Firm Heterogeneity and the Tax Elasticity of Capital*

Jackson Mejia†

November 27, 2020

Abstract

This study examines the impact on the capital stock and investment of tax shocks at the firm level. Utilizing a vector of exogenous tax shocks, we show that the capital stock net of depreciation decreases by approximately 2.4% in response to a one percentage point increase in the average corporate tax rate, in agreement with existing macroeconomic literature. Similarly, spending on intangible capital decreases by 2.8% for the typical firm in response to a one percentage point increase in the average corporate tax rate. Empirically, we show that firms exhibit substantial heterogeneity in response to a tax shock. In particular, large firms tend to be highly sensitive to a tax shock while multinationals recover much more quickly than their domestic counterparts. We also show using Jordà local projections that tax shocks tend to have deep and long-lasting effects on firm-level investment and the capital stock, reaching a peak decrease of 3.75% in the capital stock after seven quarters.

*I thank Anmol Bhandari, Ellen McGrattan, Tobey Kass, Thomas May, Guangqi Li, and Sam Jordan-Wood for their helpful comments and suggestions. Remaining errors are mine.

†Heller-Hurwicz Economics Institute, University of Minnesota. Email: mejia069@umn.edu

1 Introduction

A key question in the analysis of fiscal policy is the extent to which a particular tax shock may increase or decrease investment. In general, the utility of a tax change is based on the subsequent output response, which in turn is heavily dependent on the investment channel. In that respect, there has been little theoretical dispute since Hall and Jorgenson (1967) that increases in corporate taxation increase the user cost of capital, leading to reduced investment relative to what would have otherwise occurred. Econometric studies of aggregate investment generally agree, though there is some dispute over the extent to which a tax change affects investment (Blanchard and Perotti, 2002; Mertens and Ravn, 2013; Romer and Romer, 2010).

Even so, there has been little investigation into the cross-sectional impact of tax shocks at the firm or even sectoral level, with the notable exception of Eskandari and Zamanian (2020). This is surprising for the following two reasons. First, the cross-sectional impact of policy may arguably be more important than the aggregate impact. At the firm level, we know that the determinants of investment typically have little to do with the movements of aggregate variables. In particular, firm-specific variables such as leverage (Ahn et al., 2006), liquidity (Boyle and Guthrie, 2003), and multinational status (Bilicka, 2019) all have large effects on the investment decisions of firms (which sum to aggregate investment), but are generally difficult to capture in aggregate analysis. Taking account of this is crucial for analysis. Suppose that prior to a tax cut, the typical manufacturing firm is an overleveraged multinational. Then there would be little reason to expect the tax cut to be stimulative to those firms in particular and for aggregate investment in general because manufacturing makes up the bulk of the investment base. Failure to account for this will inevitably lead to the wrong conclusions about policy.[1] Even if aggregate impacts generally line up with the

[1] Note that the exact same tax change may have different impacts at different times due to nonlinearities in response to tax shocks and because the circumstances are different. For example, a prediction of the effect of the 2017 Tax Cuts and Jobs Act could not reasonably be made based on the effect of the Tax Reform Act of 1986 because the political economic circumstances were so divergent; the latter could be expected to be highly persistent in contrast to the former, which could not. Blanchard and Perotti (2002) exploit the characteristics of their SVAR to obtain estimates for key tax events.

conclusions shown at the firm level, it is scientifically useful to have a clearer picture of the particular effects of tax policy at all levels.

Second, the data are readily available and have been for quite some time. Time series for tax shocks have been available since the seminal Blanchard and Perotti (2002) study and Romer and Romer (2010) have developed a vector of tax shocks based on narrative evidence from the postwar era. Moreover, industry-level data on investment is readily available from the Bureau of Economic Analysis and firm-level data from Compustat has likewise been available.[2] Despite that, there is a gap in the literature on the heterogeneous impact of tax shocks at the firm level.

Consequently, we study the heterogeneous responses of firms to tax shocks using firm-level data from Compustat and the vector of corporate tax shocks from Romer and Romer (2010) and Mertens and Ravn (2013). Our study is motivated by a similar effort from Ottonello and Winberry (2018), who have written the landmark study on the heterogeneous responses of firms to monetary shocks. The key difference is that their study incorporates shocks to monetary policy from the Federal Reserve, whereas our study examines tax policy shocks. Our baseline empirical specification estimates the semi-elasticity of the capital stock with respect to a shock to the average corporate tax rate. Since investment data is incomplete and there are relatively few data points in the Romer and Romer (2010) sample, we examine the net capital stock rather than investment proper. With the intention of capturing permanent differences between firms across time, we utilize a panel regression model with time and individual fixed effects and a vector of controls.

Using this baseline specification, we find that a one percentage point increase in the average corporate tax rate reduces the tangible capital stock by 2.4 percentage points. Using a Jorda local projection, we find that the negative effect on investment persists for over 12 quarters, with a peak impact of -3.75%. We then introduce a number of different characteristics to better estimate the heterogeneous investment responses of firms to a tax shock,

[2] Even so, it is perhaps excusable that firm-level analysis of tax shocks is largely absent primarily because firm-level data is limited in scale and tends to suffer from reliability issues, particularly until the 1970s.

including whether a firm is a multinational, whether size matters, whether it is R&D intensive, and sector-by-quarter fixed effects. We also estimate investment responses using a measure of intangible investment, log R&D expenditures, as the dependent variable.

