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* Views expressed are those of the authors and do not necessarily reflect official positions of De Nederlandsche Bank.

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Corporate taxes, productivity, and business dynamism*

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Abstract

We identify the effects of corporate income tax shocks on key US macroeconomic aggregates. In response to a corporate income tax cut, we find that: (i) labor productivity increases; (ii) entry increases with delay; (iii) exit increases; (iv) total labor increases by more than production labor. To rationalize these empirical findings, we build a New Keynesian model with idiosyncratic firm productivity, and entry and exit. Our model features productivity gains due to selection and cleansing along the entry and exit margins. Models with homogeneous firms fail to account for the selection and cleansing process and produce counterfactual results.

Keywords: corporate taxation, productivity, firm entry and exit.

JEL classification: E62, E32, H25.

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1 Introduction

The debate on the effects of fiscal policy measures revolves to a large extent around the size - and even the sign - of output multipliers. In this paper, we estimate and model the impact of a fiscal stimulus package, in the form of corporate tax cuts, on productivity, firm entry and exit, and hours of work. In the academic literature, there is scant attention on the response of these variables to fiscal interventions. This is surprising for at least two reasons. First, the US economy has witnessed both productivity and business dynamism slowdowns in recent decades as reported, *inter alia*, by Akcigit and Ates (2019, 2021). In such an environment, it is all the more important to understand the transmission of fiscal measures on productivity and business creation and destruction. Second, firm entry and exit are widely thought to be major drivers of productivity growth, as shown by Foster et al. (2019).[1]

We start motivating our analysis by identifying empirically the effects of corporate income tax shocks on key US aggregates. To do so, we use both a structural vector autoregression approach (SVAR), and a reduced-form approach using panel regressions estimated on US state-level data. In the first exercise, tax shocks are identified using the methodology developed by Mertens and Ravn (2013), which uses narratively identified tax changes as proxies for structural tax shocks. In the second one, the econometric approach is that employed by Suárez Serrato and Zidar (2016) to identify the effects of business tax cuts on local economic activity, which exploits variation in state corporate tax rates. Nakamura and Steinsson (2014) use a similar approach to identify the government spending multiplier.

Our SVAR evidence suggests that, in response to an unexpected corporate tax rate reduction in the United States: (i) labor productivity displays a persistent increase; (ii)

[1] Additionally, firm tax liabilities constitute an important source of tax revenues. Milanez (2017) reports that in the US, firms' legal tax liabilities represented 29 percent of the total tax revenue in 2014.

firm entry displays an initially muted response to the shock and then increases persistently; (iii) firm exit increases; (iv) total labor increases by more than production labor, (v) the real wage increases, (vi) pre-tax profits increase persistently. The state-level estimates of tax shocks confirm the results just described. To rationalize these empirical findings, we build a dynamic stochastic general equilibrium (DSGE) model with the following features.

First, the supply side of the model builds on the heterogeneous firm literature with endogenous firm dynamics à la Melitz (2003b), augmented with nominal rigidities as in Bilbiie et al. (2007), Bergin and Corsetti (2008), Lewis and Poilly (2012), and the more recent contribution by Bilbiie (2021). Firms face initial uncertainty concerning their future productivity when deciding whether or not to enter the market. Firms' idiosyncratic productivity is assigned once and forever upon entry. Notice that Sterk et al. (2021) point out that ex-ante heterogeneity across firms, rather than persistent ex-post shocks, explains most of the differences in the performances among firms over their life-cycle. Following Bilbiie et al. (2012), firm entry is subject to sunk product development costs, which investors pay in expectation of future profits. Upon entry, production depends on a firm's idiosyncratic productivity level.

Second, firms face fixed production costs. As a result, given aggregate conditions, firms with productivity below a specific threshold will be forced to discontinue production and stay inactive until production becomes profitable again.

Third, both product development costs and fixed production costs are measured in units of labor. As a result, total hours of work are allocated to three different tasks: (i) the production of existing products; (ii) the development of new products; and (iii) other activities not directly involved in production. Kaplan and Zoch (2020) argue for the importance of distinguishing between these tasks. They report that about one-third of US workers are employed in expansionary activities, that is activities aimed at facilitating extensive-margin replication, such as product design, research and development, overhead, logistics, marketing and management capabilities. The distinction between expansionary and production activities matters since different occupations may respond differently to policy changes.

Fourth, we impose a linear tax on corporate profits. In our framework, the corporate tax rate does not affect directly the threshold productivity level, but it does so indirectly through its general equilibrium effects.

Finally, since the empirical analysis suggests that the real wage does not move one-to-one with productivity in response to the tax shock, we assume nominal wage stickiness.

Next, we illustrate the transmission mechanism that allows the model to explain the empirical findings. An expansionary corporate income tax shock increases the discounted value of future net profits. This attracts new firms to the market and leads to a higher demand of labor to expand the extensive margin. The resulting higher real wage dampens the initial response of entry, and entails higher fixed operational costs. As a result, the cut-off productivity level rises, and some firms that prior to the shock were profitable become inactive. Additionally, new entrants must have higher idiosyncratic productivity to be profitable. This leads to an impact increase in both average productivity and firm exit.[2] Notably, the impact increase of hours of work dedicated to the expansion of the extensive margin is stronger than that of hours dedicated to production activities, as suggested by our empirical analysis.

In models with homogeneous firms, there are no productivity gains in response to the shock due to the lack of selection and cleansing effects. The surge in the real wage simply makes firms less profitable, leading to a counterfactual decrease in before-tax profits. While the increase in average productivity delivered by our model is relatively small, it

[2] Strictly speaking, our model has endogenous entry and exogenous exit. However, due to the presence of firms' heterogeneity and fixed costs of production, firms with an idiosyncratic productivity below a certain threshold become idle and discontinue production. We regard adjustments along the inactivity margin as the endogenous component of firm exit.

involves a shake-up of the market that improves the fit of the model to the empirical IRFs to a corporate income tax shock, underscoring the importance of accounting for heterogeneity in the analysis.

In the extended model that accounts for price rigidities, some firms cannot adjust prices to compensate for the increase in production costs following the shock. As a result, before-tax profits display a counterfactual negative response. For this reason, we argue that the critical nominal friction to address the empirical responses of productivity, entry, exit, and profits to a corporate income tax shock is wage stickiness, not price stickiness. To sum up, in order to be consistent with facts (i)-(vi), a model must be characterized by 1) endogenous entry and exit of firms with heterogeneous productivity, 2) entry costs and fixed production costs in terms of labor, 3) nominal wage stickiness rather than price rigidities.

The remainder of the paper is organized as follows. Section 2 discusses the related literature. In Section 3, we present the empirical evidence. Section 4 lays out the theoretical model. The transmission of corporate tax shocks is presented and discussed in Section 5, and Section 6 extends our main findings to frameworks with both price and wage contracts. Section 7 concludes. In the Appendix, we run a battery of robustness tests on our empirical specifications and provide some technical details.[3]

2 Related literature

Our paper relates to several strands of the macroeconomic literature. The first one attempts to identify the effects of fiscal shocks on macroeconomic aggregates. Romer and Romer (2010), Barro and Redlick (2011), Mertens and Ravn (2013), Cloyne (2013), and Caldara and Kamps (2017), among many others, estimate the effects of tax changes on output. This strand of research does not examine the impact on productivity or

[3] Appendix A.1 spells out the model with both wage and price stickiness. Appendix A.3 reports the robustness tests on the baseline VAR model and the state-level regression analysis.

business dynamism. One exception is the work by Cloyne et al. (2022), who find that an expansionary shock to corporate taxes leads to a sustained increase in productivity and GDP. They interpret their empirical results through a model featuring R&D spending and technological adoption by incumbents, and find that R&D is key for the model's ability to generate a persistent response of productivity and output following a temporary change in corporate income taxes. Our model identifies the role played by entry and exit to generate a response of productivity and output following a temporary change in corporate income taxes. For this reason, our approach is complementary to that of Cloyne et al. (2022).

A second strand of the macroeconomic literature related to our work is that on the connection between productivity and establishment entry and exit. Empirical studies have decomposed the change in productivity growth, attributing shares to incumbents, entrants, and exiting firms. Aghion et al. (2004)'s model predicts that a substantial share of productivity comes from growth within incumbent firms as highly productive firms try to fend off competition by innovating. Lentz and Mortensen (2008) find that about 75 percent of aggregate productivity growth comes from the reallocation of inputs (employment in their setup) to innovative firms. About one third of this comes from entry and exit channels. The other two thirds occur as inputs move toward growing innovating incumbents from firms that lose market share when they fall behind the quality frontier. Foster et al. (2019) and Cunningham et al. (2021) present evidence that industries experiencing a surge in innovation exhibit a burst of firm entry.

Finally, our work is related to the literature that studies business cycles in models with endogenous entry and exit, and heterogeneous firms. Clementi and Palazzo (2016) and Hamano and Zanetti (2017) are early examples of real models in this literature. Totzek (2009), Hamano and Zanetti (2018), Rossi (2019), Hartwig and Lieberknecht (2021), Colciago and Silvestrini (2022), Ascari et al. (2021), and Hamano and Zanetti (2022), consider the role of monetary policy in economic environments close to ours. With respect to these works, we focus on the fiscal transmission mechanism. We also differ because we study productivity effects and the allocation of labor between production purposes and expansionary purposes. The role of fiscal policy, and more so the role of corporate income tax shocks, is often neglected in this literature. Notable exceptions are Davies and Eckel (2010), Sedláček and Sterk (2019), and Martin-Baillon (2021). Sedláček and Sterk (2019) study the long-run effect of fiscal reforms featuring permanent tax cuts on firms' income. They find that a permanent tax reduction leads to an increase in firm entry, exit, and the real wage, which ultimately positively impacts productivity. Thus, the channels of transmission of the tax shock that we identify in our business cycle analysis are the same as those they identify in their long-run analysis. With respect to their work, we provide empirical evidence about the effects of corporate income tax shocks on entry, exit, and productivity over the business cycle, and develop an analytically tractable model with heterogeneous firms that explains them. Davies and Eckel (2010) provide optimal corporate taxes in a static model where firms are mobile across countries. Martin-Baillon (2021) studies optimal corporate taxes over the business cycle in a heterogeneous firm model.

3 Empirical evidence

In this Section, we provide empirical evidence on the transmission of corporate tax shocks to macroeconomic aggregates, including productivity and firm dynamics. The first subsection employs structural vector autoregression (SVAR) analysis to identify corporate income tax shocks using aggregate US data, while the second subsection estimates reduced-form effects using panel regressions estimated on US state-level data.

3.1 Aggregate US evidence

Our first econometric approach estimates a set of VAR models including a mixture of macroeconomic, financial, labor market, and fiscal policy variables relative to the aggregate US economy.

VAR specifications. In our *baseline specification*, we include a fixed set of four core variables, more specifically: (1) the average corporate income tax rate, our policy variable, (2) corporate profits, (3) real output, and (4) labor productivity. Then, we estimate a number of *augmented VAR specifications* by appending, in turn, one additional variable to the vector of baseline variables. In particular, we consider three sets of additional variables. First, we add establishment entry and exit to measure expansions and contractions in the economy's productive capacity along the extensive margin. The corresponding impulse responses could provide a first indication of whether significant firm turnover can be expected at the extensive margin. Second, we analyze labor market changes in more detail by estimating, separately, the responses of the ratio between hours dedicated to production and total hours, and then wages. We add the ratio of hours of production to total hours to understand whether hours not involved in production, which include research and development, react differently, with respect to production hours, to the policy measure.

Method. To identify corporate income tax surprises, we use the external instrument estimation strategy developed by Mertens and Ravn (2013). In a nutshell, the method exploits the attractive features of both the SVAR and the narrative approach. Identification is achieved by imposing the restrictions that narrative measures of exogenous tax changes correlate with the structural tax shock, but are orthogonal to other structural shocks. There are no timing restrictions. The procedure has three stages. In the first stage, we estimate a reduced-form VAR by ordinary least squares. The second stage consists in regressing the VAR residuals of the policy indicator on the non-policy indicator by using narratives as instruments (two-stage least squares). In the third stage, we impose the covariance restrictions and compute impulse responses.

We use as instruments the measures of exogenous shocks to average tax rates narratively identified by Romer and Romer (2010).

Data. Table 1 summarizes the data sources. Data are quarterly. The sample period is 1980q1-2006q1.[4] Establishment entry and exit is available at the quarterly frequency from the BLS's Business Employment Dynamics (BED) database, starting in 1992. For the earlier period, we use yearly data from US Census Bureau's Business Dynamics Statistics starting in 1976, and interpolate the missing quarterly values between 1976 and 1992 using the method developed by Chow and Lin (1971). As for the related series, we used New Business Incorporation, which are reported at the monthly frequency in the BEA's Survey of Current Business between 1948m1 and 1993m12.[5] The latter are taken from the Economic Report of the President (various issues), where the 1984 discontinuity was corrected in accordance with Naples and Arifaj (1997).[6] The aggregate wage is the hourly compensation in the private non-farm business sector.

