plots average employment growth conditional on firm employment. Our model's implications are consistent with the empirical evidence that firm growth is unconditionally negatively correlated with size as reported by Dunne, Roberts, and Samuelson (1988). Models along the lines of Hopenhayn's (1992), such as ours, deliver this implication due in large measure to the mean-reverting nature of the stochastic process for productivity.

Figure 4. Average Employment Growth Conditional on Size



In our specific case, the presence of capital as a production input subject to financial constraints provides additional mechanisms both contributing and going against the overall pattern of Figure 4. Smaller firms in our model not only have higher expected future productivity, some of them are also financially constrained and hence have a relatively low current level of capital. These firms tend to grow fast as they catch up to their unconstrained-optimal level of capital. On the other hand, larger firms subject to low productivity shocks are unable to adjust their current level of capital instantly, hence they tend to reduce their employment level by less than what their productivity alone would imply. These features are shared by other models with pre-determined capital and either financial frictions or adjustment costs to capital (e.g Clementi and Palazzo, 2016; Khan and Thomas, 2013).

VI. Temporary Corporate Tax Cut

To quantitatively assess the effects of temporary cuts in corporate taxes, we undertake the following experiment. We assume that, in period 0, the economy is in steady-state with $\tau_0 = g$ and $b_1 = b_0 = 0$. In period 1, the government unexpectedly announces the following policy change. In period 1, corporate taxes are cut down to zero, $\tau_1 = 0$. Since the amount of government spending is held constant and no other forms of taxation are available, the tax cut is absorbed by an increase in public debt in period 1, $b_2 = g$. In period 2, the government increases corporate taxes, by an amount sufficient to cover not only the period 2 spending, but also the full servicing of the outstanding debt, $\tau_2 = (2 + r_2)g$ and $b_3 = 0$. This allows the government to fully revert back to its initial policy of funding government spending totally out of corporate taxes, with zero public debt issuance. The top panel in Figure 5 displays the dynamics of corporate taxes associated with this policy.

We assume that, in period 1, agents in our model have full information about the new government policy, and perfect foresight about its future effect on prices. Although the policy itself reverts back to its initial state after period 2, the price effects are long-lived, as the economy slowly transitions back to its initial steady-state. Appendix B provides some details on the computation of the economy's transition.

A. Transitional Dynamics

Figure 5 plots the tax policy, as well as the transitional dynamics of investment and output. In period 0, the economy is in the steady-state. After 10 periods following the tax cut, the economy approximately converges back to the initial steady-state. In period 1 there are no aggregate output effects, given that the policy is unexpected. Aggregate investment, however, increases on impact, namely due to the response of financially constrained firms. In period 2, as the tax rate increases significantly, overshooting its steady-state level, aggregate investment decreases. This decreasing in aggregate investment is relatively small, however it persists while the economy gradually converges back to its initial steady-state. These dynamics of aggregate investment imply that output increases significantly in period 2. This stimulative effect is long-lasting, with the initial investment build-up being the dominant force keeping the aggregate capital stock above its steady-state level all along the transition.

The asymmetric response of aggregate investment to initial tax cut and subsequent tax increase is a key point of our analysis, leading to persistent expansionary effects out of a purely transitory policy change. The initial tax cut allows financially constrained firms to expand their productive capacity. Some unconstrained firms may also respond by investing more, as a precaution against the possibility of becoming constrained in the future, an event that is more likely in the next period given the policy reversal. This results in a large aggregate investment effect in the current period. This initial capital build-up allows firms to generate larger cash-flows in the subsequent periods. Some of these firms are therefore able to either escape, or at least mitigate, the effect of financial constraints, resulting in higher investment levels. This effect is long-lasting because it takes time to erode the effect of the higher initial capital, requiring a sufficient number of negative productivity and exit shocks for cash-flows to return to their initial levels, and financial constraints to be as binding.

