This paper documents the first empirical evidence on how corporate tax policy affects monetary policy outcomes. Using exogenous marginal tax reforms in the US, I show that the average impact of monetary policy differs based on the tax treatments firms receive. Specifically, I find that monetary policy is more effective on employment, sales and investment for firms facing tax increases relative to those with stable statutory taxes. Moreover, I document that monetary policy is least effective when firms face marginal tax cuts. The empirical findings are rationalized using a New Keynesian model featuring capital and corporate income taxes. Both theoretical model and empirical findings suggest that tax policy could lead to considerable variation of monetary policy outcomes.

JEL Codes: E63, E52, E62.

Keywords: monetary policy, corporate tax policy, employment

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1 Introduction

Corporate taxes and monetary policy have been at the center of policy debates in recent decades. However, despite the intertwined nature of these two policies, most of the current empirical literature studies them in isolation. This paper aims to explore the intersection of these two policies by asking the following questions. Do underlying tax structures matter for monetary effectiveness? Can changes in the US corporate taxes have weakened the effectiveness of monetary policy? The answers to these questions are crucial for public policy and understanding how tax policy influences monetary policy outcomes.

This paper presents the first empirical evidence on how corporate tax policy influences the effectiveness of monetary policy in micro-data. I employ macro identification of exogenous tax changes using narrative methods,1 and build a novel quasi-experimental design testing the impact of underlying tax structures on monetary effectiveness. The main findings show that preceding tax cuts (increases) cause consequent monetary policy to be less (more) effective. In other words, changes in tax policy generate considerable variation in monetary effectiveness. I also build a conventional New Keynesian model featuring capital and corporate taxes that rationalizes the empirical findings. Both theoretical model and empirical findings demonstrate that tax policy could influence monetary policy effectiveness.

There are a set of empirical challenges in identifying the impact of monetary policy conditional on tax policy. First of all, aggregate policy measures are usually actions taken in response to prevailing economic conditions, hence it is challenging to isolate causes and effects of these policy changes. Second, identifying monetary and tax policy jointly in pure time-series setting may not yield sufficient variation to study the interaction of these two policies.

I tackle these issues using distinct institutional features of monetary and tax policy and a novel empirical design employing micro and macro data. First of all, monetary and tax policy has distinct cross-sectional features which can be pinned down in micro-data. Specifically, monetary policy is levied uniformly across the distribution of firms, whereas tax policy has considerable cross-sectional variation with multi-brackets nature in the tax code. From 1968 to 2006, US corporate tax code incorporated 12 historically stable income brackets and sizable cross-sectional variation across these brackets. Hence, I use statutory rate changes on different

1Narrative accounts use historical records such as archives of congressional reports and presidential speeches to isolate exogenous discretionary policy interventions.
income brackets to pin down tax treatment variation across firms.\textsuperscript{2} Second, I use Romer and Romer (2010, 2009) and Mertens and Ravn (2012, 2013) tax narrative accounts which provide historical records to isolate exogenous discretionary tax reforms in the United States. Combining the narrative tax reforms with corporate statutory rate changes allows me to pin down time-series and cross-sectional variation in statutory tax changes across income brackets over time.

Second, the monetary and tax policies differ significantly in terms of their effectiveness window. Tax reforms occur at much lower frequency and have longer spans. In contrast, monetary policy changes occur at a much higher frequency than tax reforms. This feature allows me to test over-time effects of tax reforms on monetary effectiveness. In sum, I use cross-sectional and time-series features of monetary and tax policy to design a novel quasi-experimental research design.

I employ annual Compustat dataset for the period 1969-2006, which contains rich income statement and balance sheet information on 20,798 publicly traded US firms. I combine this data with monetary policy shocks, constructed by Romer and Romer (2004) and updated by Wieland and Yang (2020) and narratively-identified IRS statutory rate changes in corporate income taxes. Then, I construct a taxable income measure and sort firms into respective income brackets over time. The final data has disaggregated statutory rate changes, matched to micro data, which allows me to pin down the tax treatment of firms and test its implications on monetary effectiveness. Last, I use flexible research design of local projections (LP) (Jordà, 2005) which allows me to test the effectiveness of monetary policy conditional on firms’ tax treatment using a variety of specifications.

The key results can be summarized as follows. First, changes in tax policy play an important role in monetary policy transmission. Specifically, firms facing a 1 percentage point tax increase cut employment by .25% more than firms with constant taxes in response to a contractionary monetary policy shock. The same group of firms also show on average 0.6% and 0.14% larger response in investment and sales to monetary policy, respectively. Second, I find that monetary contractions are least effective on firms receiving persistent tax cuts. As compared to firms with stable statutory tax rates, the firms facing tax cuts have considerably muted response in employment, investment and sales. These findings suggest that the di-

\textsuperscript{2}This approach builds on the dataset used in related work, Cloyne, Kurt, and Surico (2020b). This paper studies the effects of corporate tax changes on firm capital formation and employment growth, whereas my paper studies the implications of firms’ tax treatments on monetary effectiveness.
rejection of tax shifts may significantly amplify or reduce the effectiveness of monetary policy. In other words, tax reforms could explain a sizable amount of variation in monetary policy effectiveness.

The findings of this paper are robust to a series of checks including alternative empirical strategies, additional controls and underlying assumptions. In addition, I test the role of firm financial and non-financial characteristics in the baseline responses. These estimates suggest that the baseline results are robust to various firm characteristics, although some factors such as being small, holding high liquidity and low leverage significantly contribute to indirect effects of taxes on monetary effectiveness.