Results. Figure 1 displays the impulse responses to a one percentage point reduction in the average corporate income tax rate (ACITR). Solid blue lines represent point estimates, while the blue shaded areas are 90 percent bootstrap confidence intervals.

The IRF of real GDP is comparable to that reported by Mertens and Ravn (2013)

[4] Notice that the tax shocks that we use as instruments are available up to 2006.

[5] Monthly data on new incorporations from 1948m1 until 1994m12 are available on page C-29 of this file: `https://apps.bea.gov/scb/pdf/NATIONAL/BUSCYCLE/1994/1194cpgs.pdf`.

[6] Changes in the number of establishments will not be reflected in the data as changes in the number of firms. However, the model we propose in the paper interprets entry more broadly and should be seen as analyzing variations in the number of market players and not just in the number of firms. As argued by Jaimovich and Floetotto (2008), despite this caveat, there is robust evidence about the existence of significant variations in the number of market players at the business cycle frequency.

Table 1: Data sources

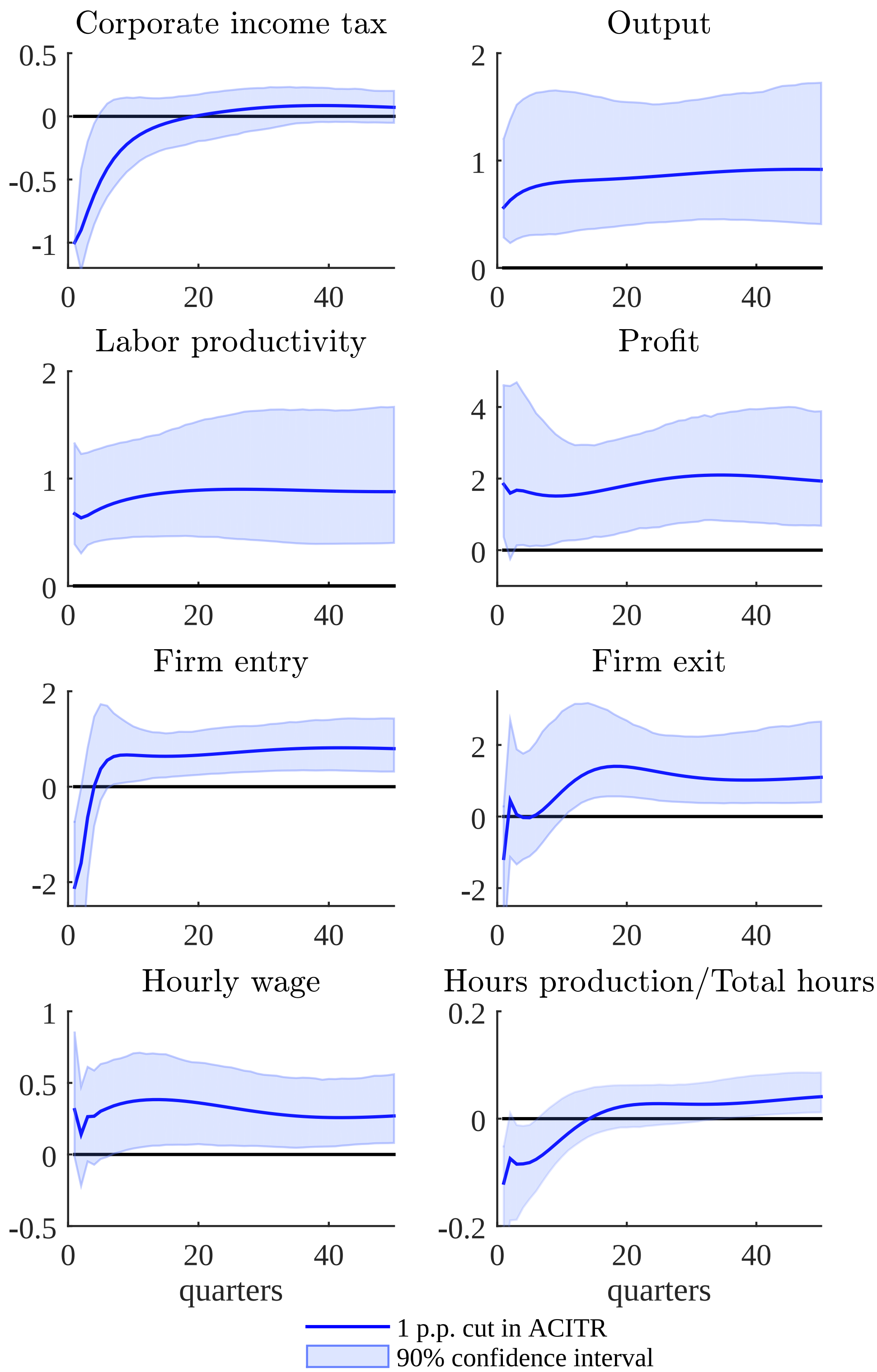
Aggregate US Vector Autoregression	
Average corporate income tax	Mertens and Ravn (2013)
Corporate profits	Mertens and Ravn (2013)
Real GDP	Mertens and Ravn (2013)
Labor productivity	Haefke et al. (2013)
Establishment entry	BLS Business Employment Dynamics, Census Business Dynamics Statistics
Establishment exit	BLS Business Employment Dynamics, Census Business Dynamics Statistics
Wage aggregate	Haefke et al. (2013)
Hours production workers	Bureau of Labor Statistics
Total hours	Bureau of Labor Statistics
US State-Level Regressions	
Corporate income tax	Suárez Serrato and Zidar (2016)
Investment tax credit	Suárez Serrato and Zidar (2016)
R&D tax credit	Suárez Serrato and Zidar (2016)
Corporate profits	Compustat
Real GDP	Bureau of Economic Analysis
CPI	Bureau of Labor Statistics
Government spending	Bureau of Economic Analysis
Total factor productivity	Ramey (2016)
Federal fund rate	Federal Reserve Bank of St.Louis
Establishment entry	BLS Business Employment Dynamics
Establishment exit	BLS Business Employment Dynamics
Real wage per worker	Bureau of Economic Analysis

Notes. The BLS's Business Employment Dynamics database is available at: www.bls.gov/bdm/home.htm. The Business Dynamics Statistics can be downloaded from: www.census.gov/ces/dataproducts/bds/.

and Cloyne et al. (2022). Indeed, despite the transitory nature of the corporate tax reduction, there are very persistent effects on real GDP. We find similarly persistent effects on productivity and profits. The response of labor productivity mimics that of output. Profits have the largest impact response among the variables we consider, increasing by around 2%.

Expectations of higher future profits should, in principle, induce forward-looking firms to enter the market. A firm decides whether or not to enter the market by comparing the present discounted value of future profits from doing so to the cost of entry. Indeed, establishment entry rises in response to a tax cut, but with delay. The immediate response is instead negative, with a 2% drop in the first quarter. Indeed, an initial drop in entry has also been observed in response to government spending shocks, see Lewis and Winkler (2017).

Figure 1: VAR impulse responses



Notes. Figure shows impulse responses to a one percentage-point cut in the average corporate income tax rate (ACITR).

Figure 1 provides some suggestive evidence of what might cause a delayed entry. The subplot in the fourth row of Figure 1 shows a positive response of hourly wages, albeit quantitatively small (around 0.25%) and persistent. The initial decrease in the number of new firms entering the market coincides with the positive response of wages. We interpret this result as suggesting that entrants face entry costs in terms of labor, as featured in Ghironi and Melitz (2005) and Bilbiie et al. (2012). This interpretation will guide our modeling choice regarding entry costs. A related intriguing explanation for the initial decline in entry is proposed by Neira and Singhania (2022), who suggest that higher wages raise the opportunity cost to would-be entrepreneurs of starting a business. We find that establishment exit rises in response to the corporate tax cut. Thus, the analysis suggests that both the exit and entry margins are sensitive to the policy shock. This will inform our choice to endogenize the dynamics of both extensive margins in our model.

Real wages do not rise as much as productivity in response to the tax cut. Among others, a potential explanation for this finding is the presence of nominal wage rigidity. For this reason, our theoretical framework will be characterized by costly wage adjustments.

As we see in the subplot in the fourth row in Figure 1, the ratio of production labor to total labor persistently declines in response to tax cuts. This implies that hours dedicate to non-production activities, such as product development, increase more than those dedicated to the production of existing goods.

Robustness checks. In the Appendix A.2, we investigate the robustness of our results by considering alternative VAR specifications. We first augment our baseline VAR model to control for the responses of government spending, since omitted variables can lead to misspecification. Estimates are displayed in Figure 5. Second, in the baseline VAR we replace labor productivity with total factor productivity. IRFs relative to this experiment are reported in Figure 6. In Figure 7 we report the IRFs obtained when augmenting the baseline VAR with the consumer price index (CPI).[7] The response of GDP, entry, exit, productivity, profits, wages, and hours are, under the alternative specifications we con-

[7] We include CPI in log-levels, rather that in first differences, following Sims et al. (1990).

sider, in line with those generated by our baseline VAR. Following the shock, government spending increases persistently. Also, we identify a significant rise in the CPI, indicating inflationary effects resulting from the shock.

Our findings are robust to the inclusion of investment in physical capital in the VAR. Notice that we do not take the VAR with investment in capital as the baseline because the general equilibrium model that we outline in the remainder does not feature physical capital. This is so for simplicity, and to disentangle productivity effects resulting from the extensive margin of investment.[8]

In our baseline VAR, all available information is used to estimate the effects of tax shocks. As a final robustness check, we removed separately one unanticipated tax shock at a time from the data. While the results of the baseline VAR are robust under the removal of most tax shocks, the IRFs are sensitive to the removal of the comparatively large 1981Q4 tax cut. More specifically, output and productivity fall once we remove that shock from the sample. We leave for future research the investigation of how the size of a corporate tax shock affects its transmission, noting that our findings of a positive output and productivity response apply to a sufficiently large tax cut.

3.2 US state-level evidence

In this section, we use variations in state-level corporate income taxes across US states to estimate tax multipliers for output, establishment entry, establishment exit, and wages. The econometric approach is similar to the one employed by Nakamura and Steinsson (2014) to identify the government spending multiplier in a monetary union, and by Suárez Serrato and Zidar (2016) to identify the effects of business tax cuts on local economic activity.

[8] Impulse responses generated by the VAR with investment in physical capital are available from the authors.

Regression model. In the main empirical specification, we follow Nakamura and Steinsson (2014) and employ a difference-in-difference panel data framework:

$$Y_{it} - Y_{it-1} = \alpha_i + \alpha_t + \beta(\tau_{it} - \tau_{it-1}) + \beta_x(X_{it} - X_{it-1}) + \varepsilon_{it}, \tag{1}$$

where Y_{it} is the logarithm of the dependent variable, namely establishment entry or exit, in state i in year t. As a result, $Y_{it} - Y_{it-1}$ measures approximately the percentage growth of the dependent variable in state i over one year. We denote with α_i and α_t state and year fixed effects, respectively. The variable τ_{it} denotes the state-level corporate income tax rate in state i in year t, while X_{it} is a vector of controls. By including state-fixed effects, we account for state-specific time trends in the dependent variable, and for unobserved time-invariant heterogeneity across states. The inclusion of time-fixed effects allows controlling for aggregate shocks and policies, such as changes in federal taxes and monetary policy. Corporate tax rate multipliers for real GDP and establishment entry obtained estimating equation (1) are reported in the first line of Table 2, while the second line reports the multipliers for establishment exit and the real wage. To the extent that the decrease in corporate taxes needs to be financed locally, states may have to use other fiscal instruments. Such a policy tightening may counteract the intended effect of tax reductions. For this reason, we include among the controls in specification (1), the variables that affect the corporate tax base, such as the investment tax credit and the research and development (R&D) tax credit, loss carry-back rule, and loss carry-forward rule. We also include per-capita government spending.

We initially estimate the multiplier in (1) with OLS. Tax multipliers obtained with this method are reported in the columns denoted with OLS in Table 2. One potential caveat of estimating the effect of a state corporate tax shock with OLS is that the corporate tax rate is potentially endogenous to the state's business cycle, in which case coefficients would be biased. Thus, we also estimate (1) using an instrumental variables approach similar to Nakamura and Steinsson (2014). Estimates obtained with this methodology are reported in the columns denoted with 'IV' in Table 2. The idea is to instrument for state corporate taxes using average corporate tax interacted with a state dummy. This instrument captures the differential sensitivity of corporate taxes across states to the national level of corporate tax. The identifying assumption is that the United States does not introduce tax reforms because states that have the highest corporate taxes are facing weaker labor market conditions relative to other states. In the first stage, we regress changes in state corporate taxes on changes in average taxes and fixed effects, allowing for different sensitivities across states. In the second stage, we estimate β in (1) using the fitted values of state corporate tax changes from the first-stage regression.