Figure 5. Transitional Dynamics of Aggregate Investment and Output

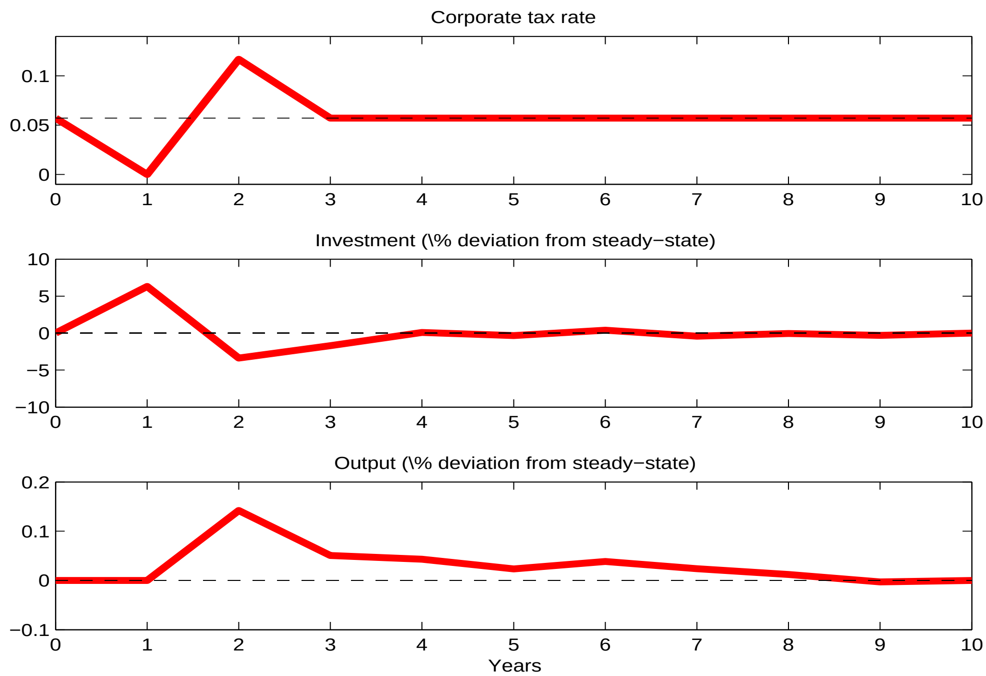
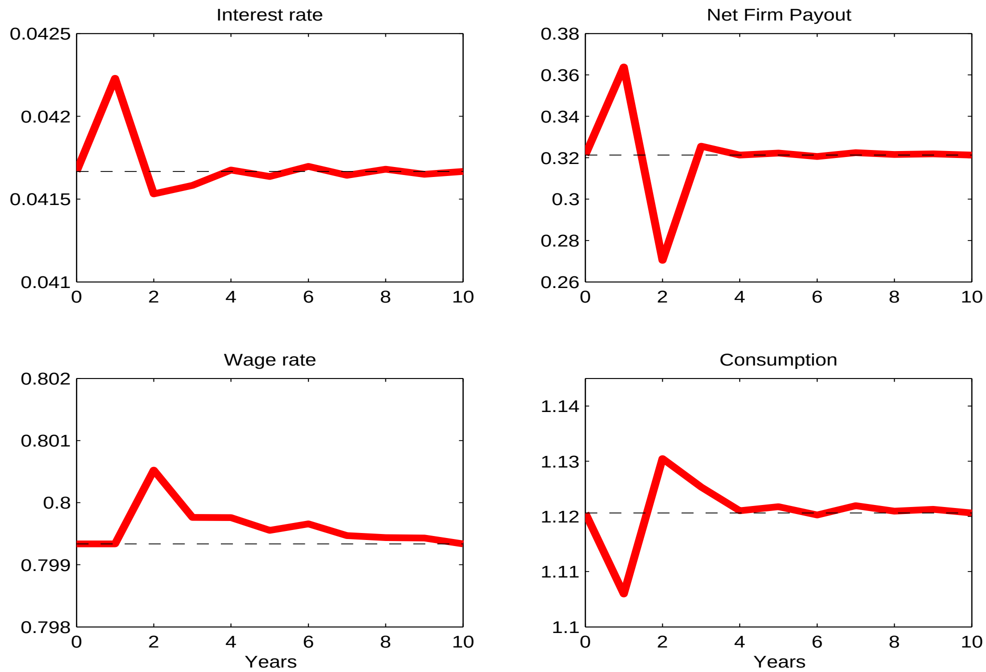