2 Related Literature

Existing studies on tax shocks focus primarily on extracting measures of the dynamic response of output to taxation or on measurements of the variance of output rather than on investment in particular.[3] McGrattan (1994), the forerunner of modern DSGE studies of fiscal shocks, finds that if capital taxes are 1% above their historical average, then taxation will be 0.88% below average. Other economists employ a similar quantitative theoretical approach in the vein of Barro and Furman (2018), focusing on the impact of tax changes on the user cost of capital with a broader view toward examining the impact of tax changes, or a particular tax change, on output.[4]

Strictly empirical papers may utilize different datasets, employ different identification strategies, and use different methods, but the goal is uniform: measure the dynamic response of output to a tax shock, with investment as a key subcomponent in that process. Blanchard and Perotti (2002) set the foundation for time series approaches, utilizing a SVAR with identification of tax shocks achieved by imposing the elasticity of net taxes to GDP from prior estimates and finding a peak impact of -0.36% in response to a 1% increase in net taxes.[5] Mountford and Uhlig (2009) estimate multipliers under different budgetary regimes by imposing sign restrictions on a VAR, most relevantly finding an impact investment multiplier of around 2% for a deficit-financed negative unit shock to taxation. Additionally, Barro and Redlick (2011) estimate an investment multiplier of around -0.35 for a 1% increase in

[3]For a related literature review on tax shocks and output, see Ramey (2016).

[4]Many policy-relevant studies focus on particular tax events and exploit a difference-in-difference approach (Dobbins and Jacob, 2016). The downside to this approach is that it tends to lack future predictive power given that it studies only one event in isolation.

[5]Caldara and Kamps (2017) criticize their identification strategy and provide an alternative dynamic response for output, but not investment.

the average marginal tax rate. Two additional studies utilize the vector of exogenous shocks compiled from narrative evidence by Romer and Romer (2010), all of which ultimately aim to estimate dynamic multipliers for output rather than investment. From a 1% increase in taxes as a share of output, Romer and Romer (2010) estimate that investment will decline by 9% after 10 quarters. Given a one percentage point decrease in the average corporate income tax rate, Mertens and Ravn (2013) find that investment will increase about 2.3% after six quarters.[6]

While there is very little theoretical dispute that a positive tax shock will decrease investment, the lack of particular focus on investment has resulted in imprecision and ambiguity in discussing the semi-elasticity of investment to taxation or the dynamic response of investment to a tax shock. For example, although Mertens and Ravn (2013) and Romer and Romer (2010) use essentially the same vector of exogenous shocks, derived results are quite different because the Mertens and Ravn (2013) decompose tax shocks into corporate and personal tax changes and hence the resultant change is derived from shifts in average corporate income taxes rather than tax revenue as a share of output. In principle, this is not a problem, but it does introduce a particular difficulty: Mertens and Ravn (2013) compute impulse responses for investment broadly as a response to corporate income tax shocks, but corporations hardly conduct all investment in the economy.[7]

Given the lack of focus on investment in particular, we argue that it is crucial for development of the literature to have a more precise idea of what is meant by the effect of changes in taxation on investment. In this respect, our study makes several contributions.

We argue in favor of a higher resolution focus on corporate investment at the firm level in response to corporate tax shocks. Aggregate quarterly measures of investment are the result

[6] There are also a host of studies examining the semi-elasticity of foreign direct investment to tax changes. de Mooij and Ederveen (2008) estimates long-run semi-elasticities between -1.5% and -6% given a 1% increase in the Devereux-Griffith Effective Average Tax Rate (Devereux and Griffith, 1998). While these estimates are important in consideration of location decisions and the growing significance of multinationals, they are not the primary focus of our paper.

[7] This is partially because aggregate corporate investment data is generally only available annually rather than quarterly from NIPA.

of investment by all legal forms, not just corporations. While it is true that a corporate tax cut may have general equilibrium effects and therefore could affect investment by other legal forms in significant ways, it makes more sense to look at panel data for individual firms for the two following reasons. First, the share of firms organized in corporate form is substantially lower than in the past (Auerbach, 2018), which means that a corporate tax cut will tend to be less effective on investment aggregates than previously. Second, there is substantial evidence that tax changes induce switching between forms (Clarke and Kopczuk, 2017), which has two effects on measures of aggregate investment that may not be desirable to measure if the goal is to isolate the effect of tax shocks on investment. First, aggregate investment by legal form will change not only because of the induced tax shock, but because firms may be switching between forms. As a result, measures of aggregate investment will measure the relative attractiveness of legal forms in addition to the increase attractiveness of investment. Relatedly, if there is substantial switching between forms following a tax shock, then a dynamic measurement of a tax shock on aggregate investment will capture the dynamic effects of firms switching legal form over time as well.[8] Second, Barro and Wheaton (2019) provide evidence that investment by the corporate form is inherently more productive than other legal types, which means that the investment measured by NIPA is not the same quality across tax changes. Broadly, these may be desirable to measure, but when solely considering the effect of taxation on investment incentives, it is better to instead examine this question at the firm level. Estimating the taxation semi-elasticity of investment with firm-level panel data ensures that these biases are not mitigated.

As in physics, early study of causation requires a broad grasp of how aggregates move in response to aggregate shocks. The key to advanced understanding lies in first comprehending how the component parts of aggregates move in response to aggregate shocks, and the most advanced stage is an understanding of the causation with respect to the most granular components. In our case, that means an estimate of how individual firms respond to firm-

[8]See, for example, Plesko and Toder (2013) on the effects of the 1986 Tax Reform Act on organizational choice.

specific tax shocks. Our study is a major step along that path.