Taken together, this paper makes two contributions to the literature. First, the results of this paper presents the first empirical evidence, to the best of my knowledge, quantifying the nature of interaction between monetary and corporate tax policy in the micro-data. This is a previously unexplored dimension that is different than the earlier approaches used in the monetary transmission literature. The main finding of my paper is that the effectiveness of monetary policy depends significantly on the dynamics of tax system. In other words, depending on the nature of preceding tax changes, monetary policy can be more or less effective than it otherwise would be. Second and more importantly, my findings can shed light on weaker effects of monetary policy documented in the last decades (Boivin et al., 2010). Bringing together the historical downward trend in corporate taxes and the evidence from my findings may account for the muted effects of monetary policy in recent decades.

Related Literature This paper connects to literatures on transmission of monetary policy, tax narrative accounts and interaction of monetary and fiscal policy. First, there is a growing literature studying heterogeneity of monetary policy on firm level data. These papers provide evidence on how financial and non-financial factors like balance sheet conditions (Gertler and Gilchrist, 1994; Ottonello and Winberry, 2020), firm age (Cloyne et al., 2019), liquidity conditions (Jeenas, 2019; Fazzari et al., 1988; Kashyap et al., 1994; Gilchrist and Himmelberg, 1995) and collateral assets (Bahaj et al., 2020) play a role in the transmission of monetary policy. I contribute to this literature by providing the first empirical evidence documenting the role of corporate tax policy in changing firms’ responsiveness to monetary policy. This is a new dimension that has not been addressed previously in the literature and my results

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3See also the ECB speech by J. M. González-Páramo in 2005 that highlights this aspect with regard to coordination of fiscal and monetary policy in European Union countries.
provide evidence for tax policy induced variation in monetary policy outcomes.

Second, this paper connects to narrative macroeconometric studies. Employing tax reforms for identification, recent studies estimate short and medium run effects of tax policy on real economic activity (Romer and Romer, 2010; Mertens and Ravn, 2013, 2012; Mertens and Olea, 2018; Zidar, 2019; Cloyne, 2013; Hayo and Uhl, 2014; Cloyne et al., 2020b; Barro and Redlick, 2011; Hussain and Liu, 2018; Nguyen et al., 2016). I contribute to this literature by providing the first analysis using corporate tax narratives joint with monetary policy in the micro-data. Among the tax narrative literature, Mertens and Olea (2018), Zidar (2019) and Cloyne, Kurt, and Surico (2020b) share the most similarities to my analysis in their use of counterfactual statutory rate analysis. Both Zidar (2019) and Mertens and Olea (2018) examine the effects of personal income tax changes at an aggregate level, either across income distribution or regions. Instead, my paper is a micro-data application on corporate taxes using narrative identification. In this respect, this paper connects more to my earlier work, Cloyne, Kurt, and Surico (2020b), in which we build narratively-identified changes in statutory tax rates. My paper differs from Cloyne, Kurt, and Surico (2020b) with its topic and empirical strategy. In Cloyne, Kurt, and Surico (2020b), we study the effects of corporate tax changes on firm capital formation and employment growth, whereas my paper explores the intersection of tax and monetary policy by questioning the short and medium term effects of tax changes on monetary effectiveness.

Third, this paper also connects to the literature focusing on regime dependent effects of monetary policy. Studies such as Tenreyro and Thwaites (2016); Auerbach and Gorodnichenko (2012); Berger and Vavra (2014); Angrist et al. (2018); Matthes and Barnichon (2015); Owyang et al. (2013) explore whether policy interventions have differential effectiveness based on whether the economy is in a recession or expansion, or based on uncertainty. My paper shares some characteristics with these studies, yet also has a fundamentally different approach. First, most of these studies estimate impulse response functions in regime-switching

\[4\]Note that recent work by Cloyne et al. (2020a) also studies tax and spending narrative joint with monetary policy. Cloyne et al. (2020a) highlights the role of monetary policy on the effectiveness of fiscal policy using international data.

\[5\]Mertens and Olea (2018) analyze the changes in average marginal tax rate across years and study the elasticity of reported income along the income distribution. Zidar (2019) constructs regional tax liability changes in personal income tax changes and estimate employment effects using income distribution differences across states.

\[6\]This is an important feature that differs my work from Mertens and Olea (2018) and Zidar (2019) as it allows me to capture clean treatment effects. Moreover, it deals with the concerns for general equilibrium effects that may arise in studies using aggregate data. Note that the decomposition approach is particularly feasible in corporate taxation due to the historically stable brackets.
environments where regimes are computed at the aggregate level with transition probabilities across regimes. In my paper, a tax regime starts following a discrete event of persistent statutory rate changes. Moreover, since I use disaggregated changes in statutory rates, my approach can be categorized as a micro-regime application where every firm gets exposed to its own shock. Taken together, my paper addresses the state dependent effects of monetary policy in the aftermath of tax shifts. However, as compared to the aggregate literature, I define regimes at the micro level and do not employ regime switching models.

Last, there is an influential strand of literature theoretically modeling the interaction of fiscal and monetary policy rules (Canzoneri et al., 2010; Chen et al., 2020; Davig and Leeper, 2011; Sargent and Wallace, 1984; Aiyagari and Gertler, 1985; Leeper, 1991). These papers study policy outcomes under alternative coordination of monetary and fiscal policy. Specifically, they characterize a non-cooperative game between the government and central bank to consider implications of active and passive monetary and fiscal policy interactions in altering the effectiveness of alternative stimulus policies as well as determining price stability. My paper diverges from these studies in that it does not explicitly model the endogenous interaction of fiscal and monetary policy. Instead, I study effectiveness of monetary transmission conditional on underlying tax structures. In order to motivate my empirical predictions, I also present a medium scale New Keynesian model featuring capital and corporate income taxes. The theoretical predictions reconcile the findings of the quasi-experimental exercise that preceding persistent tax policy interventions can influence the effectiveness of monetary policy.