Finally, we estimate β in (1) by applying identification by heteroskedasticity, as in Lewbel (2012). Multipliers obtained with this methodology are reported in the columns denoted with 'het-IV' in Table 2. This method identifies structural parameters in models with endogenous regressors, where traditional instrumental variables are either weak or not readily available. To see how structural parameter β is estimated using heteroskedastic covariance restrictions, suppose that in (1), the state corporate tax is a classical endogenous regressor. This yields the standard triangular system associated with endogenous regressor models

$$\Delta Y = \beta_x \Delta X + \beta \Delta\tau + \epsilon_1, \tag{2}$$

$$\Delta\tau = \gamma_x \Delta X + \epsilon_2, \tag{3}$$

where we omit index it for brevity, and we define changes in variables by $\Delta\tau \equiv \tau_{it} - \tau_{it-1}$, $\Delta Y \equiv Y_{it} - Y_{it-1}$, and $\Delta X \equiv X_{it} - X_{it-1}$. The standard way to obtain identification and estimate β is to assume the exclusion restriction, that one or more elements of β_x equal zero and that the corresponding elements of γ_x are nonzero. The corresponding elements of X are then instruments, and the model is estimated by linear two-stage least square, as in column denoted with 'IV' in Table 2. Suppose we do not have an outside instrument that correlates with the endogenous regressor, so we have no exclusion restriction. Structural parameter β may be identified given some heteroskedasticity. If ε_2 is heteroskedastic (and therefore not independent of X), the identification comes from restricting the correlation of $\varepsilon\varepsilon'$ with X, in particular

$$E(X\epsilon_1) = 0, \quad E(X\epsilon_2) = 0, \quad Cov(X, \epsilon_1\epsilon_2) = 0. \tag{4}$$

For identification by heteroskedasticity, estimators are obtained by two-stage least squares and identifying restrictions in (4). Since estimates can be less reliable in comparison to estimates coming from standard exclusion restrictions, they can be used when instruments are not available, or together with traditional instruments to increase efficiency. We go for the second option, and include lags of changes in the corporate tax rate, i.e. $\Delta\tau_{t-1}$, $\Delta\tau_{t-2}$, as instruments. The appropriate lag structure is chosen such that we cannot reject the null hypotheses of the Hansen test of over-identification (Hansen J-statistic) and the instrument exogeneity test (C-statistic). We also limit estimation to more parsimonious models, with a lag structure shorter than three years, to account for the duration of the election cycle, and to enhance estimation precision.

Data. The lower part of Table 1 contains the data sources related to the state-level regressions. Data are yearly and cover the period 1980-2006 for wages, and the period 1992-2010 for other variables.

Results. Table 2 reports the estimates of the tax multiplier β in equation (1) under the alternative estimation methods that we described.[9]

[9]Tables reporting the coefficients on the investment and R&D tax credits, and government spending, are reported in Appendix A.3. Notice that the coefficients in the tables denote the effects on the dependent variable of reducing controls by one percentage point.

Table 2: Effects of Corporate Tax Decrease on Local Economic Activity

OLS	IV	het-IV	OLS	IV	het-IV
	Output			**Establishment entry**	
0.21	0.27	0.35**	0.25	4.12***	1.48*
(0.173)	(0.392)	(0.156)	(0.871)	(0.999)	(0.832)
	Establishment exit			**Real wage per worker**	
-0.74	-2.49***	0.54	0.11	0.33	0.36**
(0.511)	(0.945)	(0.489)	(0.125)	(0.316)	(0.077)

Notes. Columns (OLS) to (het-IV) in Table 2, show corporate tax rate multipliers after one year, while controlling for the change in state investment tax credit, R&D tax credit, loss carry-back rule, loss carry-forward rule, and government spending. In columns (IV), we use average state corporate tax, interacted with state dummy variables as an instrument for the state corporate tax in the two-stage regression. We also estimate coefficients by identification through heteroskedasticity as in (Lewbel, 2012) in column (het-IV). Standard errors are clustered by state and statistical significance is indicated by p-values as follows: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

The point estimates of β for the output regression range from 0.21 under OLS estimation, to 0.35 in the case of identification by heteroskedasticity (het-IV). The latter is significant, but lower than the corresponding VAR estimate in the first four quarters. Nevertheless, state-level results confirm our earlier finding that corporate income tax cuts promote economic activity. The point estimates of tax multipliers for establishment entry range from 0.25 to 4.12. Again, we confirm the result we obtained with the VAR analysis, namely that an unexpected cut in corporate income taxes leads to a significant increase in entry of new establishments after one year. In particular, column (het-IV) in Table 2 shows that a one-percentage-point reduction in the corporate income tax rate induces a significant 1.48 percent increase in the growth rate of establishment entry. The Cragg-Donald statistic in Table 6 is 24.41, which exceeds the critical value (21.39) at 5% from Stock and Yogo (2005), implying that any bias from using the lags of corporate tax changes as instruments is less than 5% of the bias from an OLS regression. Relatedly, Suárez Serrato and Zidar (2016) find that a one-percentage-point cut in business taxes causes roughly a 4 percentage point increase in the establishment growth rate over ten years. We also find a 4.12% percent significant increase in entry of new establishments after one year in column (IV). However, since the first-stage F-statistic, reported in Table 6, is small (3.973), the interacted average state corporate tax is a weak instrument. Thus, our estimate may be biased upward and we might capture effects due to reallocation and establishment mobility. Indeed, higher corporate taxes in a given state may induce firms to relocate to neighboring states. This would increase establishment entry in the state where firms relocate even in the absence of local tax changes. [10] Since we do not reject the hypothesis of exogenous instruments, we regard the estimates obtained by applying identification through heteroskedasticity (het-IV) as more reliable.[11]

The point estimates of β for the exit regression range from -2.49 to 0.54. The initial decrease in establishment exit, which we also observed in the VAR analysis, does not seem to be a robust feature of the data. Finally, consistently with the results from VAR analysis, we find that the real wage per worker significantly increases by 0.36% when the corporate income tax rate is reduced by 1 percentage point.

4 The Model

In what follows, we lay out a New Keynesian model with firm entry and exit that captures the patterns of productivity, business dynamism, and hours dedicated to different occupations that we identified in the empirical analysis. Our framework is characterized by ex-ante heterogeneous firms, producing a good in different varieties, and using labor as the only input. The economy features a mass of firms of endogenous length, which compete monopolistically. Labor is used for three purposes in our model economy: production of goods, creation of new firms, and other tasks not directly related to production, which we include under the umbrella of fixed costs of production. Households use the final good for consumption.

[10]Moreover, since in both cases the p-value of the Wu-Hausman test is close to zero, we reject the hypothesis of an exogenous instrument (see Table 6), and estimates may be inconsistent.

[11] See p-value of Hansen J and C statistics in Table 6.

4.1 Firms

We assume a production structure with two layers: a perfectly competitive final goods producer that bundles an endogenous mass of intermediate goods. Firms operating in the intermediate goods sector compete monopolistically, are subject to entry and exit, and are characterized by heterogeneous levels of productivity. In what follows, we will refer to firms producing intermediate goods as firms or as producers.

There is a continuum of potential entrants of an unbounded mass. Prior to entry, firms must draw their individual productivity level, z, from a known distribution $g(z)$ with a positive support. The idiosyncratic productivity level z remains unchanged over the lifetime of a firm. In order to draw their productivity level, firms must pay an entry cost, that we describe below.

Every incumbent firm produces an imperfectly substitutable good $y_t(z)$, which is then aggregated into the bundle Y_t by a final good producer. Note that the only source of firms' heterogeneity is their idiosyncratic productivity level. For this reason, we index firms with the letter z. The final good producer operates in a perfectly competitive environment with the following Constant Elasticity of Substitution (CES) production function:

$$Y_t^c = \left[\int_0^\infty N_t y_t(z)^{\frac{\theta-1}{\theta}} g(z) dz \right]^{\frac{\theta}{\theta-1}} \tag{5}$$

where $\theta > 1$ is the elasticity of substitution between intermediate goods, Y_t is the total output, and N_t is the length of the mass of producers. The output of the economy is used by households for consumption purposes. For this reason, we denote aggregate output with the superscript c. The producer of the final good takes prices of intermediate goods, $p_t(z)$ as given, and chooses the quantities of intermediate goods as to maximize its profits:

$$P_t Y_t^c - \int_0^\infty N_t p_t(z) y_t(z) g(z) dz,$$

given constraint (5). Notice that P_t is an aggregate price index, that we define below. Profits maximization leads to the demand for intermediate good z:

$$y_t(z) = \left(\frac{p_t(z)}{P_t}\right)^{-\theta} Y_t^c \tag{6}$$

Intermediate inputs are produced by a continuum of monopolistic firms of mass N_t indexed by the idiosyncratic productivity level z. The production is linear in labor $l_t^c(z)$, and reads as

$$y_t(z) = z l_t^c(z) \tag{7}$$

The variable Z_t is an exogenous, and common to all firms, aggregate level of productivity. The variable $l_t^c(z)$ represents the demand of labor for production purposes by firm z, that, for this reason, is denoted by the superscript c. The labor input used by the firms is defined as a CES aggregator of differentiated labor inputs supplied by households, that we index with $h \in [0,1]$. The bundle is defined as:

$$l_t(z) = \left[\int_0^1 \left(l_t^h(z)\right)^{\frac{\theta_w - 1}{\theta_w}} dh\right]^{\frac{\theta_w}{\theta_w - 1}},$$

where $\theta_w > 1$ is the elasticity of substitution between labor inputs. The minimization of total labor costs $\int_0^1 W_t^h l_t^h(z)\, dh$ by firm z results in the demand of labor type h, and in the aggregate nominal wage index. The former is given by:

$$l_t^h(z) = \left(\frac{W_t^h}{W_t}\right)^{-\theta_w} l_t(z), \tag{8}$$

while the latter reads as:

$$W_t = \left[\int_0^1 \left(W_t^h\right)^{1-\theta_w} dj\right]^{1/(1-\theta_w)},$$

where W_t^h is the wage associated to labor type h. Taking the aggregate real wage $w_t = \frac{W_t}{P_t}$ as given, firms maximize profits subject to the demand constraint $y_t(z) = (p_t(z)/P_t)^{-\theta} Y_t^c$.

This results in an optimal relative price, defined as $\rho(z) \equiv p_t(z)/P_t$, given by

$$\rho_t(z) = \frac{\theta}{\theta - 1} \frac{w_t}{z}. \tag{9}$$

Real profits can be written as $d_t(z) = \frac{1}{\theta} rr_t(z) - w_t f^{fix}$, where $rr_t(z) \equiv \rho_t(z) y_t(z)$ are real revenues. We assume firms face a fixed cost of production of f^{fix} labor units. As a result, labor is used for three purposes in the model. First, for the production of the final good, second for the creation of new firms, and third to cover fixed costs of production.

4.2 Entry and exit

Building on Bilbiie et al. (2012), the creation of a new firm is equivalent to the creation of a new product. For this reason, entry costs can be regarded as product development costs. Product creation requires using f^e units of labor. Hiring labor allows potential new entrants to draw a productivity level, z, from a p.d.f. $g(z)$. As a result, product development costs are proportional to the quantity of labor used for that purpose. This assumption is meant to mirror that in idea-based growth models, such as those in Romer (1990), Aghion and Howitt (1992), and Grossman and Helpman (1993), where product development costs are proportional to the quantity of labor used for $R\&D$ purposes. Let N_t^e be the mass of firms that pay the entry cost. To capture the fact that not all attempts to create a new product are successful, we assume that just a fraction of new firms will indeed take a product to the market. The mass of successful new firms is denoted by $\Psi_t(N_t^e, N_{t-1}^e)$, which is formally defined as:

$$\Psi_t(N_t^e, N_{t-1}^e) = 1 - \frac{\psi}{2} \left(\frac{N_t^e}{N_{t-1}^e} - 1 \right)^2. \tag{10}$$

The assumption that the probability of success is a decreasing function of the change in entry can be interpreted as a flow adjustment cost to the extensive margin of investment, akin to the physical capital investment adjustment cost in Christiano et al. (2005), or as congestion effects in entry. As in Lewis and Poilly (2012), this specification allows to capture the gradual response of entry to shocks. Unsuccessful new firms disappear from the market. Firms can further exit the market when hit by an exogenous exit shock, which permanently wipes out a fraction δ of firms, both successful new firms and incumbents, in each period t. As in many other studies in the literature, we assume a one-time period to build, i.e. a one-period lag between the decision to enter the market and the beginning of production. This period represents the amount of time required to set up production facilities. As a result, the number of firms in the market evolves according to:

$$N_t = (1-\delta)(N_{t-1} + \Psi_t N_t^e). \tag{11}$$

where N_{t-1} is the mass of firms in the market at the beginning of period t. Due to the fixed costs of production, not all N_{t-1} firms will have non-negative profits, but just those whose idiosyncratic productivity, z, is high enough. Thus, a cut-off productivity can be defined as the minimal idiosyncratic productivity level such that profits are non-negative, and we denote it as z_t^*. Using the definition just provided, z_t^* can be computed by setting individual real profits equal to zero. Formally:

$$\frac{1}{\theta}\left(\rho_t(z_t^*)\right)^{1-\theta} Y_t^c = w_t f^{fix}.$$

Substituting the definition of the optimal price, given by (9), in the equation above, we obtain:

$$z_t^* = \frac{\theta^{\frac{\theta}{\theta-1}}}{\theta-1}\left(w_t\right)^{\frac{\theta}{\theta-1}}\left(\frac{f^{fix}}{Y_t^c}\right)^{\frac{1}{\theta-1}} \tag{12}$$

Firms with idiosyncratic productivity below z_t^* become idle, or equivalently, inactive. Inactive firms discontinue production, but stand ready to join the mass of active firms when their idiosyncratic productivity becomes again larger than z_t^*. Notice that z_t^* is directly affected by the magnitude of fixed costs of production, f^{fix}, by aggregate production, Y_t^c, and by the real wage w_t. Lower fixed costs of production require a lower idiosyncratic productivity level to break-even. A higher aggregate demand Y_t^c leads to a larger individual demand, which again lowers the cut-off productivity z_t^*. Finally, but importantly for our transmission mechanism, a higher real wage increases fixed costs of production, requiring a higher idiosyncratic productivity level to break-even.