Hence our main contribution to the literature is to provide an estimate of how the typical firm responds to a tax shock, as well as how different types of firms react. We demonstrate, in agreement with the existing macroeconomic literature, that tax shocks have a strongly negative effect on investment. Our study agrees on this with Eskandari and Zamanian (2020), though the additional value of our research is that we are better able to show heterogeneity, provide semi-elasticities for tangible and intangible investment, and implement different vectors of tax shocks. In particular, we show how firm-level characteristics such as leverage, multinational status, industry, R&D intensity, and size contribute to a given firm's investment response.

Our study is motivated not only by prior macroeconomic estimates of the response of investment to tax shocks, but also by prior attempts to get better measures of firm-level investment responses to policy shocks. Yagan (2015) exploits changes in depreciation allowances, while Zwick and Mahon (2017) and House and Shapiro (2008) study the effect on investment of changes in the investment tax credit and the dividend tax credit, respectively. We show both the dynamic response of different types of investment to tax shocks as well as the semi-elasticities derived from panel regression.

The remainder of the paper is organized as follows. Section 3 describes the data we use. Section 4 provides the results of different panel regression specifications and section 4.2 shows the dynamic response. Section 5 concludes.

3 Data

Our analysis combines a vector of shocks to fiscal policy with quarterly firm-level Compustat data from 1975Q1-2007Q4.

3.1 Tax Shocks

A key benefit to our approach is that it can take any vector of exogenous shocks τ_t.[9] Given a vector of shocks to firm i at time t, a panel regression with time and individual fixed effects and a Jorda local projection can be carried out. For our study, we begin with the vector of tax shocks compiled by Romer and Romer (2010) from narrative evidence and further specified by Mertens and Ravn (2013). Each shock consists of an increase or decrease in the average corporate income tax rate. Because of the limitations of quarterly Compustat data, our sample period begins in 1975q1 and therefore contains fewer shocks than in the Romer and Romer (2010) sample.

3.2 Firm-level Investment Data

Firm-level data is sourced from Compustat, which in principle includes all public firms in the United States. We have four reasons for using this dataset rather than another (e.g., the U.S. Census Bureau's Quarterly Financial Report). First, quarterly data is necessary to make a comparison to aggregate measures and to account for the fact that shocks are quarterly rather than annual. Second, it is a long panel, something which allows us to exploit individual fixed effects. Third, it measures critical balance sheet variables for firms that are important determinants of investment. Finally, Compustat has a broad array of firms from every sector rather than exclusive or heavy concentration in one particular industry. No other dataset has these key characteristics.

We utilize two measures of investment. First, we attempt to capture investment with $\log k_{it+1}$, where k_{it+1} is the book value of the tangible capital stock of firm i at the end of quarter t. The book value of tangible capital stock is defined using Compustat's net plant, property, and equipment variable. A limitation of Compustat is that traditional measures of investment are not widely available until the quantity of tax shocks becomes

[9] Optimally, each firm i would face its own vector of policy shocks, or at least a sector-specific vector of shocks. We utilize aggregate shocks as a first step in the analysis.

alarmingly small, so our best option is instead to examine changes in the capital stock and thereby make inferences about investment. A potentially better measure of investment would instead follow either the traditional gross investment rate defined as in Rajan and Zingales (1998) or the net investment rate defined as in Gutiérrez and Philippon (2016), where the former is defined as the ratio of capital expenditures at time t to net property, plant, and equipment at time $t-1$ (and the latter is computed net of depreciation). However, reliable quarterly measures of capital expenditures in Compustat do not begin until the late 1980s, which constrains our sample significantly. As a result, we limit ourselves to analyzing the net tangible capital stock, which is closely related to investment. Given the increasing importance of intangible investment for firms, particularly multinationals (see, e.g., Peters and Taylor (2017) and McGrattan (2017)), we view it as important to have a measure of the semi-elasticity of intangible investment to taxation. We measure intangible investment as log R&D. Summary statistics for these variables are given in table 1.

Statistic	N	Mean	St. Dev.	Min	Pctl(25)	Pctl(75)	Max
log(Capital Stock)	312,026	4.600	2.607	−1.578	2.667	6.608	10.201
log(R&D)	51,164	2.150	1.908	0.001	0.554	3.389	7.037

Table 1: Summary Statistics for Firm Investment Measures

Recent studies on firm-level investment have shown that several balance sheet variables are significant determinants of investment. By their very nature, these are difficult to control for at an aggregate level, but use of firm-level data presents no problem. In particular, we control for firm i's prior period leverage (Ahn et al., 2006), size (Weinberg, 1994), liquidity (Boyle and Guthrie, 2003), Tobin's Q (Abel and Eberly, 2011), sales growth, and investment. Summary statistics are presented in table 2.