The rest of the paper is organized as follows. Section (2) discusses firm-level data, tax policy variables and monetary policy shocks. Section (3) presents the empirical strategy, main results and robustness checks. Section (4) provides the theoretical model and conducts an experiment to motivate the empirical results. Section (5) concludes.

2 Dataset

2.1 Firm level variables

This paper uses the annual Compustat database on the publicly traded C corporations in North America. Compustat provides high-quality information on balance sheet and income statement components of active and inactive companies. The sample spans from 1969 to
2006 and consists of 205,342 firm-by-year observation from a total of 20,357 firms. The main explanatory variables I analyze are the number of employees \( (\text{emp}, \text{Compustat item 29}) \), investment (defined as capital expenditures, \( \text{capx}, \text{Compustat item 128} \)) of firm \( j \) in period \( t \) and net sales \( (\text{sale}, \text{Compustat item 12}) \). Other variables of interest are book value of total assets \( (\text{at}, \text{Compustat item 6}) \), liquidity ratio\(^7\), leverage (total debt divided by the book value of total assets)\(^8\) and cash dividends paid \( (\text{dv}, \text{Compustat item 127}) \). Details of data construction is discussed in Appendix A.

Using Compustat data in this paper is advantageous for a couple of reasons. First, Compustat is a long enough panel to study within-firm variation. I analyze thirty-seven years of annual firm level data where the average firm is observed for about 11 years. Second, Compustat has a rich cross-sectional dimension. The rich balance-sheet information in Compustat allows me to construct a new taxable income measure, test alternative hypotheses and conduct heterogeneity analysis.

There are a few limitations of using Compustat data. First, Compustat only consists of publicly held companies, hence the estimates represent only the effects of the corporate tax code on the behavior of publicly traded C-corporations. Second, despite the good coverage across different sized firms, Compustat data may disproportionately feature large companies, and therefore may underrepresent small firms. Last, Compustat is mainly a report of financial statements, hence the gross income and tax variables are not reported for the purposes of tax books. Although a growing public finance literature (Kleven et al., 2016) increasingly suggests the use of third-party information on business records in developed countries to be legitimate and accurate with little discrepancy between the tax reports and the third-party information\(^9\), extracting the corporate tax variable out of Compustat (despite being second-party information) may still be subject to measurement error and bias.

Since both marginal tax rates and taxable income are unobserved data in the generic financial statements in Compustat, I construct a taxable income measure using balance sheet variables. The taxable income variable is measured using the following:

\[^7\text{Liquidity ratio is calculated as the share of cash and short term investments (cheq, Compustat item 1) to total assets.}\]

\[^8\text{Total debt is calculated as the sum of debt in current liabilities (dlc, Compustat item 34), and long term debt (dltt, Compustat item 9).}\]

\[^9\text{Kleven et al. (2016) further suggests this transparency to be especially true for the large firms where the tax enforcement through auditing is strong.}\]
\[ TI = \text{Net Income} - \text{Interest Paid} - \sum_{n=t-3}^{n=t-1} \frac{\text{Tax Loss Carryforward}_n}{3} + \text{Special items} - \text{Depreciation and Depletion Expense} + \frac{\text{Income from extraordinary items}}{(1 - mtr)} \] 

According to the definition, taxable income is generated using firms’ profits net of allowable cost deductions.\(^{10}\) The definition mainly builds on existing definitions in the literature (Graham, 1996; Blouin et al., 2010; Shevlin, 1990), and further supplements them with the 1984 IRS instructions (See Appendix A Figure A.1) on corporate tax filings. The definition accounts for firms’ incentives to allocate income across time through carryforwards and allows for forward-looking behavior. The goal is to generate a taxable income definition closest to the actual reports, to the extent of data availability. In Appendix A, I detail the construction of taxable income as well as comparisons to Graham (1996) and Blouin et al. (2010) measures.

### 2.2 Corporate tax variable

This section constructs firm-level measure of exogenous statutory corporate tax changes over time. This is a two stage procedure. In the first stage, I select tax reforms from the tax narrative accounts of Romer and Romer (2009) focusing on corporate income tax reforms that have persistent statutory rate changes and are classified as exogenous by Romer and Romer (2009) and Mertens and Ravn (2013).\(^ {11}\) According to Romer and Romer (2009) categorisation, a tax reform is exogenous if its motivation is to address inherited budget deficits or to achieve some long-run goal such as increasing fairness or changes in philosophy of the government.\(^ {12}\) Hence, discarding the changes in tax liabilities that are related to the current state of the economy fulfills the required assumption on the orthogonality of tax reforms, and therefore form the exogenous series. Next, many corporate reforms are implemented with either delay or have gradual multiyear phase-ins such as Economic Recovery Tax Act of 1981 and Tax Reform Act of 1986. To strip the policy variation with elements of surprise, I focus on tax changes implemented within one quarter of their legislation to avoid anticipation effects (Mertens and Ravn, 2012). After the elimination of tax changes based on exogenous,

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\(^{10}\)The deductions are guided by the IRS instructions to the extent of data availability.

\(^{11}\)The narrative accounts use historical records of congressional reports and presidential speeches to construct exogenous discretionary tax shocks with descriptive information on size, timing and motivation. Mertens and Ravn (2013) disaggregated tax narratives are originated from Romer and Romer (2009) aggregate series and provide exogenous tax policy shocks on the US corporate and personal income tax separately.