Figure 6 shows the response of the interest rate, wages, and aggregate consumption and the net firm payout to the household sector. As firms increase labor demand from period 2 onwards, and given our inelastic aggregate labor supply, wages are higher along the transition. Wages decline monotonically toward the steady-state, alongside labor demand. The real interest rate parallels the dynamics of aggregate investment, increasing initially and then decreasing, and finally converging back to its initial steady-state from below.

The net firm payout increases initially, as only some incumbent firms rely on the additional cash-flows generated by the corporate tax cut in order to increase investment, whereas others simply transfer it back to consumers in the form of higher dividends. In period 2, the net firm payout collapses significantly, given the sharp increase in corporate taxes and the need to keep funding investment and make payments to labor.

Aggregate consumption is the mirror image of the net firm payout. It declines in period 1, in spite of an increase in net firm payout. The latter, however, is less than the full amount of

Figure 6. Prices, Net Firm Payout, and Consumption

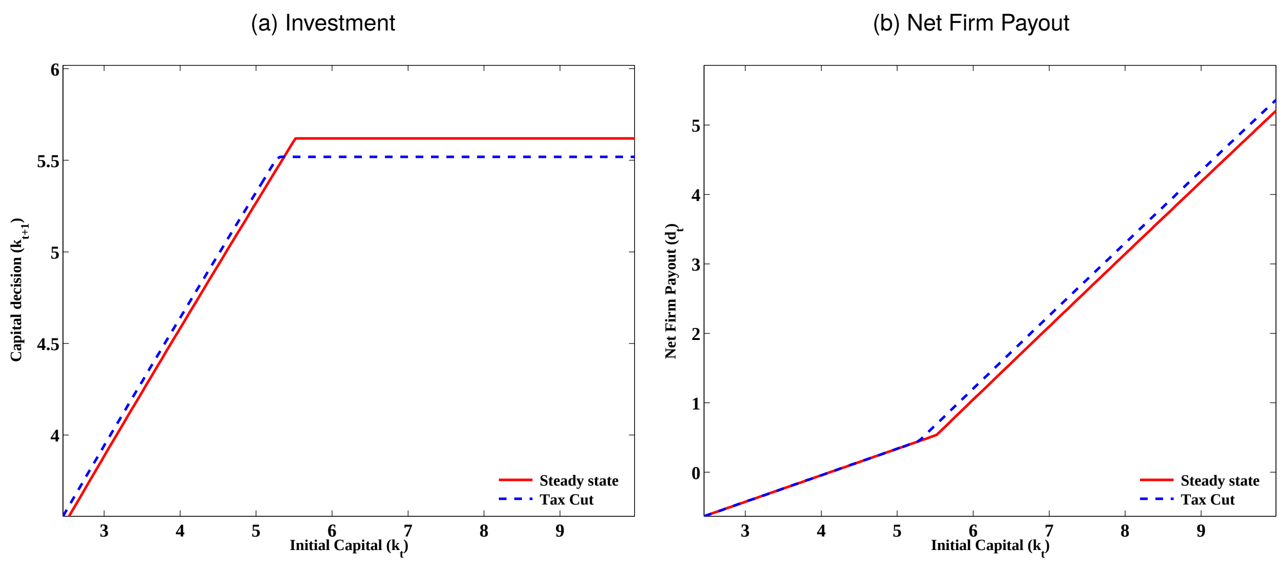


the corporate tax decline, as some firms invest out of this windfall, and there is no change in production. The household must therefore be enticed to save more, via a higher interest rate, to purchase the government debt necessary to finance the level of government expenditure. Consumption increases in period 2, since again the net firm payout varies by less than the amount of period 2's tax increase, as firms rely partially on the higher retained earnings afforded by the increased production. The supply of government bonds, however goes back to zero, and a lower interest rate is needed to encourage the household to actually increase consumption.