The primary focus of our study goes beyond how a typical firm responds to a tax shock, instead focusing on how firms with particular characteristics respond to a tax shock. To account for this heterogeneity, we include dummy variables that we consider significant to the investment decision and therefore worth investigating further. These include proxies for

Statistic	N	Mean	St. Dev.	Min	Pctl(25)	Pctl(75)	Max
Sales Growth	315,210	0.015	0.213	−1.000	−0.069	0.106	1.000
Tobins's q	284,148	1.889	2.041	0.077	1.037	2.027	181.799
Leverage	315,210	0.749	0.974	0.000	0.106	1.014	10.000
Liquidity	315,210	0.143	0.191	0.00000	0.016	0.190	0.995
log(sales)	315,210	4.528	2.228	−6.925	3.047	6.097	11.789
Net Leverage	315,210	0.107	0.456	−0.984	−0.214	0.417	20.050

Table 2: Summary Statistics for Firm Controls

firm size using market capitalization, multinational status, 2-digit NAICS code dummies, whether a firm is R&D intensive, and whether a firm is overleveraged.[10]

4 Results

4.1 Measuring Heterogeneous Responses to Tax Shocks

To estimate the heterogeneous effects of tax shocks, we use a panel regression with the following baseline specification:[11]

$$\log k_{it+1} = \alpha_i + \beta\tau_{t-1} + \Gamma' Z_{i,t} + \epsilon_{it} \tag{1}$$

where α_i is a firm i fixed effect, τ_{t-1} is the quarterly tax shock, $Z_{i,t}$ is a vector of controls and $\epsilon_{i,t}$ is a residual. Under all specifications, the primary coefficient of interest is β because it estimates the semi-elasticity of investment $\log k_{i,t+1}$ with respect to a tax shock. Note that we lag the tax shock to account for the fact that firms may take some time to adjust to a tax shock.[12] Indeed, an intraquarter shock would be nearly meaningless because the

[10]Consult the appendix for details on data construction.

[11]The results of a Hausman test, available upon request, show that a panel regression with individual and time fixed effects should be performed in preference to a random effects regression.

[12]We tested different specifications of (1) for different lags of tax shocks and found a lag of two to be the most significant. Intuitively and theoretically, this makes the most sense in light of tax planning. We could have followed Romer and Romer (2010) and specified tax shocks lagged by twelve quarters, but we found this to be unnecessary.

quarterly shock could occur at the end of the quarter after all investment has already been made. Hence we lag the tax shock to avoid timing issues and because investment is typically planned in advance for tax reasons and would therefore require an adjustment period.

As noted previously, we control for a number of variables that have been shown to affect investment position, including sales growth, liquidity, leverage, size, Tobin's Q, and prior-period investment. In particular, sales growth is thought to affect investment because rapidly growing firms have both the resources and the incentive to capitalize on previous investments and continue their growth. If sales grow substantially between periods, then it follows that investment would likewise grow for the firm to maintain its investment intensity. Liquidity also matters because theory predicts that firms with low liquid asset positions will tend to have more limited access to debt markets (Gertler, 1988; Whited, 1992). In general, highly levered firms are less likely to invest in valuable growth opportunities in comparison to firms that are similarly oriented but with lower leverage, something which has tended to be supported by empirical results (Aivazian et al., 2005). Additionally, firm size tends to have an effect on investment because larger firms have greater access to capital markets and have greater flexibility in investment timing than smaller firms.[13] Finally, the mechanism behind the Q-investment relationship is that if $Q > 1$, then the market value of the firm exceeds its replacement cost and an incentive exists for firms to invest until $Q = 1$, i.e., until the market value of the firm equals its replacement cost.

Table 3 reports the regression results for the baseline specification in addition to further specifications intended to explore some of the heterogeneous effects of a tax shock to investment.[14] With or without sector-specific controls, the semi-elasticity of the capital stock with respect to a tax shock is close to -2.4%, a result that is statistically significant. That is, for a one percentage point increase in the average corporate tax rate, the tangible capital stock of the typical firm will on average be reduced by 2.4%. Sectoral results are unsurprising.

[13] However, Kadapakkam et al. (1998) show that large firms tend to be more sensitive to cash flow (internal funding) considerations than smaller firms. Regardless of the sign of the effect of firm size on investment, it is generally agreed that size matters for investment.

[14] Coefficients for firm-level controls are omitted from the results. They are available upon request.

Manufacturing (NAICS 54) has a semi-elasticity of -9% for a one percentage point increase in the average corporate tax rate, while the retail trade sector reacts insignificantly to a tax shock. Indeed, this is unsurprising given that the former participates heavily in investment while the latter does not.

	log(Tangible Capital Stock)					
	(1)	(2)	(3)	(4)	(5)	(6)
Shock	-0.024^{***}	-0.024^{***}	-0.023^{***}	-0.019^{***}	-0.024^{***}	-0.022^{***}
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.005)
Shock:MNC			-0.003			
			(0.002)			
Shock:Big Firm				-0.008^{***}		
				(0.002)		
Shock:High Leverage					0.004	
					(0.003)	
Shock:High R&D						0.008^{**}
						(0.004)
Sector Dummies?	No	Yes	Yes	Yes	Yes	Yes
Individual Effects?	Yes	Yes	Yes	Yes	Yes	Yes
Firm Controls?	Yes	Yes	Yes	Yes	Yes	Yes
Observations	213,588	213,588	213,588	211,523	213,588	114,918
R^2	0.493	0.494	0.494	0.560	0.496	0.487
Adjusted R^2	0.480	0.481	0.481	0.548	0.483	0.472

Note: Reported coefficients are for dummy interactions with the tax shock.
$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Table 3: Panel Regression Results for Tangible Capital Stock (1975Q1-2007Q4)