Operative firms, which have mass S_t, are those with idiosyncratic productivity larger or equal to z_t^*. The set of operating firms at time t is, thus:

$$S_t = N_{t-1} Pr[z \geq z_t^*] = [1 - G(z_t^*)] N_{t-1}, \tag{13}$$

where $G(z)$ is the cumulative distribution function associated to the probability distribution function $g(z)$: $G(z) = \int_0^z g(x)dx$. For this reason, only successful new entrants with productivity larger than the cut-off level will become operative. In the BED dataset, openings are defined as those establishments that had positive employment for the first time in the third month of the current quarter with no link to the previous quarter. Thus, to be consistent with the data, only new firms that become operative should be considered as new entrants.[12]

The entry condition is specified in the households' problem. Since the idiosyncratic productivity z is unknown ex-ante, the expected value of a firm is evaluated using a specific average productivity, that we define below. We refer to the firm endowed with the specific average productivity as to the average firm.

4.3 Households

The economy is populated by a unit mass of households with expected lifetime utility given by:

$$U(h) = E_0 \sum_{t=0}^{\infty} \beta^t \left(\log C_t(h) - \chi \frac{L_t(h)^{1+1/\phi}}{1 + 1/\phi} \right), \tag{14}$$

[12] In other words, a new entrant is a firm that, one period after the entry decision, hires production workers and workers employed in other tasks not directly related to production, besides product development. The Product development process happens in the stage prior to starting actual production, and it does not necessarily lead to the launch of a new product.

The variables $L_t(h)$ and $C_t(h)$ denote hours of work and consumption of the final good, respectively. As customary, we denote the discount factor with the letter β, while the parameter χ is a disutility of labor multiplier, and ϕ the Frisch elasticity.

Households are assumed to have access to a complete set of nominal state-contingent assets. Agents can purchase any desired state-contingent nominal payment $A_{t+1}(h)$ for period $t+1$ at the dollar cost $\Lambda_{t,t+1}A_{t+1}(h)$. The variable $\Lambda_{t,t+1}$ denotes a stochastic discount factor in nominal terms between periods t and t+1. Additionally, the household invests in equity, $\mathcal{E}_t(h)$. Total investment in equity can be expressed as $\widetilde{v}_t\mathcal{E}_t(h)$, where $\widetilde{v}_t$ denotes the real value of the average firm, that is the value of the firm with average productivity. Finally, the household invests $w_t f_t^e N_t^e(h)$ in startup costs. Each household has monopoly power over the differentiated labor input it provides. We introduce wage stickiness in the model by assuming that wage adjustments are costly, as in Lewis and Stevens (2015). To adjust its wage, W_t^h, the household pays an adjustment cost given by $wac_t(h) = \frac{1}{2}\kappa_w(W_t^h/W_{t-1}^h - 1)^2 W_t(h)L_t(h)/P_t$ in real terms. At the beginning of period t, the household owns equity in incumbent firms and in the successful entrants that entered in the previous period. The value of the portfolio of the household can be expressed as $(1-\delta)\widetilde{v}_t[\mathcal{E}_{t-1}(h) + \Psi_{t-1}(\cdot)N_{t-1}^e(h)]$. At time t, the household receives real labor income equal to $\frac{W_t^h L_t(h)}{P_t}$, state-contingent nominal payment $A_t(h)$, and dividend income. Notice that only operative firms can distribute dividends. Thus, after-tax dividends received by the household can be written as $(1-\delta)(1-\tau_t)\widetilde{d}_t[\mathcal{E}_{t-1}(h) + \Psi_{t-1}(\cdot)N_{t-1}^e(h)]$, where τ_t is the tax rate on dividend income, and $\tilde{d}_t$ denotes average dividends, that is dividends distributed by the firm endowed with the average productivity level.[13] Lump-sum transfers are denoted by $T_t(h)$. As a result, the households flow budget constraint in real terms reads

[13] Households own firms and firms distribute all their profits in each period. As a result, whether the tax is at the household or firm level makes no difference.

as:

$$\frac{W_t^h}{P_t}L_t(h) + T_t(h) + (1-\delta)\left[\widetilde{v}_t + (1-\tau_t)\widetilde{d}_t\left(\frac{S_t}{N_{t-1}}\right)\right][\mathcal{E}_{t-1}(h) + \Psi_{t-1}(\cdot)N_{t-1}^e(h)] + \frac{a_t(h)}{\pi_t} \geq$$
$$\widetilde{v}_t\mathcal{E}_t(h) + w_t f_t^e N_t^e + C_t(h) + \Lambda_{t,t+1}a_{t+1}(h) + wac_t(h). \tag{15}$$

The variable $\frac{a_t(h)}{\pi_t} = \frac{A_t(h)}{P_t}$ denotes the real payoff in period t of nominal state-contingent assets purchased in period t-1, while the variable $\pi_t = \frac{P_t}{P_{t-1}}$ denotes consumer price inflation. Households maximize lifetime utility by choosing consumption, the nominal wage for the specific labor type it supplies, and how much to invest in state-contingent assets, equity, and in new entrants. Anticipating symmetry, the first-order conditions for consumption and contingent claims jointly imply:

$$\Lambda_{t,t+1} = \beta E_t \frac{C_t}{C_{t+1}}\frac{P_t}{P_{t+1}}, \tag{16}$$

while the first-order condition with respect to equity delivers the firm valuation equation:

$$\widetilde{v}_t = (1-\delta)E_t\{\Lambda_{t,t+1}[\widetilde{v}_{t+1} + (1-\tau_{t+1})\widetilde{d}_{t+1}S_{t+1}/N_t]\}. \tag{17}$$

The absence of arbitrage opportunities in financial markets requires that the gross risk-free nominal interest rate, which we denote by R_t, be equal to the reciprocal of the price in period t of a nominal security that pays one unit of currency in every state of period t + 1. Formally $R_t = \frac{1}{E_t\Lambda_{t,t+1}}$. This relationship together with the household's first-order condition for contingent claims implies that:

$$1 = \beta R_t E_t \frac{C_t}{C_{t+1}}\frac{1}{\pi_{t+1}}, \tag{18}$$

which is a standard Euler equation for pricing nominally risk-free assets. Imposing symmetry and defining the gross wage inflation rate $\omega_t \equiv W_t/W_{t-1}$, we can write the first order condition for the wage W_t^h as:

$$\theta_w \frac{\chi L_t^{1/\phi} C_t}{w_t} = (\theta_w - 1)[1 - \frac{\kappa_w}{2}(\omega_t - 1)^2] + \kappa_w \omega_t (\omega_t - 1)$$
$$-\kappa_w E_t \left\{ \beta \frac{C_t}{C_{t+1}} \omega_{t+1}(\omega_{t+1} - 1) w_{t+1} L_{t+1} / (w_t L_t) \right\} \tag{19}$$

Wage inflation and the real wage are related through the identity $\omega_t/\pi_t = w_t/w_{t-1}$. The entry condition states that the cost of entry must be equalized to the value of a firm. Formally:

$$\frac{w_t f_t^e}{Z_t} = \widetilde{v}_t(\Psi_t + \Psi_{1t} N_t^e) + E_t \left\{ \Lambda_{t,t+1} \widetilde{v}_{t+1} \Psi_{2t+1} N_{t+1}^e \right\}, \tag{20}$$

where Ψ_{it} is the first derivative of the success rate with respect to its ith argument. The left-hand side of (20) represents the startup cost in terms of the final good. The right-hand side captures the expected change in the value of the average firm resulting from the marginal entrant. It has three components. The first one is average firm value, $\widetilde{v}_t$, multiplied by the start-up success rate, Ψ_t. The marginal entrant affects both the current and future value of entry through its effect on the success rate. Indeed, the second term to the right-hand side of the entry condition accounts for the effect of entry on the current success rate. Through the congestion externality, entry lowers the probability of success in the current period which is captured by $\Psi_{1t} N_t^e$. Finally, since the congestion effect depends on the change in entry rather than on its level, the number of entrants today raises, *ceteris paribus*, the entry success probability tomorrow. This is captured by the term $\Psi_{2t} N_t^e$ that multiplies tomorrow's value, and affects the continuation value of the firm.

4.4 Government

The Government levies dividend income taxes and redistributed revenues in a lump sum fashion to households. The period-by-period budget constraint of the government is given by:

$$\tau_t \widetilde{d}_t S_t = T_t, \tag{21}$$

where $T_t = \int_0^1 T_t(h)dh$ are aggregate transfers. The tax rate τ_t is modelled as an autoregressive process,

$$\tau_t = (1-\rho_\tau)\tau + \rho_\tau \tau_{t-1} + \varepsilon_t. \tag{22}$$

4.5 Monetary policy

The central bank sets the nominal interest rate, R_t, according to the following Taylor rule with smoothing:

$$\ln\left(\frac{R_t}{R}\right) = \phi_R \ln\left(\frac{R_{t-1}}{R}\right) + (1-\phi_R)\left[\phi_\pi \ln\left(\frac{\pi_t}{\pi}\right) + \phi_Y \ln\left(\frac{Y_t}{Y}\right)\right], \tag{23}$$

where variables without time subscripts denote steady-state values. For simplicity, we assume that the steady state gross inflation rate equals one.

4.6 Pareto Productivity Distribution

We assume that the function $g(z)$ is Pareto with minimum equal to z_{min} and tail parameter equal to κ. This assumption simplifies considerably several equilibrium conditions, and allows to compute analytical solutions. Following Melitz (2003a), a special average productivity $\tilde{z}_t$ is defined over operating firms. This moment summarizes the relevant information of the model since the entire economy is isomorphic to one populated by a mass S_t of homogeneous firms, each endowed with productivity $\tilde{z}_t$. Using the properties of the Pareto distribution, this productivity can be written as a function of cut-off productivity, z_t^*, as follows:

$$\tilde{z}_t = \left[\frac{1}{1-G\left(z_t^*\right)} \int_{z_t^*}^{\infty} z^{\theta-1} g(z) dz\right]^{\frac{1}{\theta-1}} = \nu z_t^*, \tag{24}$$

where $\nu = [\kappa / (\kappa - (\theta - 1))]^{1/(\theta-1)}$. Given that only a subset of firms is active in the market in a given period, the aggregate price index, P_t, reads as:

$$P_t = \left[\frac{1}{1 - G(z^*)} \int_{z^*}^{\infty} p_t(z)^{1-\theta} S_t g(z) dz \right]^{\frac{1}{1-\theta}}. \tag{25}$$

With the average productivity level given by (24), one can show that the optimal real price of the firm with average productivity, can be written as:

$$\rho_t(\widetilde{z}) = S_t^{\frac{1}{\theta - 1}}. \tag{26}$$

Further, given the properties of the Pareto distribution, it follows that:

$$1 - G(z_t^*) = \left(\frac{z_{min}}{z_t^*} \right)^{\kappa}.$$

In the Appendix, we show that aggregate variables can be obtained by multiplying idiosyncratic quantities, evaluated for a firm endowed with the average productivity $\tilde{z}_t$, by the number of active firms. In other words, type-$\tilde{z}$ variables represent average quantities across active firms. Formally, we can define aggregate labor demand for production purposes as $L_t^c = S_t \tilde{l}_t^c$, while aggregate dividends as $D_t = S_t \tilde{d}_t$, where variables characterized with a tilde refer to the firm with productivity level $\tilde{z}_t$, that is the average level of productivity. Notice that the total value of the firms in the economy, V_t, is defined using the total number of firms, N_t, and not just the number of operative firms, S_t. This is so since idle firms have a non-zero value. Indeed, the total value is:

$$V_t = N_t \tilde{v}_t.$$

4.7 Aggregation and market clearing

Aggregating the budget constraint over households, imposing asset market clearing, and combining this with the government budget constraint, we obtain the aggregate account-