It is useful to consider the situation in which financial frictions are absent. In this case, the full amount of the corporate tax decline is transferred to the household in the form of higher dividends, and there is no impact on production. The household behaves just like in the standard Ricardian Equivalence result. Rather than changing (in this case increasing) consumption, the consumer opts to save all the extra income. The real interest rate remains unchanged. This saving serves to pay for the future anticipated decline in dividends, which will occur as firms seek resources to cover the corporate tax increase.

Figure 7 shows how the incumbent's decision rules for investment and the net firm payout (just dividends in this case) change as a result of the cut in corporate taxes. The figure plots the decision rules in period 1 under two scenarios, the benchmark steady-state and the tax cut policy. All decision rules are conditional on the same level of productivity. Notice that the tax cut produces a direct effect on the decision rules, by increasing cash flows, and an indirect general equilibrium effect by increasing the wage rate and the interest rate.

Figure 7. Decision Rules in Period 1



In both panels, the kink occurs at the level of capital beyond which the firm ceases to be constrained. Figure 7a shows that the impact of the tax cut is to relax the financial constraint, in the sense that the kink moves to the left, and also in the sense that investment is higher in the constrained region. The same figure also reveals that the tax cut produces the opposite effect for unconstrained incumbents. For them the investment is lower, due to both a higher wage rate (higher production costs) and a higher interest rate (heavier discounting of future dividends). The tax cut therefore crowds-out the investment among the larger, unconstrained firms.

Figure 7b provides a consistent message. Dividend payouts remain unchanged for firms that remain constrained, as the full amount of the tax windfall is used to fund investment. For unconstrained incumbents, however, dividend payouts increase, as firms pass the corporate tax cut to consumers, given that their investments needs are met with their level of retained earnings.

B. Corporate Tax Cut Multipliers

To quantify the stimulative effects of the transitory corporate tax cut, we compute the associated aggregate output and investment tax cut multipliers. We are interested in comparing aggregate output and investment along the transition relative to the steady-state. We also look at the behavior of the net firm payout, in order to better understand the behavior of external funding from the household sector.

More specifically, let $\{x_t\}_{t=1}^{\infty}$ denote the transition path for either aggregate output, aggregate investment, or the net firm payout, following period 1's tax cut. Let $\bar{x}$ be the steady-state value, and define the change relative to steady state as $\Delta x_t \equiv x_t - \bar{x}$. Similarly, the extent of the tax cut is $\Delta\tau_1 \equiv -(\tau_1 - \tau_0) = g$. We compute two types of multiplier:

1. Impact Multiplier: $mi_t(x) \equiv \frac{\Delta x_t}{\triangle \tau_1}$, for $t = 1, 2$.
2. Cumulative Multiplier: $mc(x) \equiv \sum_{t=1}^{\infty} \frac{1+r_1}{\prod_{i=1}^{t}(1+r_i)} \frac{x_t - \bar{x}_t}{\Delta\tau_1}$.

Given the different timing of the impact responses of aggregate output and investment seen in Figure 6, we compute the impact multipliers $mi_1(i)$ and $mi_1(np)$ for aggregate investment and net firm payout, respectively, and the impact multiplier $mi_2(y)$ for aggregate output. For the cumulative multipliers, we compute $mc(i)$, $mc(np)$ and $mc(y)$ for aggregate investment, net firm payout, and output, respectively. The model's equilibrium interest rate sequence along the transition is used to discount future changes back to period 1. Based upon our results, the cumulative multiplier computed over a ten-year long transition provides a good approximation to the one computed over the whole transition.