Our experiments with dummy variables are more interesting. First, the coefficient on multinational corporations is small and insignificant, meaning that the effect of a tax shock on multinationals tends to be minuscule. This confirms theory and intuition; multinationals are more flexible than their locally fixed counterparts and can therefore minimize their tax burden optimally such that a tax change will have little effect. Even so, "big firms," i.e., firms which have a market capitalization greater than $100m (inflation-adjusted) tend to be quite adversely affected by a positive tax shock. In this case, we observe that a one percentage point increase in the average corporate tax rate tends to decrease the tangible capital stock of big firms by -2.7%, while smaller firms tend to experience a much smaller decrease. This suggests that a size-weighted panel regression would likely result in even greater effects on the capital stock and hence on investment. Despite that, it is unclear whether our results overstate or understate the effects of tax shocks. While capital is relatively more mobile today than in the past, which suggests that tax shocks would tend to have a smaller effect on investment, it is also true that our results show that the effect of tax shocks is greater for bigger firms. On the other hand, if we consider that there is a slightly positive, significant effect of a tax shock on R&D-intensive firms, which in general tend also to be large multinationals, then evidence for the fact that investment is not significantly affected by a tax shock grows. Note also that highly levered firms tend not to be adversely affected by a tax shock relative to firms which are not.

	log(R&D)					
	(1)	(2)	(3)	(4)	(5)	(6)
Shock	-0.028^{***}	-0.028^{***}	-0.024^{**}	-0.013	-0.026^{***}	-0.014
	(0.009)	(0.009)	(0.010)	(0.011)	(0.009)	(0.011)
Shock:MNC			-0.011			
			(0.008)			
Shock:Big Firm				-0.014^{*}		
				(0.008)		
Shock:High Leverage					-0.015	
					(0.014)	
Shock:High R&D						-0.011
						(0.009)
Sector Dummies?	No	Yes	Yes	Yes	Yes	Yes
Individual Effects?	Yes	Yes	Yes	Yes	Yes	Yes
Firm Controls?	Yes	Yes	Yes	Yes	Yes	Yes
Observations	51,164	51,164	51,164	50,717	51,164	51,157
R^2	0.319	0.321	0.321	0.359	0.322	0.351
Adjusted R^2	0.288	0.290	0.290	0.329	0.290	0.321

Note: Reported coefficients are for dummy interactions with the tax shock.
$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Table 4: Panel Regression Results for R&D (1989Q4-2007Q4

We also report results for our measure of intangible investment in Table 4.[15] Here, the dependent variable is log R&D expenditures. In this case, the results are somewhat stronger than for tangible investment; a one-percentage point increase in the average corporate tax rate leads on average to a 2.8 percentage point decrease in inflation-adjusted R&D expenditures. However, only manufacturing has a weakly significant coefficient—and it has the wrong sign. If we look closely at the dummy coefficients, we see that they have some similarity to those for tangible capital. It bears repeating that the coefficient on multinational corporations is weakly positive and insignificant, which is expected if firms can choose location and thereby optimize over taxes. Highly levered firms exhibit little response to a tax shock and so do firms which already are R&D-intensive. This last result is economically significant. Given the coefficient on the baseline specification, this indicates that the firms most affected by a tax shock tend to be those marginal firms which are making a choice between making no R&D expenditures and very little expenditures, while inframarginal firms in terms of R&D expenditures are hardly affected by a tax shock. This nonlinearity is perhaps peculiar, but not particularly surprising if we consider that R&D expenditures for R&D-intensive firms are likely highly inelastic and tend to receive a different tax treatment from tangible investment.

4.2 Dynamic Response of Investment to Tax Shocks

As a means of measuring the dynamic response of the typical firm, we estimate Jordà (2005) local (linear) projections with the specification:

$$\log k_{i,t+h} - \log k_{i,t} = \alpha_{i,h} + \alpha_{s,t,h} + \beta_h \tau_{t-1} + \Gamma'_h Z_{i,t-1} + \epsilon_{i,t,h} \tag{2}$$

We present dynamic responses only for tangible capital in this section; the sample period is too constrained for intangible investment. In figure 1, we show the dynamic response of net

[15] Note that positive quarterly data for R&D does not begin until 1989, so the sample here is quite small.

property, plant, and equipment to a one percentage point increase in the average corporate tax rate. The initial decline is slow and linear, averaging about half a percentage point drop per quarter until reaching peak impact just after seven quarters at -3.75% before rising again and recovering after twelve quarters. While the measurement variable is not precisely the same as used in Mertens and Ravn (2013), Eskandari and Zamanian (2020), or Romer and Romer (2010) (we are forced by data limitations to use the capital stock rather than investment), the trajectory is quite similar and displays the same pattern of a slow, deep decline and slow recovery.