\(^{12}\)Similarly, a tax reform is considered endogenous if the tax reform is influenced by current economic conditions.
unanticipated and persistent ones, the selection procedure yields 5 tax reforms between 1969 and 2006 with significant and immediate impact on corporate statutory tax rates. Appendix C Table C.1 lists these reforms together with their direct impact on the corporate statutory rate schedule.\textsuperscript{13}

In the second step, I follow the approach in my earlier work Cloyne, Kurt, and Surico (2020b) and decompose the selection of Romer and Romer (2009, 2010) tax reforms into a panel of statutory rate changes across taxable income brackets. Tracking the statutory rate changes across 12 distinct income brackets over years allows the 5 benchmark tax reforms to generate a large amount of variation in statutory tax rates. The details of this step are explained below in detail.

**Corporate income tax code** US corporate income tax code is a piecewise linear system where the taxable income is divided into brackets where marginal tax rates are fixed within but vary across these brackets. Appendix A Table A.3 provides an overview of the IRS historical statutory marginal tax rates across different taxable income brackets from 1968 to 2016.\textsuperscript{14} This table reveals a number of unique features of the corporate tax code. First, corporate tax code has adhered to 12 historically stable taxable income brackets ranging from under 25,000 dollars to over 18.333 million dollars.\textsuperscript{15} Second, the gradual rate structure has consistently been an important characteristic of corporate tax code since the late 1960s. Specifically, the Revenue Act of 1978, the 1986 Tax Reform Act\textsuperscript{16} and the Omnibus 1993 shows examples of detailed size-dependent tax rates. Third, the tax legislations change the statutory rates in the same direction for all taxable income brackets, but there is considerable heterogeneity in the dose of tax changes. For example, the 1975 legislation suggests an 18 percentage point (ppt) decline in top statutory tax rate for firms with taxable income from $50,000 to $75,000 and a 2 ppt decline in the top statutory tax rate for firms with taxable income above $100,000.\textsuperscript{17} Next, there is considerable variation in the tax cuts and tax increases. Of the five exogenous tax reforms, two (1984 and 1993) are tax increases and three (1979, 1982, 1987) are tax cuts.

\textsuperscript{13}There are 10 total number of statutory tax changes from 1969 and 2006.

\textsuperscript{14}See the full historical data on IRS historical Table 13.

\textsuperscript{15}These brackets are $0 - $25,000, $25,000 - $50,000, $50,000 - $75,000, $75,000 - $100,000, $100,000 - $335,000, $335,000 - $1,000,000, $1,000,000 - $1,405,000, $1,405,000 - $10,000,000, $10,000,000 - $15,000,000, $15,000,000 - $18,333,000 above $18,333,000.

\textsuperscript{16}1986 Tax Reform Act implemented two step changes occurring in years 1987 and 1988.

\textsuperscript{17}However, not surprisingly since the 18 ppt is only levied on the $25,000 income from $50,000 to $75,000, the dollar impact of the 18 percentage points cut is actually quite small. The liability impact of 18 ppt change is $4,500 at maximum. Note that this feature of varying progressiveness is an obstacle in terms of making direct comparisons of marginal tax rate changes across firms of different income brackets. In order to facilitate this type of comparison, I use a liability based measure across firms through time.
The larger number of tax cuts are also due to the lack of indexation in the tax code. Last, not all the tax brackets receive statutory rate shocks at every new legislation. For example, in the 1993 tax reform only large firms with income greater than $10 million faced a statutory tax change. All these features form the basis of my quasi-experimental research design using time-series and cross-section variation in marginal tax rates.

Figure 1 sketches the basic research design. Consider an economy with alternative marginal tax rates, \( \tau_1, \tau_2, \tau_3 \) and \( \tau_4 \) on alternative taxable income brackets. At time \( t \), a new legislation is executed which changes the marginal tax rate for some brackets and leaves it unchanged for some others. I take this feature and form a quasi-experimental research design using variation in the direction and level of tax treatment across income brackets through time. My identification strategy has two layers. First, I exploit the direction of statutory rate changes where the treatment group consists of the firms which are in the taxable income brackets receiving a statutory rate change and the control group consists of the firms in the brackets that do not receive any change in statutory rate. Specifically, I generate a binary measure of tax treatment across income groups that pins down the direction of statutory tax rate change. Second, I explore tax treatment dose across the treated groups, which allows me to test the role of intensity of tax treatment across firms. The next section details the construction of the two measures and underlying identifications strategies.

### 2.3 Treatment in marginal tax rate

This section constructs a measure of statutory rate changes that deals with the endogenous nature of marginal tax rates. I follow the earlier methods in Mertens and Olea (2018), Zidar (2019) and Cloyne, Kurt, and Surico (2020a) where the estimated statutory change in year \( t \) is calculated as the difference between a counterfactual statutory rate calculated using year \((t - 1)\) taxable income and year \( t \) rates and the actual year \((t - 1)\) statutory tax rate. The use of the previous year’s taxable income is to strip away the behavioral responses of firms in adjusting their income.\(^{19}\) Equation 2 formulates \( \Delta mtr_t \) measure which is interpreted as the change in the statutory rate on an additional $1 income earned today. This is a proxy for the changes

\[^{18}\]The marginal tax rate is defined as the statutory rate that incurs on the additional dollar of income. Throughout the paper, I use marginal and statutory tax rates interchangeably.

\[^{19}\]On the corporate income side, the tax brackets are matched to brackets on a nominal basis at every year, hence I do not deflate the taxable income measure through time. Similarly in the liability changes, I use a share of liability change measure which also do not require deflating.
change in statutory rate, with no income response.