Table 5 reports the responses of aggregate and firm-level investment, output, and net firm payout. The top panel reveals that per dollar of tax stimulus, these variables increase on impact by 25.7, 3.5, and 74.3 cents, respectively.

Compared with the impact multipliers, the cumulative multipliers are substantially lower for investment and the net firm payout. In particular, the cumulative investment effect is only about one quarter of the impact effect. The net firm payout increases only by 1 cent over the long run, while it increases by more 70 cents instantaneously with the tax cut. For output, instead, the cumulative multiplier is about twice as high as the impact multiplier since, as explained previously, the temporary tax cut generates a long-lasting stimulative production effect.

Table 5. Corporate Tax Cut Multipliers (cents per dollar of tax stimulus)

	Investment	Output	Net Firm Payout
Aggregate			
impact	25.7	3.5	74.3
cumulative	4.6	7.2	1
Firm-level, impact			
Startups	68.1	15.9	31.9
constrained	100	24.8	0
unconstrained	-0.02	-3.0	100.02
Mature	23.4	2.2	76.6
constrained	82.4	16.5	17.6
unconstrained	-34.1	-11.8	134.1

The bottom panel of Table 5 reports the impact multipliers conditional on specific firm-types. For startups, the investment multiplier is of 68 cents per dollar of tax revenue, whereas the remaining 32 cents are paid out as dividends. The stimulative effect on output is of 16 cents. These multipliers are naturally higher for constrained startups. For these, the full amount of the tax reduction is channeled to investment, with no additional dividend payouts. As a result, the output effect is also maximized with an impact multiplier of about 25 cents. The opposite happens for the relatively fewer number of unconstrained startups, who channel the entirety of the additional cash-flows to dividend payouts. Their investment and output end up declining in the end, given that prices increase on impact.

The response of mature incumbents is qualitatively similar, although the multipliers are of lower magnitude overall. In particular, the stimulative effect on investment is only about 23 cents, whereas on output is only 2 cents per dollar of tax revenue. For constrained mature incumbents the multipliers are higher, without reaching the same level as the startups. The decline in corporate taxes is sufficient to allow some of these firms to become unconstrained, and hence transfer some of this tax decline back to consumers in the form of higher dividends. The unconstrained mature incumbents, instead, face negative growth, as they face higher prices without any productive use for the higher cash flows.

C. Quantifying the Crowding-Out Effect

We have shown how the tax cut crowds out investment among larger, unconstrained firms due to higher prices. To quantify the dampening effect of general equilibrium price movements, we now perform a partial equilibrium analysis, by implementing the temporary tax cut while fixing the wage rate and the interest rate at their steady-state levels.

Figure 8. Transitional Dynamics, benchmark (solid) vs partial equilibrium (dashed)