Table 3: EQUILIBRIUM CONDITIONS: BASELINE MODEL

Marg. firm's revenue	$\theta w_t f^c = \widetilde{rr}_t \left(\widetilde{z}_t / z_t^*\right)^{1-\theta}$
Marg. firm's productivity	$\widetilde{z}_t = (\frac{\kappa}{\kappa-(\theta-1)})^{1/(\theta-1)} z_t^*$
Avg. firm's revenue	$\widetilde{rr}_t = \widetilde{\rho}_t \widetilde{y}_t$
Avg. firm's profits	$\widetilde{d}_t = \frac{1}{\theta}\widetilde{rr}_t - w_t f^{fix}$
Avg. firm's value	$\widetilde{v}_t = (1-\delta) E_t\{\Lambda_{t,t+1}[\widetilde{v}_{t+1} + (1-\tau_{t+1})\widetilde{d}_{t+1} S_{t+1}/N_{t+1}]\}$
Entry condition	$w_t f_t^e = \widetilde{v}_t(\Psi_t + \Psi_{1t} N_t^e) + E_t\{\Lambda_{t,t+1}\widetilde{v}_{t+1}\Psi_{2t+1} N_{t+1}^e\}$
Entry success rate	$\Psi_t = 1 - 0.5\psi(N_t^e/N_{t-1}^e - 1)^2$
Entry success, deriv. 1	$\Psi_{1t} = -\psi(N_t^e/N_{t-1}^e - 1)/N_{t-1}^e$
Entry success, deriv. 2	$\Psi_{2t} = \psi(N_t^e/N_{t-1}^e - 1)N_t^e/(N_{t-1}^e)^2$
Active firms	$S_t = (z_{\min}/z_t^*)^{\kappa}\, N_{t-1}$
Firm dynamics	$N_t = (1-\delta)(N_{t-1} + \Psi_{t-1} N_t^e)$
Price setting	$\widetilde{\rho}_t = \widetilde{\mu}_t w_t / (\widetilde{z}_t)$
Avg. firm's markup	$\widetilde{\mu}_t = \theta/(\theta-1)$
Price index	$\widetilde{\rho}_t = S_t^{1/(\theta-1)}$
Bond holdings	$1 = R_t E_t\{\Lambda_{t,t+1}/\pi_{t+1}\}$
Wage setting	$\theta_w \chi L_t^{1/\phi} C_t / w_t = (\theta_w - 1)\left[1 - \frac{\kappa_w}{2}(\omega_t - 1)^2\right] + \kappa_w \omega_t(\omega_t - 1) - \kappa_w E_t\left\{\Lambda_{t,t+1}\omega_{t+1}(\omega_{t+1}-1) w_{t+1} L_{t+1}/(w_t L_t)\right\}$
Wage inflation identity	$\omega_t = \pi_t^C w_t / w_{t-1}$
Resource constraint	$(w_t f_t^e) N_t^e + C_t + 0.5\kappa_w(\omega_t - 1)^2 L_t = \widetilde{d}_t S_t + w_t L_t$
Stochastic discount factor	$\Lambda_{t-1,t} = \beta C_{t-1}/C_t$
Firm output	$\widetilde{y}_t = \widetilde{z}_t \widetilde{l}_t^c$
GDP	$Y_t = \widetilde{d}_t S_t + w_t L_t$
Hours prod./hours total	$h_{pt} = S_t \widetilde{l}_t^c / L_t$
Monetary policy	$\ln(R_t/R) = \tau_R \ln(R_{t-1}/R) + (1-\tau_R)[\tau_\pi \ln(\pi_t/\pi) + \tau_y \ln(Y_t/Y)]$
Tax rule	$\tau_t = (1-\rho_\tau)\tau + \rho_\tau \tau_{t-1} - \varepsilon_t^\tau$

Notes. Endogenous variables: z_t^*, $\widetilde{z}_t$, $\widetilde{rr}_t$, $\widetilde{d}_t$, $\widetilde{v}_t$, N_t^e, Ψ_t, Ψ_{1t}, Ψ_{2t}, S_t, N_t, $\widetilde{\rho}_t$, $\widetilde{\mu}_t$, w_t, ω_t, L_t, C_t, $\Lambda_{t-1,t}$, $\widetilde{l}_t^c$, $\widetilde{y}_t$, Y_t, h_{pt}, R_t, τ_t.

ing relation,

$$\widetilde{d}_t S_t + w_t L_t = w_t f^e N_t^e + C_t + wac_t. \tag{27}$$

As mentioned earlier, labor is used for three purposes in the model: production, creation of new firms/products, and for activities not directly related to the other two, which we included under the umbrella of fixed costs. The creation of a new firm requires f^e effective units of labor, thus labor demand for the creation of new firms is $L_t^e = N_t^e f^e$. Labor demand to cover fixed costs is $L_t^{fix} = S_t f^{fix}$, and production hours are $S_t \widetilde{l}_t^c$. Summing labor demand for the three purposes, it follows that labor market clearing condition requires:

$$L_t = S_t\left(\widetilde{l}_t^c + f^{fix}\right) + N_t^e f^e. \tag{28}$$

A summary of the baseline model's equilibrium conditions is provided in Table 3. The computation of the steady-state of the baseline model is provided in Table 9 in the Appendix.

Table 4: Equilibrium conditions: symmetric firm model

Firm revenue	$rr_t = \rho_t y_t$
Firm profits	$d_t = \frac{1}{\theta} rr_t - w_t f^c$
Firm value	$v_t = (1-\delta)E_t\{\beta_{t,t+1}[v_{t+1} + (1-\tau_{t+1})d_{t+1}]\}$
Entry condition	$w_t f^e = v_t(\Psi_t + \Psi_{1t} N_t^e) + E_t\{\beta_{t,t+1} v_{t+1} \Psi_{2t+1} N_{t+1}^e\}$
Entry success rate	$\Psi_t = 1 - 0.5\psi(N_t^e/N_{t-1}^e - 1)^2$
Entry success rate, deriv. 1	$\Psi_{1t} = -\psi(N_t^e/N_{t-1}^e - 1)/N_{t-1}^e$
Entry success rate, deriv. 2	$\Psi_{2t} = \psi(N_t^e/N_{t-1}^e - 1)N_t^e/(N_{t-1}^e)^2$
Active firms	$S_t = N_t$
Firm dynamics	$N_t = (1-\delta)(N_{t-1} + \Psi_{t-1} N_{t-1}^e)$
Price setting	$\rho_t = \mu_t w_t$
Markup	$\mu_t = \theta/(\theta-1)$
Price index	$\rho_t = S_t^{1/(\theta-1)}$
Bond holdings	$1 = R_t E_t\{\Lambda_{t,t+1}/\pi_{t+1}\}$
Wage setting	$\theta_w \chi L_t^{1/\phi} C_t/w_t = (\theta_w - 1)\left[1 - \frac{\kappa_w}{2}(\omega_t - 1)^2\right] + \kappa_w \omega_t(\omega_t - 1) - \kappa_w E_t\left\{\Lambda_{t,t+1}\omega_{t+1}(\omega_{t+1} - 1)w_{t+1}L_{t+1}/(w_t L_t)\right\}$
Wage inflation identity	$\omega_t = \pi_t^C w_t/w_{t-1}$
Resource constraint	$w_t f^e N_t^e + C_t + 0.5\kappa_w(\omega_t - 1)^2 L_t w_t = d_t N_t + w_t L_t$
Stochastic discount factor	$\beta_{t-1,t} = \beta C_{t-1}/C_t$
Firm output	$y_t = l_t^c$
GDP	$Y_t = d_t S_t + w_t L_t$
Hours prod./hours total	$h_{pt} = N_t l_t^c / L_t$
Monetary policy	$\ln(R_t/R) = \tau_R \ln(R_{t-1}/R) + (1-\tau_R)[\tau_\pi \ln(\pi_t/\pi) + \tau_y \ln(Y_t/Y)]$
Tax rule	$\tau_t = (1-\rho_\tau)\tau + \rho_\tau \tau_{t-1} - \varepsilon_t^\tau$

Notes. Endogenous variables: rr_t, d_t, v_t, N_t^e, Ψ_t, Ψ_{1t}, Ψ_{2t}, S_t, N_t, w_t, ω_t, ρ_t, μ_t, L_t, C_t, $\Lambda_{t-1,t}$, l_t^c, y_t, Y_t, h_{pt}, R_t, τ_t.

4.8 Special case: model with symmetric firms

In Section 5, we turn to the transmission of tax cuts implied by the model and how this is shaped by the different model features and parameter values. For comparison, we also study the dynamics in response to a tax cut in a model with homogeneous firms and exogenous exit, similar to Bilbiie et al. (2012). In the model with symmetric firms, there is no distinction between the average and the marginal firm. The equations defining equilibrium in the case of homogeneous firms are reported in Table 4. The conditions defining the steady state of this economy are reported in Table 10 in the Appendix.

4.9 Calibration

The time period is a quarter. In calibrating the model, we opt for parameter values that are commonly used in the business cycle literature. Parameters that are specific to our framework are, instead, calibrated on the basis of the available empirical evidence. The discount rate β is set to 0.99, consistent with a 4% real interest rate in a quarterly model, which implies that the gross quarterly real interest rate is $R = 1.01$. The Frisch elasticity of labor supply, ϕ, is set to 4 as in King and Rebelo (1999). The elasticity of substitution between goods is set to $\theta = 3.8$ from Bernard et al. (2003), which is calibrated to fit US plant and macro trade data. The elasticity of substitution across labor types, θ_w, is set to the same value, in line with the calibration adopted by Smets and Wouters (2007). As a result, the steady-state wage and price markups are identical and equal to 36 percent. The wage adjustment cost parameter, κ_w, is set such that the slope of the implied wage Phillips curve equals 0.05 as estimated by Lewis and Poilly (2012).[14] The parameterization of the productivity distribution is as follows. We normalize, with no loss of generality, z_{min} to 1. In the spirit of Gabaix (2011) and Di Giovanni and Levchenko (2012), our economy can be defined as granular when $1 < \frac{\kappa}{\theta-1} < 2$. In the granular view, idiosyncratic shocks to large firms have the potential to generate nontrivial aggregate shocks that affect GDP, and via general equilibrium, all firms. Given the value assigned to θ, we set the baseline value of the Pareto tail parameter $\kappa = 6$. Under this calibration, the benchmark economy is just short of being granular. As a result, the Herfindahl-Hirschman Index (HHI) of market concentration is well-defined. Since one could use the HHI to calibrate the productivity distribution used in our framework to specific sectors or countries, as in Colciago and Silvestrini (2022), we regard the latter as a desirable property.[15] We choose to calibrate the steady-state productivity cut-off z^* in order to match the average share of zombie firms in the US, which according to Banerjee and Hofmann (2020) is roughly 10% since the mid-1980s, i.e. $S/N = 0.9$.[16]

The parameter δ is set to 0.025 to match the US empirical level of 10% job destruction

[14] Lewis and Poilly (2012) consider a model with entry of homogeneous firms and quadratic wage adjustment costs. They derive and estimate a wage Phillips curve. Since firm heterogeneity does not affect wage setting, we can calibrate the wage adjustment cost parameter in order to match the slope of the wage Phillips curve they estimated. Notice that the slope of the curve is $\frac{\theta_w - 1}{\kappa_w} s_l$, where s_l denotes the labor share of income. See Lewis and Poilly (2012) for details.

[15] Indeed, the HHI is not properly defined if the economy is granular.

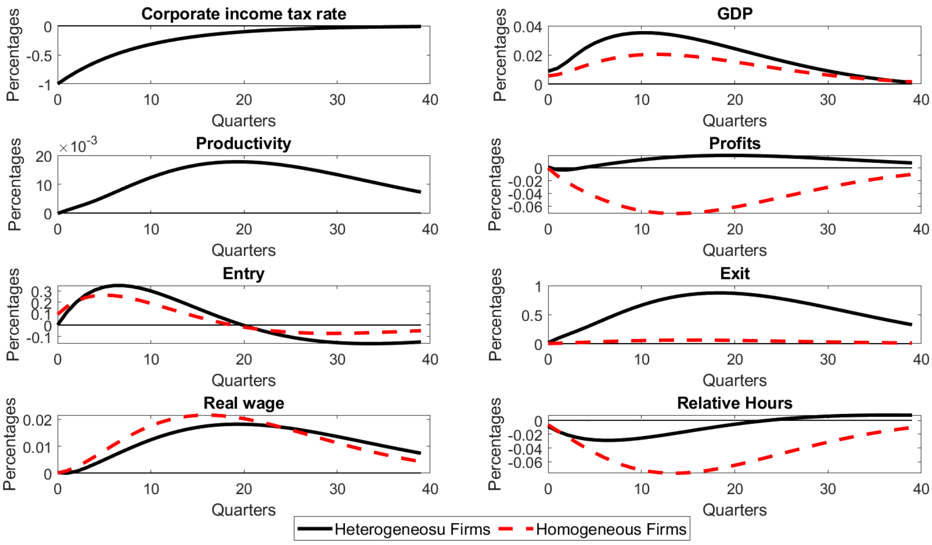
[16] We experimented with alternative values of this ratio and results are robust. We also applied a different calibration strategy in order to pin down the ratio S/N. Namely, we fixed the ratio between fixed costs and entry costs to match the evidence reported by Collard-Wexler (2013), who finds that the ratio of entry costs to fixed production costs is approximately 4.5. Impulse responses are not qualitatively altered.

per year, as in Bilbiie et al. (2012). Considering the estimate in Lewis and Poilly (2012), we set the parameter ψ, characterizing the function determining the probability of successful entry, to 8.31. We normalize f^e to 1, as in Bilbiie et al. (2012). The parameters of the interest rate rule are held constant across experiments and are set to the customary values of $\phi_\pi = 1.5$, $\phi_Y = 0$ and $\phi_R = 0.8$. The steady-state dividend tax rate is set to $\tau = 0.22$. This value represents the mean dividend income tax rate in the US over the period 1980:Q1–2006:Q1. The persistence parameter ρ_τ, is set to 0.89 as estimated from the tax rule (22).