\[
\Delta mtr_t = \tau_t(TI_{t-1}) - \tau_{t-1}(TI_{t-1})
\]  

(2)

I repeat this exercise for 12 distinct taxable income brackets from 1968 to 2006 and generate a new time-series measure capturing variation in statutory rate changes across income brackets. Figure 2 plots the output of this exercise where the y axis has the percentage point change in the statutory tax rate ($\Delta mtr_t$) of different income brackets from 1968 to 2006. Positive numbers show statutory rate increases and negative numbers show statutory rate cuts. In order to visualize the labels clearly, the figure is split across large and small firms such that Figure 2a(2b) covers firms with taxable income less (higher) than 1 million dollars. Figure 2 shows three interesting features of statutory corporate income tax changes. First, the figure uses cross section of income brackets which allows us to visualize time-series variation by brackets. For example, Figure 2a shows that firms with taxable income between $25,000 and $1,000,000 taxable income faced a statutory tax increase of 4.8 percentage points in the year 1968. The same group of firms also receive a tax cut of 3.6 and 1.2 percentage points in the following years in 1970 and 1971, respectively. Second, Figure 2 illustrates the variation difference within tax legislations. For instance, the Revenue Act of 1978 act lowered statutory tax rates across firms at four different rates for firms of different sizes. Third, both Figure 2a
and Figure 2b suggest that there is sizable variation in the sign of treatment across different brackets. Particularly for large firms, there are three years of tax increases and five years of tax cuts that impact various brackets. The selected exogenous statutory rate changes in Romer and Romer (2009) and Mertens and Ravn (2013) are marked with stars and will be used in the baseline results. These also correspond to reforms summarized in Appendix C Table C.1. After generating different tax treatments across income brackets, I match the Compustat constructed taxable income variable to the right taxable income brackets which allows me to generate a firm level measure of tax treatment over time.20

Figure 2: Corporate tax rate changes by alternative taxable income brackets
Note: The 1979, 1982, 1984, 1987 and 1993 are exogenous acts based on Romer and Romer (2009) and Mertens and Ravn (2013). All the tax changes are categorized as persistent in Mertens and Ravn (2012).

Next, in order to study monetary policy in the aftermath of tax legislations, I define the term, tax regime to refer to periods following discrete and persistent tax policy changes in micro-data. Using the sign of tax change, I assign firms to three possible tax regimes: expansionary, contractionary and neutral. For example, if a firm has received a tax cut at year $t$, it enters an expansionary tax regime. Similarly, if a firm has received a tax increase at year $t$, it enters a contractionary tax regime. The firms that have not received any change in statutory rate are assigned to the neutral regime. This exercise labels the tax treatment of firms in the aftermath of persistent tax shifts. Once a firm is allocated to a new regime, unless an opposite tax change occurs in the subsequent years, the firm continues to stay in the relevant regime for up to five years. The choice of five years is guided by the persistent nature of specific tax

---

20This part of my methodology follows from my earlier work Cloyne, Kurt, and Surico (2020b).
legislations and the maximum length of years in between exogenous reforms. Figure 3 plots example tax regimes for the sample of large firms. The left panel shows the marginal tax treatment of large firms (same as Figure 2) and the right panel sketches the tax regimes across income brackets using the shaded colors. Figure 3 left panel shows that firms with taxable income greater than $1,405,000 received a tax increase of 4.8 percentage points in year 1968, a tax cut of 2.6 percentage points in 1970 and another tax cut of 1.2 in year 1971. In the right panel, I shade the respective tax regimes for firms in this bracket, which marks 1968 to 1970 as contractionary tax regime years and 1970 to 1974 as expansionary tax regime years. Since this particular income bracket does not receive any more treatment in the following years, the firms switch to neutral regime in 1974, five years after the reform. Hence, repeating this exercise across income brackets allows me to construct micro tax regimes of income brackets through time. Using exogenous tax reforms, 4 percent of the sample is identified to receive a persistent tax increase and 18 percent of the sample is identified to receive a persistent tax cut.

One of the underlying assumptions of this framework is that it allocates firms to a regime using last year’s taxable income which may overlook potential income responses. In order to not rely on the assumption of static taxable incomes through time, I restrict my sample to firms who continue to stay in the treated brackets when the policy changes. In other words, once a firm is allocated to a regime, I continue to track its income for the next year to

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21 Figure H.6.1 in Appendix H provides robustness on the maximum regime length.
22 The final data consists of 8,251 observations in contractionary regime and 32,960 observations in expansionary regime, forming 4% and 18% of the total estimation sample.
confirm that they continued to stay in that particular reform’s treated brackets. Although this certainly decreases the number of firms allocated to a regime, it minimizes the measurement error regarding the assumptions on dynamics of income. I also drop the regime observations of firms who jump more than one neighboring income bracket after a tax reform. This also automatically deals with firms that switch to zero or negative taxable income after the tax reform as well.

**Constructing tax treatment dose** The US tax code has a non-linear structure, hence it restricts statutory treatment comparisons across brackets. In order to overcome this, I construct a firm-level dose measure that captures treatment variation in statutory rate changes. Using the difference between tax liabilities based on the previous and the new legislation, I calculate the changes in share of tax burden for each firm that has received a statutory rate change. In order to facilitate comparison across firms and time, I also scale liability changes with lagged taxable income:

\[
Dose = \frac{\Delta mtr \times (TI_{t-1} - TI_{t-1})}{TI_{t-1}}
\]

where \(TI\) is the threshold taxable income starting that particular bracket. Appendix B Figure B.1 presents a detailed example. Repeating this exercise for every firm at every tax legislation generates a firm-level dose variable which measures share of tax burden changes after every tax reform.