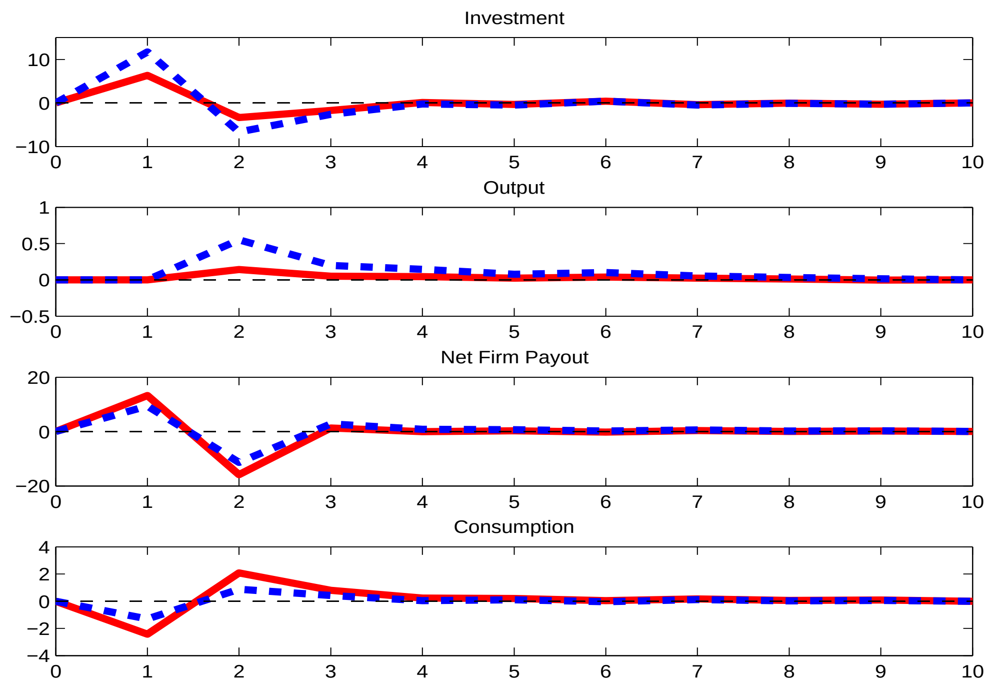


Figure 6 compares the transition dynamics with and without the price adjustment. To facilitate the comparison, all variables are reported in percentage deviation from their steady-state values. As anticipated, the investment, output, and consumption effects are stronger in partial equilibrium, whereas the net firm payout is weaker.

Table 6 gives a sense of the magnitudes, by computing the same multipliers as in Table 5. Comparing the two tables shows that both the impact and the cumulative multipliers are significantly larger in partial equilibrium, not only in the aggregate, but also conditional on firm types. The impact effect is around two times larger for investment and four times larger for output. The reason is once again that the partial equilibrium exercise eliminates the crowding-out effect among unconstrained firms. Further, there is also an additional positive effect among constrained firms, as they are able to channel some of the lower wage level into further investment.

Table 6. Partial Equilibrium Multipliers (cents per dollar of tax stimulus)

	Investment	Output	Net Firm Payout
Aggregate			
impact	47.6	13.6	52.4
cumulative	9.4	25.2	5.9
Firm-level, impact			
Startups	68.1	20.0	31.9
constrained	100	29.3	0
unconstrained	0	0	100
Mature	46.5	12.6	53.6
constrained	94.1	25.4	5.9
unconstrained	0.0013	0.0003	99.87

VII. Discussion

We highlight some important features that we abstracted from in our analysis, and discuss how they might affect our corporate income tax multipliers.

(a) Distortionary taxation. We have abstracted from distortionary taxation in order to isolate the mechanisms underlying changes in the timing of taxation. This is useful in contrasting with the intertemporal substitution mechanisms that have been emphasized in the literature. Our abstraction is not without shortcomings. An important one is that, with lump-sum taxation, small firms are paying a proportionally large amount of taxes, which exacerbates the presence of financial frictions. Recall, however, that we do not require new entrants to pay corporate taxes. Nevertheless, given the importance of small constrained firms in generating large multipliers, lump-sum taxation is indeed likely to overestimate their magnitude. On the other hand, distortionary taxation does introduce an intertemporal substitution effect on investment, which could generate higher multipliers.

(b) Endogenous entry and exit. We do not think endogeneizing entry and exit would produce clear effects on our multipliers. Regarding entry, we would expect the tax cut to produce more entrants following the tax cut, with possibly lower average productivity.[17] If all entrants

[17]To be able to talk about these effects, the tax cut should last more than just one period, so that entrants have a chance to benefit from it (alternatively, the policy could be pre-announced). Also, one could consider that firms

are constrained, irrespective of initial productivity, then the main effect on the multiplier should come from the extensive margin, and we should expect our multipliers to be higher with endogenous entry.

We expect the opposite effects from endogenous exit. That is, the tax cut should make some of the less productive firms to survive. This should imply lower overall turnover in the economy, with more low expected productivity-low investment firms staying and less high expected productivity-high investment firms entering. We would expect lower multipliers due to this effect alone.