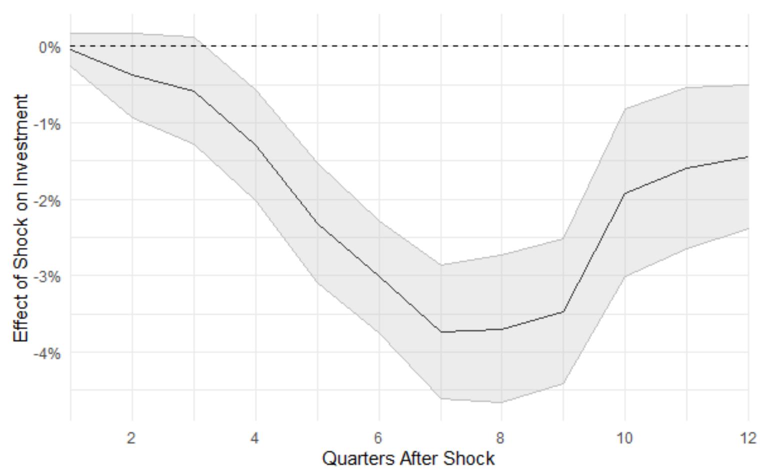
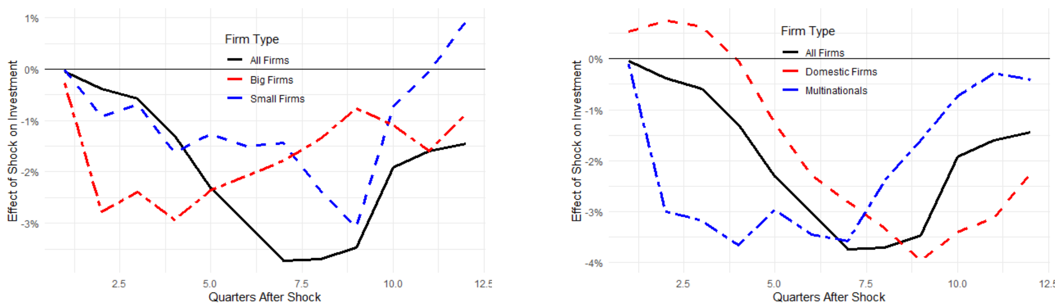


Figure 1: Dynamic response of the typical firm to a one percentage point increase in the average corporate tax rate. Plotted with 90% confidence interval.

The results are more interesting if we instead view some firm-level heterogeneity in figure 2a. We overlay our dummy measure of firm size on top of the overall dynamic response. Note that small firms tend to be relatively insensitive to a tax shock, with a much shallower decline (though a longer period of decline) before recovering much more quickly after eleven quarters. In contrast, big firms (defined as having a market capitalization greater than $100m in inflation-adjusted dollars) exhibit a much more rapid and deep decline, with a peak occurring after only two quarters at -2.75%.[16] Our results tend to support the view

[16]Because of the way Jorda local projections are calculated, the multiplier effect of a shock on all firms is not precisely the average of small and big firm paths.

that larger firms are more sensitive to tax shocks than smaller firms. At question is the hypothesis that larger firms tend to rely on internal financing in addition external financing (i.e., debt) for investment, whereas smaller firms tend to be more reliant on debt rather than capital and hence are relatively less sensitive to a tax shock. Since we find that large firms are relatively more sensitive, our results are in line with Eskandari and Zamanian (2020) and Kadapakkam et al. (1998).



(a) Dynamic response of different firm size

(b) Dynamic response of multinationals vs domestic firms

Figure 2: Dynamic responses for the typical firm accounting for heterogeneity.

In figure 2b, we plot the dynamic responses of multinationals and domestic firms. Note that the initial impact is much higher for multinationals, reaching peak impact at -3.5% after three quarters and staying below -3% from quarters 2-6 after initial impact. On the other hand, domestic firms display very little response to a tax shock, increasing slightly and only falling below zero after four quarters before reaching a peak impact of -4% after nine quarters. In consideration of existing evidence, this response seems reasonable, though still worth investigating further. Relative to domestic firms, multinationals tend to face lower tax rates because they can minimize tax bills through location choice. If shocks are truly anticipated, then multinationals should not be affected at all. However, an unanticipated shock would still hit multinationals deeply, particularly because they are large firms and hence face different financing constraints than smaller domestic firms which render them relatively more sensitive to an initial shock. Yet because multinationals can minimize taxes through location choice, they also can quickly reoptimize in the face of a shock, which is why they can recover so much more quickly than domestic firms as in 2b.

5 Concluding Remarks

Substantial research remains to be done on the heterogeneous effects of tax shocks on investment at the firm level. A formidable task lies ahead for economists hoping to tackle the endeavor for two reasons. First, the existing data is not well-suited to using macroeconomic tax shocks because macroeconomic shocks are few and poorly distributed across time, with very few in the era most relevant for policy. Consequently, economists must seek to either identify sectoral or firm-level shocks. The former may be easier simply because a narrative approach could be used once more with a source like the IRS's SOI tax stats. Even so, the latter is eminently desirable. If we take a tax shock to mean an unanticipated change in tax rates for a particular firm, then there are many of these occurring to all firms, perhaps every quarter. The difficulty lies in the identification of these, especially since the nature of the shock may or may not originate in policy. Secondly, macroeconomic shocks do not lend themselves well to firm-level analysis. Firms may respond differently to a tax shock because they are by nature different from other firms (i.e., Firm A is in manufacturing while Firm B is in retail), because they face different balance sheet constraints at the time of the tax change, or because the actual details of the tax change inherently target one industry above others. The objective of examining the heterogeneous effects of tax shocks at the firm level is to target the first while controlling for the latter two reasons. This difficulty is exceedingly tricky to overcome with macroeconomic shocks.

Our research is intended to be a step in that direction. Our results show the following. First, that tax shocks have deep, significant effects on the capital stock and hence investment both immediately and dynamically. The immediate impact semi-elasticity is -2.4%, while the peak impact reaches -3.75% after seven quarters. Moreover, these effects differ significantly across firms and industries, tending to affect investment-heavy industries more severely. It tends not to matter whether firms are highly levered or are R&D-intensive, but there are substantially different effects on investment for big and small firms, with big firms exhibiting much greater sensitivity. This result is in line with related analysis from Eskandari and Zamanian (2020). Although a panel regression does not reveal significantly different responses to tax shocks for multinationals and domestic firms, dynamic responses reveal them to be substantially different, with multinationals experiencing a much larger immediate impact while returning to normal much more quickly.. Our hope is that economists will build on these results in the future.