Appendix G Figure G.1 plots histogram of tax treatment dose in my sample. I use regime based thresholds pointing mean of tax burden changes and allocate firms into groups that received a high or low dose tax treatment by regime. The final tax treatment variable consists of the following five categories: contractionary high, contractionary low, expansionary high, expansionary low and neutral. For instance, if a firm has received a low dose tax cut (e.g. the change in tax burden is lower than the cutoff tax burden change), it is assigned to expansionary low regime. Alternatively, if a firm has received a high dose tax cut, it is assigned to expansionary high regime. The new measure of groups allows me to explore both the direction and the intensity of the tax treatment which facilitate treatment comparisons across time and firms. Furthermore, the use of a liability based measure allows me to test the implications of cash flow or balance sheet channel across firms.
2.4 Summary statistics

Table A.2 presents summary statistics of key variables of interest in the firm-level data covering the sample period 1969-2006. The sample contains 205,342 observations on 20,357 firms. Since the sample consists of public firms, the average size (total assets) is $1,169 million and average taxable income is $105 million over the sample. The right-skewed size distribution of firms motivates the use of log variables in regressions. The average number of employees in the sample is 6.8 thousand. The average leverage ratio is 29 percent and the average marginal tax rate is 27 percent. The taxable income and marginal tax rate are variables constructed in the paper and income taxes (txt) is a tax variable reported in Compustat. The numbers at different percentiles of the “income tax” variable and the generated “taxable income” variable suggest that the constructed variables are in line with the reported data.

The summary statistics are also provided across different tax regimes. Neutral regime firms account for 80 percent of the total sample and consists of 20,333 unique firms with 164,131 observations. Contractionary tax regime firms account for 4 percent of the total sample and consists of 2,027 firms with 8,251 observations in total. Expansionary tax regime firms account for 18 percent of the total sample and consists of 5894 firms with 32,960 observations. The comparison across tax groups suggests expansionary tax regime firms are larger in size than contractionary or neutral regime firms. Comparisons of employment, asset and income taxes also confirms this. Regarding leverage, firms that are subject to tax increases seem to have lower debt to asset ratio than the rest of the groups. Regarding the marginal tax rate, all groups seem to have sizable variation, which confirms the sizable heterogeneity in the treatment groups.

Finally, Figure E.1 in Appendix E presents descriptive charts that lay out characteristics of each tax regime. In terms of number of firms, contractionary regime consists of 2,027 unique firms, expansionary regime consists of 5,894 firms. The total number of firms is 20,357. Figure E.1 shows that contractionary regime firms heavily consist large firms (high assets and high sales) with high debt to asset ratios and low investment rates. In contrast, expansionary and neutral regime firms are more homogeneous across alternative firm characteristics. In the robustness section, I provide alternative specifications that address confounding effects of firm characteristics in the main results.
2.5 Monetary Policy Shocks

I use the Romer and Romer (2004) monetary policy shock series (Romer shocks) that have recently been updated by Wieland and Yang (2020). These are residuals from a regression of the federal funds rate on lagged values and the Federal Reserve’s information set using Greenbook forecasts. The series are summed to an annual frequency and span from 1969 to 2006. Following Gertler and Karadi (2015), I instrument changes in 1 year treasury rate with the Romer shocks. Since my paper is a micro-data application using aggregate shocks, I use panel-data feasible local projection (Jordà, 2005) method with instrumental variables (LP-IV) as in Bahaj et al. (2020), Ramey (2016).

There are many alternative approaches to identify monetary policy shocks in the monetary policy literature. First of the many prominent approaches is using a SVAR framework complemented with Cholesky decomposition, evidence or theory-based sign restrictions or calibrated elasticities. Although SVAR approaches provide a valid characterization of the transmission mechanism, they are not feasible for micro-data applications. Another alternative measure is to use high frequency shocks to fed funds futures rate (Jeenas, 2019; Gurkaynak et al., 2011; Gertler and Karadi, 2015). These studies employ a hybrid approach to identify exogenous shocks via high frequency surprises on interest rate futures around policy shocks. However, many of these measures are only available starting late 1980s and 1990s due to the record of federal funds meeting dates. Since I need a larger window to capture enough variation in both tax and monetary policy, they are not a good candidate for this paper.

3 Empirical Framework

This section provides the empirical framework that explores the role of tax changes on the effectiveness of monetary policy. Given the lack of existing work on the interaction of tax and monetary policy, pinning down the precise estimation is not straightforward. My empirical strategy is geared towards examining heterogeneous effects of monetary policy conditional on preceding tax treatment of firms.

3.1 Panel IV local projection (LP) using tax treatment

I use local projections instrumental variable (LP-IV) approach combining local projections (Jordà, 2005) with instrumental variables (See Ramey (2016), Bahaj et al. (2020) among others).
The LP-IV allows me to estimate a flexible specification without imposing VAR dynamics on the main variables. Equation (3) presents the baseline LP-IV estimating dynamic causal effects of exogenous monetary policy changes subject to alternative tax treatment of firms:

\[ \Delta_h \log(y_{j,t+h}) = \alpha_{j,t}^h + \beta^h \Delta R_t + \Gamma^h \Delta R_t \text{Dose}_{j,t} + \theta^h \text{Dose}_{j,t} + \Omega' (L) Z_{j,t-1} + \epsilon_{j,t+h} \]  