(c) Growth dynamics of entrants. In our model, the reason young firms growth more rapidly is because they start out small and face financing constraints in reaching their optimal size. In reality, there might be other important reasons why entrants start small and grow more rapidly. For example, a large literature has emphasized the presence of adjustment costs, particularly regarding capital (Cooper and Haltiwanger, 2006). These may consist of delivery lags, disruption of production upon installation, learning how to operate the new capital, or irreversibility of the old capital.

Another possibility is that younger firms are either less efficient, or take time to learn about their efficiency (Jovanovic, 1982).

A more recent literature has been emphasizing demand-size constraints. Firms may face low initial demand, and slow accumulation of a costumer base, because of sluggish dissemination of information, or slow reputation buildup (Foster, Grim, and Haltiwanger, 2016; Moreira, 2017).

It is clear that if the growth dynamics of entrants are driven primarily by these alternative forces, instead of financing constraints, then we should expect lower multipliers than the ones we obtain.

(d) Endogenous financing constraints. An important question is whether tax cuts are indeed able to relax financing constraints. Our view is that this might depend on the exact type of friction giving rise to the constraint. For example, suppose the constraint solves a lack of enforcement problem, where the firm manager is able to run away with the after tax

receive a signal about their productivity upon the entry decision, in order for the selection margin to be operative (Clementi and Palazzo, 2016).

profits and consume or invest them informally. In this case the manager never faces the future increase in the tax rate. The tax cut should then be compensated by a tightening of the financing constraint. We should therefore not expect multipliers as large as the ones we obtain.

However, this effect depends critically on what the outside option of the manager is. If the manager is able to run another formal business, then it will face the future tax increase. In this case it is not clear whether the financing constraint is tightened in response to the tax policy, and we might expect multipliers not too different from the ones we obtain.

(e) Multipliers estimated in the empirical literature. Three recent papers have attempted to estimate the aggregate output multiplier with respect to change in the corporate income tax rate. Mertens and Ravn (2013) use narratively identified tax changes as structural shocks in a structural vector autoregression model. They estimate the effect of a one percentage point cut in the corporate income tax rate to produce a 0.4% increase in output on impact, rising to about 0.6% after one year.

Ljungqvist and Smolyansky (2018) use the cross-state and cross-time variation of corporate tax rates to estimate the 'output' (aggregate labor earnings of contiguous counties straddling a state border) effect of differences in corporate tax rates. They find that a 1 percentage point decrease in the corporate tax increases output by 1 percentage point during recession times (the effect is negligible without controlling for the business cycle).

More recently, Mertens (2018) estimates that the 2017 U.S. Tax Cuts and Jobs Act lowers average corporate tax liabilities in the first quarter of 2018 by 7.4% of 2017 corporate profits and finds that this tax cut will imply an increase in GDP by 2 percentage points in 2018.

These estimates are not comparable to the multipliers delivered by our model because empirical multipliers suffer from the lack of counterfactual (no policy-change scenario) and are subject to endogeneity (tax changes may themselves be driven by prevailing economic and other factors). Moreover, they do not control for the effects of the tax change on government debt.

VIII. Conclusion

We have assessed the effectiveness of temporary reductions in corporate taxes in raising aggregate investment and output. We consider lump-sum taxation to isolate the intertemporal substitution effects from the timing effects of the tax policy. The mechanism we have focused upon relies on 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. The effects are substantially higher when controlling for the investment crowding-effect among larger and unconstrained firms.

An important avenue for future research is to study the policy experiment in an environment with aggregate uncertainty, and cyclical variation in the severity of financing frictions. It could 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 amended to feature distortionary taxation, which would allow incorporating the intertemporal substitution effects typically considered in the literature.

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Appendix A. Stationary Equilibrium

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

1. Guess wages and solve for the decision rules incumbents and new entrants.
2. Compute the stationary distribution by simulation.
3. Verify that the labor market clears.