5 Transmission of corporate income tax shocks

Figure 2 depicts the model equivalent of the empirical IRFs identified in Section 3.1. Solid lines refer to our baseline model, characterized by heterogeneous firms, while dashed lines refer to the model with symmetric firms. The vertical axis of each panel reports percentage deviations from the steady state of the variables of interest.

Figure 2: Responses to corporate income tax cut: baseline vs symmetric-firm model



Notes. Figure displays impulse response functions of key macroeconomic variables to a one percentage point decrease in the corporate income tax rate. Solid lines: baseline model; dashed lines: symmetric-firm model. Vertical axis measures percentage deviations from steady state.

Let us initially focus on the transmission of the shock in our *baseline* model. The model responses to the fiscal shock are qualitatively in line with the empirical ones. The transmission mechanism of the tax shock is as follows. By leading to a higher discounted value of future net profits, lower corporate taxes stimulate the creation of new firms and aggregate demand. This leads to a surge in labor demand for both production and development purposes. The increase in labor demand translates into a higher real wage. The latter entails cleansing along the exit margin and selection along the entry one.

A higher real wage leads to an increase in fixed costs of production. As a result, firms need higher idiosyncratic productivity to break even. For this reason, only the most productive firms remain active. Firms with lower productivity discontinue production, inducing an increase in the endogenous component of exit due to cleansing. Firms that remain operative benefit from a rise in demand for their products as consumers switch expenditure from discontinued products to surviving ones. As a result, profits respond positively despite the rise in production costs: the revenue channel dominates the labor cost channel.

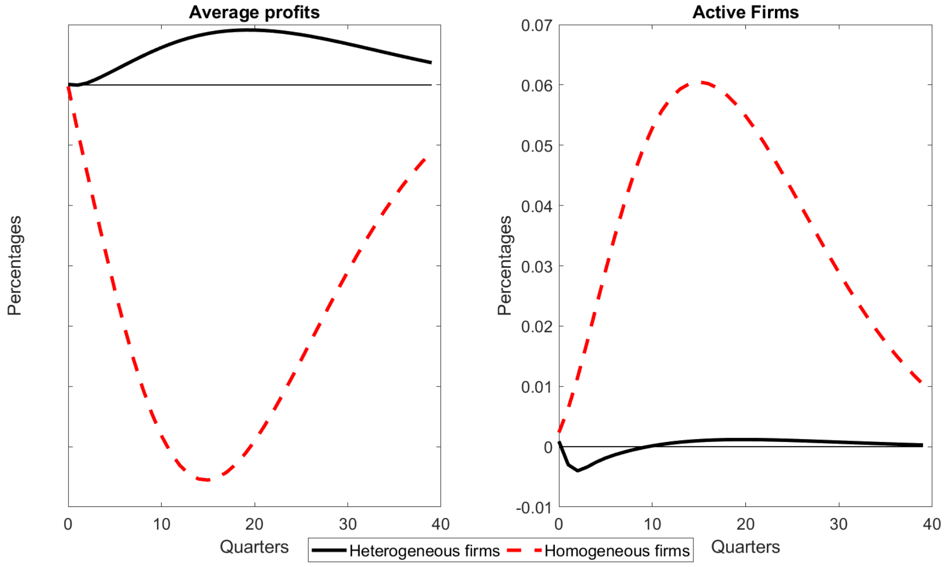
The tax cut makes it more attractive to invest in new firms. However, not all startups will become new entrants. This is so for two reasons. The first one is that, with congestion effects in entry, not all startups will be successful. The second one is an endogenous selection effect at the entry stage. Indeed, since entry costs are measured in terms of labor, the higher real wage implies a temporary rise in entry costs. As a result, only those new firms with sufficiently high productivity will become operative. As mentioned above, in the data new entrants are those firms that actually make it to the production stage. Failed attempts to enter into an industry are not registered. Thus, to be consistent with the data, Figure 2 displays the response of operative new firms, that is new firms that actually produce for the first time. Due to selection, the response of operative new firms is muted on impact. However, it has to be considered that failed attempts to enter the market are, nevertheless, costly in terms of labor. For this reason, while the impact response of operative new firms is muted, the impact response of labor required for the development of new firms is stronger than that of production labor. As a result, relative hours, i.e. production hours relative to total hours worked, decrease on impact.

In the case of *symmetric* firms, the key difference with respect to the previous case is the absence of both selection and cleansing. This leads to several differences in the dynamic responses to the shock across the two models. As described earlier, the tax rate cut induces investment in new firms and a positive demand effect that fuels both the real wage and output. However, the increase in the real wage does not entail neither section nor cleansing. Indeed, due to lack of selection, entry displays a quantitatively stronger response with respect to the case where firms are heterogeneous. Exit, by construction, does not display any endogenous reactions. As a result, (average) firm productivity does not increase, and firms do not benefit from the industry shake-up described in the case of heterogeneity. The surge in the real wage in response to the fiscal stimulus entails higher costs of production, fixed and variable, for incumbent firms. Absent productivity gains, these translate into a counterfactually negative response of aggregate before-tax profits in the model with homogeneous firms. In other words, the labor cost channel dominates the revenue channel when firms are homogeneous.

To see this more transparently, Figure 3 decomposes the variation in aggregate profits into an intensive and extensive margin by displaying, respectively, the response of average profits and the response of operative firms to the shock. Recall that, in the symmetric-firm model, all the firms in the market are operative.

Average profits reflect the difference between revenues and costs for the firm with average productivity, and it is a measure of profitability. In the case of homogeneous firms, the absence of both selection and cleansing implies that the increase in the real wage is not accompanied by an increase in average productivity. As a result, average profits

Figure 3: RESPONSES TO CORPORATE INCOME TAX CUT: DECOMPOSING TOTAL PROFITS



Notes. Figure displays IRFs of average profits and operative firms in response to a one percentage point decrease in the corporate income tax rate. Vertical axis measures percentage deviations from steady state.

decrease. Lack of selection and cleansing leads to a surge in operative firms in the case of homogeneity. On the contrary, in response to the tax cut, heterogeneity entails fewer active firms that are on average more productive and earn higher profits. To summarise, while the increase in average productivity delivered by our model is relatively small, it involves a shake-up of the market that improves the fit of the model to the empirical IRFs to a corporate income tax shock, underscoring the importance of accounting for heterogeneity in the analysis.

6 Extension: price rigidities

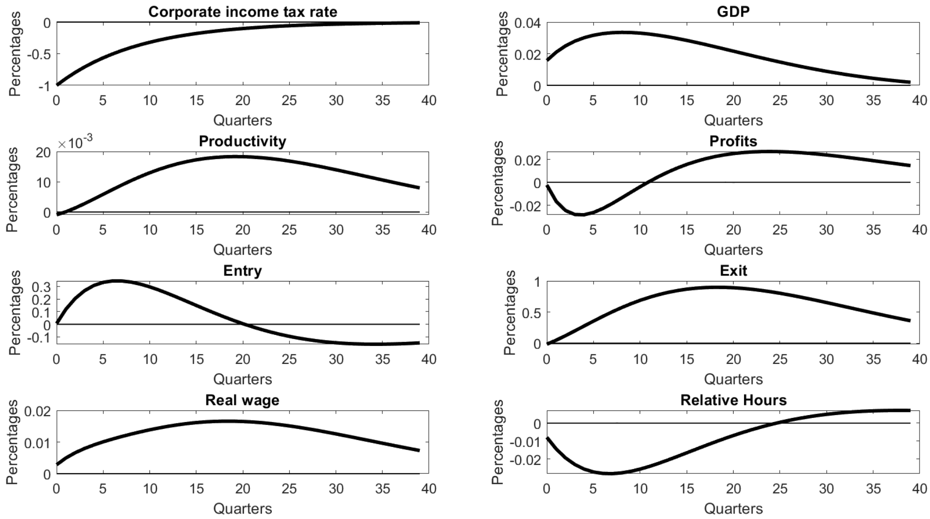
In this section, we enrich the baseline model with price rigidities. Following Rotemberg (1982), we stipulate that firms face a quadratic price adjustment cost measured in terms of their sales:

$$pac_t = \frac{\kappa_p}{2}\left(\frac{p_t(z)}{p_{t-1}(z)} - 1\right)^2 p_t(z)y_t(z). \tag{29}$$

The price adjustment costs can be interpreted as the amount of marketing material that a firm must purchase when implementing a price change. We follow Rotemberg (1982) and interpret the time $t-1$ price in (29) as the notional price that the firm would have set at time $t-1$ if it had been producing in that period. All firms incur the marketing costs in (29) when implementing a price decision. As argued by Bilbiie et al. (2007), this assumption is consistent with the original Rotemberg (1982) setup, and with the time-to-build-a-firm assumption. Specifically, as in Rotemberg (1982)'s framework, the initial condition for the individual price is dictated by nature. We assume that a new entrant, at the time of its first price-setting decision, knows the previous period's product price. This is consistent with the timing assumption regarding entry: given that an entrant starts producing with a one-period lag, it can learn the product price during the entry phase. Price adjustment costs affect the definition of the price markup, profits and of cut-off productivity level. Appendix A.1 provides technical details concerning the model with both price and wage stickiness. Figure 4 displays the effects of a one percent unexpected cut in the corporate tax rate when both types of nominal rigidities are present, i.e. when prices and wages are sticky.

The IRF of aggregate profits represents the main difference with respect to our baseline case. Indeed, a framework characterized by both price and nominal wage stickiness delivers a counterfactually negative response of before-tax profits to the tax cut. As in the case of homogeneity, the reason is that the labor cost channel dominates the revenue channel. However, under price stickiness and heterogeneous firms, the mechanism that leads to this outcome is different from that described when comparing the heterogeneous and the homogeneous case. In the case of homogeneous firms, there are no productivity gains in response to the shock. On the contrary, when the baseline model is augmented with price stickiness, the selection and cleansing process is at work. As a result, productivity increases in response to the shock. In this case, profitability is impaired because a

Figure 4: Responses to corporate income tax cut: both prices and wages sticky



Notes. Figure displays IRFs of key macroeconomic variables to a one percentage point decrease in the corporate income tax rate when both prices and wages are sticky. Vertical axis are percentage deviations from steady state.

fraction of firms cannot adjust prices.

7 Conclusion

This paper is an exploration of the effects of a corporate income tax stimulus on firm dynamics and productivity in the United States. We find that establishment entry increases with delay in response to an unexpected cut in the corporate income tax rate. On the contrary, the shock entails immediate benefits in terms of productivity and GDP. To interpret the evidence, we present a New Keynesian industry dynamic model where firms have heterogeneous productivity, and entry and exit are endogenous. The model features a selection and cleansing process in response to the tax shock that helps to explain the estimated responses of productivity and business dynamism. Our paper does not account for technological adoption by incumbents. Considering both margins of technological adoption, the intensive and extensive one, could deliver a better quantitative matching of the empirical impulse response functions that we identify. A further direction for future research involves a decomposition of corporate tax into dividend and capital gains tax to study the implications of heterogeneity for tax reforms.