(3)

where horizon is \( h = 0, 1, \ldots, 4 \) years and \( j \) and \( t \) denote firm and time, respectively. The left hand side of equation 3 is the cumulative change in the outcome variable \( y \), \( \Delta_h \log(y_{j,t+h}) \equiv \log(y_{j,t+h}) - \log(y_{j,t-1}) \), where \( y \) is log employees, log real investment and log real sales. The specification regresses the dynamic cumulative change in variable \( y \) on monetary policy changes subject to firms’ tax treatment. \( \alpha_{j,t}^h \) denotes firm fixed effect which soaks up permanent differences across firms and allows me to explore within firm variation. \( \Delta R_t \) is the changes in 1 year treasury rate instrumented with extended Romer and Romer (2004) monetary policy shocks. One year treasury rate is scaled by a quarter, so the instrument reflects 25 basis points increase in one year treasury rate. The main coefficient of interest, \( \beta^h \), gives the impulse response of left hand side variable at time \( t+h \) to a monetary policy change at time \( t \). \( \Gamma^h \) captures the marginal effect of tax treatment on firms’ responsiveness to monetary policy, where the dose variable is calculated as the percentage change in liability share of firms using previous and the next year’s rate.\(^{23}\) The interaction term is instrumented with the interaction of Romer shocks and Dose variable. In the robustness section, I also provide a less parametric estimation using bins of tax treatment (See Figure H.1.1a). Both specifications confirm the main findings that tax policy generates differential monetary policy outcomes.

The identifying assumptions for this model are as follows. First, monetary policy shocks should satisfy the conventional instrument validity and exogeneity conditions, where the former suggests the shocks to be correlated with movements in 1-year treasury rate and the latter suggests that the shocks to be uncorrelated with all other shocks. I address these two conditions by using plausibly exogenous monetary shocks of Romer and Romer (2004) which isolates changes the federal funds rate that are orthogonal to the information set reported in the Greenbook forecasts. Regarding the instrument validity, the first-stage F statistic is above the threshold value of 10 proposed by Stock and Yogo (2005), suggesting Romer shocks is a relevant instrument for changes in one year treasury rates.

\(^{23}\)Note that Dose is positive when statutory tax rate increases, implying firms to have higher tax liabilities and vice versa.
Second, dynamic structure of LP’s requires monetary policy innovations to be exogenous with respect to other current and lagged endogenous variables (Stock and Watson, 2018; Nakamura and Steinsson, 2018). In my particular setting, since I test the implications of an aggregate shock on micro data, the analysis does not suffer from reverse causality which would imply firm-level variables to affect aggregate shocks. However, since my particular research design incorporates two aggregate policy measures, I test the current and lagged exogeneity within the tax and monetary policy measures. Appendix H Table H.1 provides two-way Granger causality estimates that suggest orthogonality between monetary shocks and statutory rate changes. The Granger causality results are discussed in detail in robustness section.

Finally, specific to my research design, I use narratively identified exogenous and unanticipated tax reforms which deals with anticipation effects and endogenous selection into tax treatment (Romer and Romer, 2009; Mertens and Ravn, 2013). In addition, I use lagged taxable income to compute tax regimes of firms which ensures that monetary policy do not affect firms’ tax treatment through income changes.

\[ Z_{jt-1} \] includes the following control variables: change in log employees, change in log sales, real asset growth, real investment growth, log real assets, top statutory tax rate and an indicator variable for dividends paid. Firm level controls in logs help soak up differences in cross-sectional characteristics in financial and nonfinancial variables. The variables in log difference or growth form are to capture the time-series trend. All the control variables in \[ Z_{jt-1} \] are measured at the end of last year before the monetary shocks and tax changes to ensure exogeneity with respect to the shock. The estimation is done up to horizon of \( H = 4 \) years and the lag structure on control variable is 2 year.\(^{25}\) The standard errors are clustered two-way at the firm by year level where serial correlation adjustment is set to 2 year using Driscoll and Kraay (1998) methodology. This is a standard method to account for serial correlation at the firm level and through time (See Cloyne et al. (2019), Bahaj et al. (2020)). Following Mertens and Olea (2018), I use year dummy on 1981 and 2001 as a dependent variable. These corresponds to a period of relative macroeconomic turbulence and unusual policy variation associated with Volker era and Dot Com recession. Finally, note that the baseline specification imposes linearity in the effect of the tax treatment on explaining firms’

\(^{24}\) Note that since the policy shocks only contains variable realized at date \( t \) or earlier, the lead exogeneity requirement is less concerning (See Stock and Watson 2018, page 10)

\(^{25}\) See Appendix A for the sample selection procedure.
responsiveness to monetary policy changes.

3.2 Results

This section presents the impulse responses of specification 3 where I plot estimated coefficients as well as their 95% confidence intervals on the number of employment, investment and sales, respectively.

Figure 4 plots the estimates on the number of employees. For neutral regime firms, shown in Figure 4a, I find that the number of employees have an average semi-elasticity of -0.4 percent to monetary policy. The peak effect is -0.7 percent occurring two years after the monetary policy shock and the effect is not significant across the horizon. For firms with alternative tax treatments, shown in Figure 4b, I find sizable heterogeneity in monetary policy outcomes conditional on the changes in statutory rate. Specifically, firms with tax cuts respond monotonically less to contractionary monetary policy. In contrast, firms facing a statutory tax increase experience a larger fall in employees relative to the neutral regime firms. Figure 4b estimates suggests that on average firms facing 1% tax hikes (cuts) respond to monetary policy about 0.25 percent more (less) than the firms with stable taxes. Since firms with tax cuts has a sizable share (18%) of the total sample of firms, these findings highlight an important result that contractionary monetary policy is significantly ineffective on firms facing statutory tax cuts. (See Appendix H Figure H.2.1 for standard errors of Figure 4b) Finally, Figure 4c plots the interaction coefficient ˆg where the shaded areas capture 90% and 95% confidence intervals. The interaction coefficient is significant at 90% confidence interval.