A.1. Firm Optimization

1. Construct a grid for capital $\mathcal{K} \equiv \{k_1, k_2, \cdots, k_{N_k}\}$, with k_1 sufficiently low and k_{N_k} sufficiently large that changing them further has a negligible effect on the solution. In practice $N_k = 300$. We use $N_\varepsilon = 5$ states for the Markov chain.
2. For given wages, solve the dynamic program of the incumbent by value iteration. We linearly interpolate the value function for investment levels outside $\mathcal{K}$. For each state (k_p, ε_q) in the grid and for iteration j:

$$V^{j+1}(k_p, \varepsilon_q) = \max_{k' \in \mathcal{K}} \left\{ d(k_p, \varepsilon_q, k') + \beta \left[\eta k' + (1-\eta) \sum_{\varepsilon'} \pi(\varepsilon'|\varepsilon_q) V^j(k', \varepsilon') \right] \right\},$$

   where $d(k_p, \varepsilon_q, k')$ is the dividend conditional on an optimal labor choice, which also incorporates the dividend constraint.
3. Iterate on the Bellman equation until the following convergence criterion is satisfied:

$$\max_{k_p, \varepsilon_q} \left| \frac{V^{j+1}(k_p, \varepsilon_q) - V^j(k_p, \varepsilon_q)}{10^{-3} + |V^j(k_p, \varepsilon_q)|} \right| < 10^{-6}.$$

4. The solution to the new entrant's problem is simply $k^e = \bar{d}$. We verify that the dividend constraint is in fact binding.

A.2. Market Equilibrium

1. Conjecture wages w_0.
2. Select a simulation length $S = 3$ million $+ 1000$. Choosing a larger number produces no significant changes to the stationary distribution of capital. Initialize an incumbent firm with some arbitrary state (k_0, ε_0).

3. Simulate a sequence of exit shocks of length S by drawing random numbers from a Bernoulli distribution with success probability η.
4. For each period the firm is to continue, compute investment using the incumbent's decision rule $k'(k_p, \varepsilon_q)$, and draw next period's productivity shock from the conditional distribution π.
5. For each period the firm is to exit, compute investment using the new entrant's decision rule $k' = \bar{d}$, and draw next period's productivity shock period from the long-rung distribution $\bar{\pi}$.
6. Discard the first 1000 observations, and use the empirical distribution of capital over the remaining simulation periods as an approximation to the steady-state cross-sectional distribution of capital.
7. Check whether $\sum\limits_{s=1001}^{S} n_s/(S-1000) \approx 1$, where n_s is the firm's optimal labor choice at time s.

Appendix B. Transition Dynamics

Given the steady-state solution and the policy described in section , we solve for the transitional dynamics as follows.

1. Compute the stationary equilibrium objects: w, r, c, V, V^e, and set the length of the transition T to 10. Increasing further T does not produce any effect.
2. Guess paths for consumption $\{c_t\}_{t=1}^{10}$ and wage $\{w_t\}_{t=1}^{10}$ such that $c_{10} = c$ and $w_{10} = w$.
3. Given the consumption path, derive the path for interest rate, $r_{t+1} = \frac{c_{t+1}}{\beta c_t} - 1$, and $r_{11} = r$.
4. Given wages and interest rates, solve the dynamic problem of incumbents by backward induction assuming that $\hat{V}_{11} = V$, where $\hat{V}$ is the value function during the transition.
5. Given the policy and value functions of incumbents, compute the value and policy functions of new entrants.
6. Simulate a sequence of entry/exit and productivity shocks of length 10, and track the whole distribution of firms over 10 periods.
7. Given the implied sequence of cross-sectional distributions, compute aggregate investment i_t, output y_t and labor demand n_t at each period of the transition. Then, derive the implied value of consumption $\hat{c}_t$, using the resource constraint $\hat{c}_t = y_t - i_t - g$.
8. Check whether $\hat{c}_t \approx c_t$ and $n_t \approx 1$.