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A Appendix

A.1 Price stickiness: analytical details

Firms face price stickiness à la Rotemberg (1982), as specified in the main text. Nominal profits are:

$$p_t(z)y_t(z) - MC_t(z)y_t\left(z\right) - \frac{\kappa_p}{2}\left(\frac{p_t(z)}{p_{t-1}(z)} - 1\right)^2 p_t(z)y_t(z) - W_t f^{fix},$$

where:

$$MC_t\left(z\right) = \frac{W_t}{z}.$$

Let $\rho_t(z) = p_t(z)/P_t$. Intermediate goods producers maximize real profits by choosing the optimal real price $\rho_t\left(z\right)$. Firm z's maximization problem reads as:

$$\max_{\rho_t(z)} \quad \rho_t(z)y_t(z) - mc_t(z)y_t\left(z\right) - \frac{\kappa_p}{2}\left(\frac{p_t(z)}{p_{t-1}(z)} - 1\right)^2 \rho_t(z)y_t(z) - f_t,$$

subject to the demand constraint:

$$y_t(z) = \left(\frac{p_t(z)}{P_t}\right)^{-\theta} Y_t = \rho_t(z)^{-\theta} Y_t.$$

Profit maximization delivers the optimal relative price $\rho_t\left(z\right)$ as:

$$\rho_t\left(z\right) = \mu_t(z) mc_t\left(z\right), \tag{30}$$

where $\mu_t\left(z\right)$ is the idiosyncratic markup:

$$\mu_t(z) = \frac{\theta}{\theta - 1} \frac{1}{1 - \frac{\kappa_p}{2}\left(\frac{p_t(z)}{p_{t-1}(z)} - 1\right)^2 + \frac{1}{\theta - 1}\kappa_p \Gamma_t(z)},$$

and

$$\Gamma_t(z) = \left[\left(\frac{p_t(z)}{p_{t-1}(z)} - 1\right)\frac{p_t(z)}{p_{t-1}(z)} - E_t(1-\delta)\Lambda_t \frac{y_{t+1}(z)}{y_t(z)}\frac{P_t}{P_{t+1}}\left(\frac{p_{t+1}(z)}{p_t(z)} - 1\right)\left(\frac{p_{t+1}(z)}{p_t(z)}\right)^2\right].$$

Note that when $\kappa_p \to 0$ the markup reduces to $\frac{\theta}{\theta-1}$ as in the baseline specification. The variable Λ_t represents the household's stochastic discount factor, which equals $\beta E_t \frac{c_t}{c_t+1}$. Using equation (30), individual real profits can be written as:

$$d_t\left(z\right) = \rho_t(z)y_t(z) - \frac{\rho_t(z)}{\mu_t(z)}y_t\left(z\right) - \frac{\kappa_p}{2}\left(\frac{p_t(z)}{p_{t-1}(z)} - 1\right)^2 \rho_t(z)y_t(z) - w_t f^{fix},$$

or, by using the demand constraint:

$$d_t(z) = \left[1 - \frac{1}{\mu_t(z)} - \frac{\kappa_p}{2}\left(\frac{p_t(z)}{p_{t-1}(z)} - 1\right)^2\right]\rho_t(z)^{1-\theta}Y_t - w_t f^{fix}. \tag{31}$$

The cut-off productivity, $z_t^(*)$, is the productivity level associated to null individual profits. Imposing the latter condition:

$$f_t = \left[1 - \frac{1}{\mu_t^*} - \frac{\kappa_p}{2}\left(\frac{\rho_t^*}{\rho_{t-1}^*}\pi_t - 1\right)^2\right](\rho_t^*)^{1-\theta}Y_t,$$

where μ_t^* and ρ_t^* represent, respectively, the markup and the real price p_t^*/P_t of the firm endowed with the cut-off productivity z_t^*. Additionally, note that:

$$\mu_t^* = \frac{\theta}{\theta-1}\frac{1}{1 - \frac{\kappa_p}{2}\left(\frac{\rho_t^*}{\rho_{t-1}^*}\pi_t - 1\right)^2 + \frac{1}{\theta-1}\kappa_p\Gamma_t^*},$$

where:

$$\Gamma_t^* = \left[\left(\frac{\rho_t^*}{\rho_{t-1}^*}\pi_t - 1\right)\frac{\rho_t^*}{\rho_{t-1}^*}\pi_t - E_t\Lambda_t\frac{Y_{t+1}}{Y_t}\left(\frac{\rho_{t+1}^*}{\rho_t^*}\right)^{2-\theta}\pi_{t+1}\left(\frac{\rho_{t+1}^*}{\rho_t^*}\pi_{t+1} - 1\right)\right].$$

Solving these equations delivers the cut-off productivity as:

$$z_t^* = \mu_t^*\frac{w_t}{\rho_t^*}.$$

Regarding aggregation, first note that $\rho_t(\tilde{z}) \equiv \tilde{\rho}_t = (S_t)^{\frac{1}{\theta-1}}$. Thus:

$$\frac{\tilde{p}_t}{\tilde{p}_{t-1}} = \frac{\tilde{\rho}_t}{\tilde{\rho}_{t-1}}\frac{P_t}{P_{t-1}} = \left(\frac{S_t}{S_{t-1}}\right)^{\frac{1}{\theta-1}}\pi_t = \pi_t^P$$

where π_t^P represents producer price inflation. The markup of the firm endowed with productivity $\tilde{z}_t$ is:

$$\tilde{\mu}_t = \frac{\theta}{\theta - 1} \frac{1}{1 - \frac{\kappa_p}{2}\left(\pi_t^P - 1\right)^2 + \frac{1}{\theta-1}\kappa_p \tilde{\Gamma}_t},$$

where:

$$\tilde{\Gamma}_t = \left[\left(\pi_t^P - 1\right)\pi_t^P - E_t \Lambda_t \frac{Y_{t+1}}{Y_t}\left(\frac{S_{t+1}}{S_t}\right)^{-1} \pi_{t+1}^P \left(\pi_{t+1}^P - 1\right)\right].$$

Using this result, real profits for firm $\tilde{z}_t$ can be written as:

$$\tilde{d}_t = \left[1 - \frac{1}{\tilde{\mu}_t} - \frac{\kappa_p}{2}\left(\pi_t^P - 1\right)^2\right] \tilde{\rho}_t^{1-\theta} Y_t - w_t f^{fix}.$$

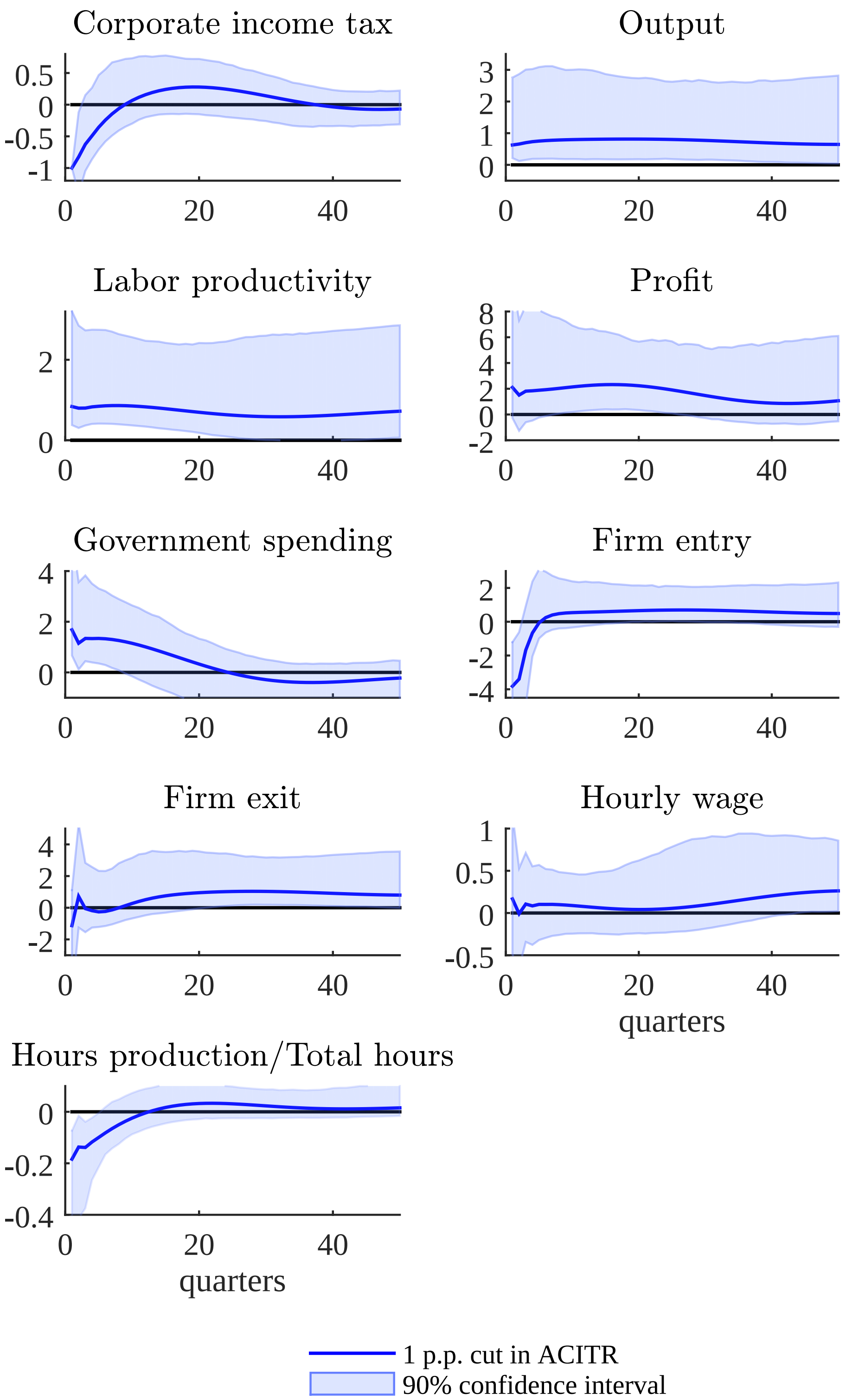
Finally, with respect to the benchmark model with wage stickiness only, the final good is also used to cover the aggregate adjustment costs. The latter are:

$$S_t \frac{\kappa_p}{2}\left(\pi_t^P - 1\right)^2 \tilde{\rho}_t^{1-\theta} Y_t = \frac{\kappa_p}{2}\left(\pi_t^P - 1\right)^2 Y_t.$$

A.2 VAR Analysis: Robustness

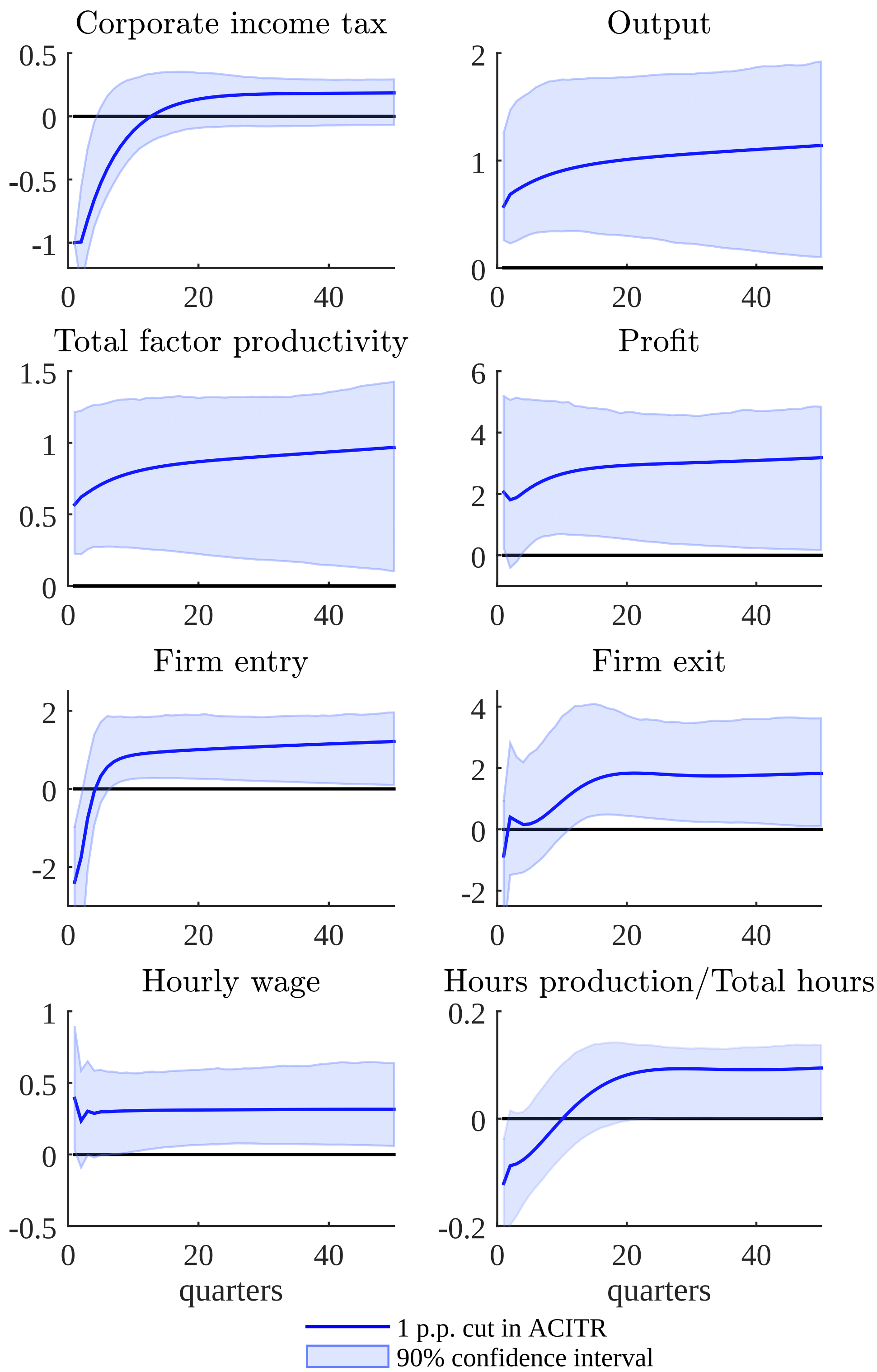
In this section, we perform robustness checks of the baseline VAR by accounting for changes in government spending and inflation. Figure 5 reports impulse response functions when we augment baseline VAR with government spending, while the VAR in 7 includes CPI in log-levels. Relative to the baseline VAR without government spending or CPI, we observe that the result that output, productivity, firm entry, and exit increase, in the long run, is preserved by accounting for these channels. Finally, we use a different measure of firm productivity by replacing labor productivity with total factor productivity. Figure 6 presents the results from this exercise, where we find similar estimates to our baseline results in Figure 1.