References

Abel, A. B. and J. C. Eberly (2011, oct). How Q and Cash Flow Affect Investment without Frictions: An Analytic Explanation. *The Review of Economic Studies 78*(4), 1179–1200.

Ahn, S., D. J. Denis, and D. K. Denis (2006). Leverage and investment in diversified firms. *Journal of Financial Economics 79*(2), 317–337.

Aivazian, V. A., Y. Ge, and J. Qiu (2005, mar). The impact of leverage on firm investment: Canadian evidence. *Journal of Corporate Finance 11*(1-2), 277–291.

Auerbach, A. J. (2018). Measuring the Effects of Corporate Tax Cuts. *Journal of Economic Perspectives 32*(4), 97–120.

Barro, R. and B. Wheaton (2019). Taxes, Incorporation, and Productivity. Technical report, National Bureau of Economic Research, Cambridge, MA.

Barro, R. J. and J. Furman (2018). The macroeconomic effects of the 2017 tax reform.

Barro, R. J. and C. J. Redlick (2011, feb). Macroeconomic Effects From Government Purchases and Taxes *. *The Quarterly Journal of Economics 126*(1), 51–102.

Bilicka, K. A. (2019). Comparing UK Tax Returns of Foreign Multinationals to Matched Domestic Firms. *American Economic Review 109*(8), 2921–53.

Blanchard, O. and R. Perotti (2002). An Empirical Characterization of the Dynamic Effects of Changes in Government Spending and Taxes on Output. *Quarterly Journal of Economics 117*(4), 1329–1368.

Boyle, G. W. and G. A. Guthrie (2003). Investment, Uncertainty, and Liquidity. *Journal of Finance 58*(5), 2143–2166.

Caldara, D. and C. Kamps (2017, jul). The Analytics of SVARs: A Unified Framework to Measure Fiscal Multipliers. *The Review of Economic Studies 84*(3), 1015–1040.

Clarke, C. and W. Kopczuk (2017, jan). Business Income and Business Taxation in the United States since the 1950s. *Tax Policy and the Economy 31*(1), 121–159.

de Mooij, R. A. and S. Ederveen (2008). Corporate tax elasticities: A reader's guide to empirical findings. *Oxford Review of Economic Policy 24*(4), 680–697.

Devereux, M. P. and R. Griffith (1998). Taxation and the location of production: evidence from a panel of US multinationals. *Journal of Public Economics 68*, 335–367.

Dobbins, L. and M. Jacob (2016, nov). Do corporate tax cuts increase investments? *Accounting and Business Research 46*(7), 731–759.

Eskandari, R. and M. Zamanian (2020). Marginal Tax Rates and Investment Behavior of Small and Large Firms.

Gertler, M. (1988). Financial structure and aggregate economic activity. *Journal of Money, Credit, and Banking 20*, 559–588.

Gutiérrez, G. and T. Philippon (2016, dec). Investment-less Growth: An Empirical Investigation. Technical report, National Bureau of Economic Research, Cambridge, MA.

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

House, C. L. and M. D. Shapiro (2008, may). Temporary Investment Tax Incentives: Theory with Evidence from Bonus Depreciation. *American Economic Review 98*(3), 737–768.

Jordà, Ò. (2005, feb). Estimation and Inference of Impulse Responses by Local Projections. *American Economic Review 95*(1), 161–182.

Kadapakkam, P.-R., P. Kumar, and L. A. Riddick (1998, mar). The impact of cash flows and firm size on investment: The international evidence. *Journal of Banking & Finance 22*(3), 293–320.

Kim, I. S. and H. V. Milner (2019). Multinational Corporations and their Influence Through Lobbying on Foreign Policy.

McGrattan, E. (2017, mar). Intangible Capital and Measured Productivity. Technical report, National Bureau of Economic Research, Cambridge, MA.

McGrattan, E. R. (1994). The macroeconomic effects of distortionary taxation. *Journal of Monetary Economics 33*, 573–601.

Mertens, K. and M. O. Ravn (2013, jun). The Dynamic Effects of Personal and Corporate Income Tax Changes in the United States. *American Economic Review 103*(4), 1212–1247.

Mountford, A. and H. Uhlig (2009, sep). What are the effects of fiscal policy shocks? *Journal of Applied Econometrics 24*(6), 960–992.

Ottonello, P. and T. Winberry (2018). Financial Heterogeneity and the Investment Channel of Monetary Policy.

Peters, R. H. and L. A. Taylor (2017). Intangible capital and the investment-q relation. *Journal of Financial Economics 123*(2), 251–272.

Plesko, G. A. and E. J. Toder (2013, dec). Changes in the Organization of Business Activity and Implications for Tax Reform. *National Tax Journal 66*(4), 855–870.

Rajan, R. G. and L. Zingales (1998). Financial Dependence and Growth. *American Economic Review 88*(3), 559–586.

Ramey, V. A. (2016). *Macroeconomic Shocks and Their Propagation* (1 ed.), Volume 2. Elsevier B.V.

Romer, C. D. and D. H. Romer (2010). The Macroeconomic Effects of Tax Changes: Estimates Based on a New Measure of Fiscal Shocks. *American Economic Review 100*(3), 763–801.

Weinberg, J. A. (1994). Firm Size, Finance, and Investment. *FRB Richmond Economic Quarterly 80*(1), 19–40.