Figure 5: VAR impulse responses



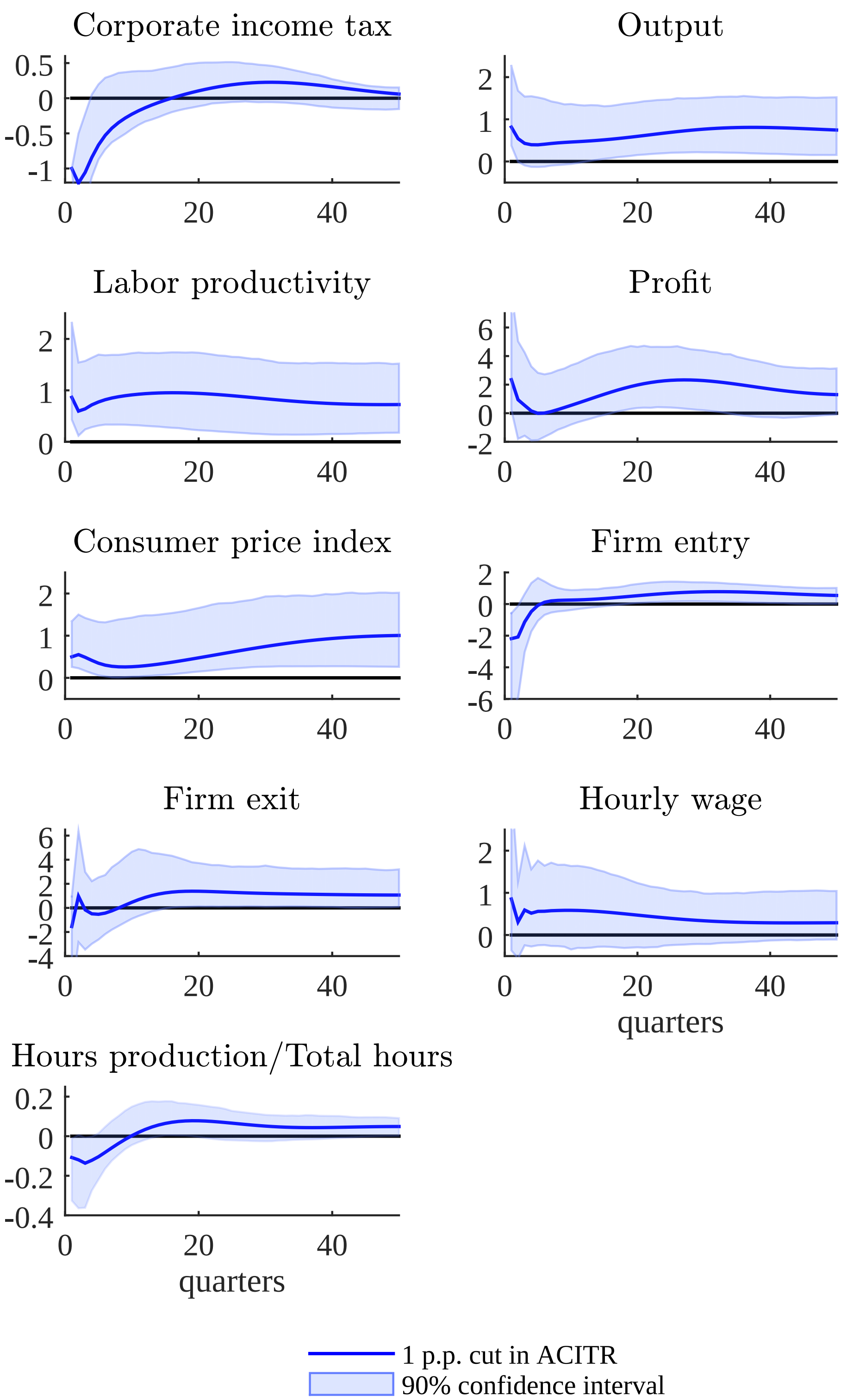
Notes. Baseline VAR augmented with government spending. The Figure shows impulse responses to a one-percentage-point cut in the average corporate income tax rate (ACITR).

Figure 6: VAR impulse responses



Notes. Baseline VAR with TFP instead of labor productivity. The Figure shows impulse responses to a one-percentage-point cut in the average corporate income tax rate (ACITR).

Figure 7: VAR impulse responses



Notes.. Baseline VAR augmented with the CPI in log-levels. The Figure shows impulse responses to a one-percentage-point cut in the average corporate income tax rate (ACITR).

A.3 State-level regressions

In this appendix, we report the tables detailing the effect of corporate income tax cuts on the variables of interest, controlling for government per capita spending. In Tables 5 to 8, all three columns show the effect of corporate tax shocks while controlling for state investment tax credit and R&D tax credit, loss carry-back rule, loss carry-forward rule and per capita government spending. The first column presents the results of the OLS estimation. In the second column, we report estimates using standard identification using average state corporate tax interacted with a state dummy as an instrumental variable. To assess the appropriateness of this instrument, we carry out tests of over-identification and orthogonality assumptions as well as the strength of the instruments. As the first test, we examine the F-statistics of the first-stage regression of our endogenous variable on the instruments. To assess the validity of our instrument, we report p-values of Wu-Hausman statistics and the p-value of Sargan statistics. In column (3), we use identification by heteroskedasticity introduced in Lewbel (2012), with lags structure chosen such that p-value for the Hansen test of over-identification (Hansen J statistics) and p-value for instrument exogeneity test (C statistics) are such that we do not reject the null hypotheses. To test for the weakness of the instrument, we compare a Cragg-Donald statistic to critical values for instrument weakness developed by Stock and Yogo (2005). All regressions include statefixed effects and time fixed effects; standard errors are clustered by state and reported in brackets.

Table 5: Output

	(1) OLS	(2) IV	(3) het-IV
Corporate Tax	0.21	0.27	0.35**
	(0.173)	(0.392)	(0.156)
Investment Tax Credit	-0.09**	-0.09***	-0.05***
	(0.037)	(0.035)	(0.019)
R&D Tax Credit	-0.01	-0.01	-0.02
	(0.028)	(0.026)	(0.025)
Government Spending	-0.44***	-0.44***	-0.44***
	(0.031)	(0.029)	(0.018)
Observations	768	768	672
R-squared	0.767	0.766	0.730
1st stage F-stat		3.973	
Prob >Wu-Hausmann		0.886	
Prob>Sargan		0.465	
Cragg-Donald statistic			24.41
Prob>Hansen J			0.934
Prob>C stat			0.830

Notes. Robust standard errors in parentheses, ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table 6: Establishment Entry

	(1) OLS	(2) IV	(3) het-IV
Corporate Tax	0.25	4.12***	1.48*
	(0.871)	(0.999)	(0.832)
Investment Tax Credit	-0.14	-0.13	-0.05
	(0.148)	(0.141)	(0.089)
R&D Tax Credit	0.01	-0.02	-0.17
	(0.147)	(0.143)	(0.138)
Government Spending	0.03	0.02	0.02
	(0.071)	(0.072)	(0.057)
Observations	768	768	672
R-squared	0.231	0.216	0.225
1st stage F-stat		3.973	
Prob>Wu-Hausmann		0.0487	
Prob>Sargan		0.469	
Cragg-Donald statistic			24.41
Prob>Hansen J			0.372
Prob>C stat			0.545

Notes. Robust standard errors in parentheses, ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table 7: Establishment Exit

	(1) OLS	(2) IV	(3) het-IV
Corporate Tax	-0.74	-2.49***	0.54
	(0.511)	(0.945)	(0.489)
Investment Tax Credit	-0.17	-0.17**	-0.07
	(0.101)	(0.086)	(0.071)
R&D Tax Credit	0.01	0.03	-0.03
	(0.111)	(0.106)	(0.124)
Government Spending	0.01	0.01	-0.03
	(0.066)	(0.063)	(0.058)
Observations	768	768	672
R-squared	0.407	0.404	0.412
1st stage F-stat		3.973	
Prob>Wu-Hausman		0.299	
Prob>Sargan		0.523	
Cragg-Donald statistic			24.41
Prob>Hansen J			0.120
Prob>C stat			0.173

Notes. Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 8: Real Wage per Worker, BEA

	(1) OLS	(2) IV	(3) het-IV
Corporate Tax	0.11	0.33	0.36***
	(0.125)	(0.316)	(0.077)
Investment Tax Credit	-0.05	-0.05*	-0.01
	(0.030)	(0.029)	(0.012)
R&D Tax Credit	-0.00	-0.00	-0.03*
	(0.020)	(0.019)	(0.019)
Government Spending	-0.05***	-0.05***	-0.04***
	(0.014)	(0.013)	(0.010)
Observations	768	768	672
R-squared	0.535	0.534	0.497
1st stage F-stat		3.973	
Prob>Wu-Hausmann		0.409	
Prob>Sargan		0.189	
Cragg-Donald statistic			24.41
Prob>Hansen J			0.689
Prob>C stat			0.916

Notes. Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 9: Steady state: baseline model

Marginal firm's productivity	$z^* = z_{\min}(S/N)^{-1/\kappa}$
Average firm's productivity	$\widetilde{z} = (\frac{\kappa}{\kappa-(\theta-1)})^{1/(\theta-1)} z^*$
Fixed production cost	$f^{fix} = f^e[(\widetilde{z}/z^*)^{\theta-1} - 1]^{-1} \frac{1-\beta(1-\delta)}{\beta(1-\delta)(1-\tau)(S/N)}$
Marginal firm's output	$y^* = z^* f^{fix}/(\mu - 1)$
Average firm's output	$\widetilde{y} = y^*(\widetilde{z}/z^*)^{\theta}$
Average firm's labor input	$\widetilde{l^c} = \widetilde{y}/(\widetilde{z})$
Number of active firms	$S = L[\widetilde{l^c} + f^{fix} + \frac{\delta}{1-\delta} f^e/(S/N)]^{-1}$
Number of firms	$N = S/(S/N)$
Relative price	$\widetilde{\rho} = S^{1/(\theta-1)}$
Number of entrants	$N^e = \delta N/(1-\delta)$
Consumption	$C = \widetilde{\rho}\widetilde{y}S$
Average firm's markup	$\widetilde{\mu} = \theta/(\theta-1)$
Wage	$w = \tilde{\rho}\tilde{z}/\widetilde{\mu}$
Average firm's value	$\widetilde{v} = w f^e$
Average firm's profits	$\widetilde{d} = \frac{1-\beta(1-\delta)}{\beta(1-\delta)(1-\tau)(S/N)} \widetilde{v}$
Average firm's revenue	$\widetilde{rr} = \rho y$
Weight on labor in utility	$\chi = \frac{\theta_w - 1}{\theta_w} w/(CL^{1/\phi})$

Notes. Steady state variables: z^*, $\widetilde{z}$, f^c, y^*, $\widetilde{y}$, $\widetilde{l^c}$, S, $\widetilde{\rho}$, N, N^e, C, w, χ, $\widetilde{v}$, $\widetilde{d}$, $\widetilde{rr}$.

Table 10: Steady state: symmetric firm model

Firm output	$y = (\theta-1)\left[\frac{1-\beta(1-\delta)}{\beta(1-\delta)(1-\tau)} f^e + f^{fix}\right]$
Labor input	$l^c = y$
Number of active firms	$S = L(l^c + f^{fix} + \frac{\delta}{1-\delta} f^e)^{-1}$
Number of firms	$N = S$
Number of entrants	$N^e = \frac{\delta}{1-\delta} N$
Relative price	$\rho = S^{1/(\theta-1)}$
Consumption	$C = \rho y S$
Firm revenue	$rr = \rho y$
Markup	$\mu = \theta/(\theta-1)$
Wage	$w = \rho/\mu$
Firm value	$v = w f^e$
Firm profits	$d = \frac{1-\beta(1-\delta)}{\beta(1-\delta)(1-\tau)} v$
Weight on labor in utility	$\chi = \frac{\theta_w - 1}{\theta_w} w/(CL^{1/\phi})$

Notes. Steady state variables: y, l^c, S, N, N^e, ρ, w, C, χ, v, d, rr.

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