Whited, T. M. (1992, sep). Debt, Liquidity Constraints, and Corporate Investment: Evidence from Panel Data. *The Journal of Finance 47*(4), 1425–1460.

Yagan, D. (2015, dec). Capital Tax Reform and the Real Economy: The Effects of the 2003 Dividend Tax Cut. *American Economic Review 105*(12), 3531–3563.

Zwick, E. and J. Mahon (2017, jan). Tax Policy and Heterogeneous Investment Behavior. *American Economic Review 107*(1), 217–248.

Appendix A. Data Construction

Here, we describe the firm-level variables used in the analysis. Note that, following Ottonello and Winberry (2018), the definitions of the variables used are typical in the literature and are based on Compustat data. Each item taken from Compustat has been deflated by the implicit GDP deflator using 2012 as the base year.

Variables

1. *Investment*: We use several definitions of investment:

   (a) *Investment*: In the basic case, we use a variable related to investment rather than investment itself. Using net plant, property, and equipment, we estimate the capital stock of each firm at time t (ppentq, Compustat item 42). For firms with a single missing observation between filled observations, we linearly interpolate with the values immediately prior and after. We include firms with at least five years (20 quarters) of investment observations.

   (b) *R&D Expenditures*: Defined as the natural logarithm of R&D expenditures (xrdq, item 4). If R&D is missing, we set it equal to zero.

   (c) *Gross Investment*: Following Rajan and Zingales (1998), defined as capital expenditures (capxy, item 90) to plant, property, and equipment (ppentq). Since capxy is a cumulative variable in Compustat, we construct a new variable of capital expenditures using capxy to capture the net quarterly increase. Note that this variable is generally unavailable before 1984.

2. *Tax Shocks*: Our measure of a tax shock is taken from the vector of exogenous shocks to corporate taxation developed by Mertens and Ravn (2013) and Romer and Romer (2010). For each quarter, the value is set to zero if there is no shock. In quarters with a shock, we take the expected value of the tax change divided by corporate profits. Note that this follows directly from Mertens and Ravn (2013).

3. *Leverage*: defined as the ratio of total debt to stockholder's equity (seqq, item 60). Total debt is defined as the sum of long-term financial debt (dlttq, item 51) and financial debt in current liabilities (dlcq, item 45).

4. *Tobin's Q*: Taken as the sum of total assets and market capitalization less book value divided by total assets. Market capitalization is defined as the product of quarterly price per share (prccq) and common shares outstanding (cshoq, item 61). Book value is measured as common/ordinary equity (ceqq, item 59).

5. *Net leverage*: Total debt less net current assets divided by total assets. Net current assets is defined as current assets (item 40) minus current liabilities (item 49).

6. *Real sales growth*: Measured as log differences in sales (saleq, Compustat item 2).

7. *Size*: We use log net sales as a proxy for firm size.

8. *Liquidity*: Defined as the ratio of cash and short-term investments (cheq, item 36) to total assets.

9. *Sectoral Dummies*: We consider 2-digit NAICS codes excluding NAICS 52 (finance and insurance) and NAICS 53 (real estate and rental and leasing). Using the Census Bureau's 1987-1992 SIC-NAICS crosswalk, we convert 4-digit SIC codes to their 2-digit NAICS counterparts for years preceding 1985.

10. *Big Firm Dummy*: We assign a firm-quarter dummy value of one if the deflated market capitalization is greater than $100m.

11. *R&D Intensity Dummy*: If a firm-quarter observation has an R&D intensity (see above for definition) greater than .05, then it takes a dummy value of one.

12. *Multinational Dummy*: Following Kim and Milner (2019), we assign a firm-quarter observation a dummy value of one if the ratio of foreign profits to total profits exceeds 0.02139.

Sample Selection

Largely following the procedure of Ottonello and Winberry (2018), we selected our sample as follows:

1. We excluded firms in finance, insurance, and real estate (NAICS codes 52 and 53).
2. Excluded firms not incorporated in the United States
3. Firm-quarter observations that fail to satisfy the following conditions:
   (a) Positive capital or assets
   (b) Investment rate in the middle 99% of the distribution
   (c) Positive sales and positive liquidity
   (d) Investment spell greater than 20 quarters (five years)
   (e) Net current assets as a share of total assets less than 10 and greater than -10.
   (f) Leverage between zero and ten
   (g) Quarterly sales growth between -1 and 1

Since we examine different investment variables, a separate dataset is created for each type of investment. The datasets for change in firm capital stock and R&D intensity begin in 1975q1. The dataset for gross investment begins in 1984q1.

Because we are interested in aggregate as well as firm-level effects, it is crucial that our Compustat series are at least somewhat representative of aggregate data. This is useful not only because we will then be able to estimate the causal effects of a tax shock, but because it will enable us to make broad comparisons with the existing aggregate literature. The closest measure to our measure of investment, log differences in property, plant, and equipment, is NIPA Fixed Asset Table 6.2, percentage change in non-financial corporate net stock of private fixed assets. Because this measure is annual, we took annual log differences in our Compustat variable. Figure 3 plots our measure next to the NIPA measure. The correlation between the series is 63% and both exhibit the same time trends. However, note that because of the arguments we make in Section 2 with respect to the differences between our panel data series and aggregate data, that it is not at all problematic for us if the aggregate series do not match up well with ours; this is expected.

Figure 3: Aggregate Investment: NIPA vs. Compustat