Next, Figure 5 shows the impulse responses of investment, where the dependent variable is the cumulative change in log real capital expenditures. For neutral regime firms, shown in Figure 5a, I find -0.3 percent average semi-elasticity of investment to monetary policy shock. The peak effect is reached two years after the monetary shock, at a value around -1.1 percent. In comparison, Figure 5b suggests that firms with statutory tax increases show a noticeable on-impact drag on investment following a monetary innovation. The estimates are mostly negative across the horizon for firms with increasing taxes. Comparison of the average effects suggest that firms facing 1% tax increase (decrease) show a -0.6 percent larger (smaller) semi-elasticity to monetary shocks. The estimates of expansionary regime firms is mostly positive across the horizon and significant in the first two years after the monetary shock (See Appendix H Figure H.2.2 for standard errors of Figure 5b).
Figure 4: Impulse responses of number of employees using equation 3.

(a) Neutral Regime ($\hat{\beta}^h$)  (b) Total effects by dose ($\hat{\beta}^h + \hat{\Gamma}^h$)  (c) $\hat{\Gamma}^h$

Note: The plots show impulse responses of employees using IV local projection regressions with Romer and Romer (extended) monetary policy shocks instrumenting 1 year government bond rate. Horizon is 4 years, lag is set to 2. The time span is 1969-2006. The control variables are change in log employees, change in log sales, real asset growth, real investment growth, log real assets, top statutory tax rate and an indicator variable for dividends paid. Standard errors are clustered by firm and year. Dose = 0% is equal to neutral regime plot. Dashed line in panel (a) shows 95% confidence intervals. Shaded areas in panel (c) show 90% and 95% confidence intervals. Shaded area in panel (a) shows 95% confidence intervals.

Figure 5: Impulse responses of investment using LP-IV specification in equation 3.

(a) Neutral Regime ($\hat{\beta}^h$)  (b) Total effects by dose ($\hat{\beta}^h + \hat{\Gamma}^h$)  (c) $\hat{\Gamma}^h$

Note: The plots show impulse responses of investment using IV local projection regressions with Romer and Romer (extended) monetary policy shocks instrumenting 1 year government bond rate. Horizon is 4 years, lag is set to 2. The time span is 1969-2006. The control variables are change in log employees, change in log sales, real asset growth, real investment growth, log real assets, top statutory tax rate and an indicator variable for dividends paid. Standard errors are clustered by firm and year. Dose = 0% is equal to neutral regime plot. Dashed line in panel (a) shows 95% confidence intervals. Shaded areas in panel (c) show 90% and 95% confidence intervals. Shaded area in panel (a) shows 95% confidence intervals.

Last, Figure 6 presents the estimates on log real sales using equation 3. Figure 6a suggest that firms in the neutral regime have on average -0.2 percent semi-elasticity of sales to monetary policy shocks, where the peak effect is -0.5 percent occurring four years after the monetary shock. Similar to the previous results, firms experiencing a contractionary tax display a larger response to monetary shocks, where average semi-elasticity is -0.45 percent. In contrast, firms with tax cuts have much less response to monetary policy relative to the contractionary and neutral regime firms. The average semi-elasticity of a firm with 1% tax cut is 0.14 percent lower on average than firms in neutral regime. The effect of monetary policy for
expansionary regime firms is not significantly different from zero across the forecast horizon (See Appendix H Figure H.2.3 for standard errors of Figure 6b).

Figure 6: Impulse responses of log real sales using LP-IV specification in equation 3.

Note: The plots show impulse responses of sales using IV local projection regressions with Romer and Romer (extended) monetary policy shocks instrumenting 1 year government bond rate. Horizon is 4 years, lag is set to 2. The time span is 1969-2006. The control variables are change in log employees, change in log sales, real asset growth, real investment growth, log real assets, top statutory tax rate and an indicator variable for dividends paid. Standard errors are clustered by firm and year. Dose = 0% is equal to neutral regime plot. Shaded area in panel (a) shows 95% confidence intervals. Shaded areas in panel (c) show 90% and 95% confidence intervals.

Taken together, there are two main results that emerge from Figure 4, 5 and 6. First, firms facing tax increases exhibit larger responses to monetary policy shocks than firms in expansionary or neutral tax regimes. Second, firms facing statutory rate cuts have much lower responses to monetary innovations. These findings suggest that underlying tax shifts can account for a considerable amount of variation in monetary effectiveness. In other words, the underlying tax treatment of companies can amplify or reduce their responsiveness to monetary policy.

Last, I confirm the baseline continuous interaction results using a less parametric estimation. In this specification, I use bins of tax regimes as described in the data section and estimate the marginal effects of the 1 percent contractionary or expansionary tax change on the effectiveness of monetary policy. Equation 5 in Appendix H provides the details of the specification and Figure H.1.1-H.1.3 in Appendix H plots the impulse responses. Overall, the results from the less parametric specification aligns with the results of the baseline specification. Specifically, in all three outputs we can observe that receiving a 1 percent tax cut offsets the effectiveness of monetary policy and receiving a 1 percent tax increase amplifies the effectiveness of monetary policy. The results are more pronounced for employment than investment and sales. Overall, both continuous interaction and group-based estimation results underscores the interaction between firms’ tax treatments and the responsiveness to
3.3 Robustness

This section conducts a large number of checks that show the robustness of the baseline results. In particular, I confirm that the results are robust to alternative estimation strategies, control set and underlying assumptions. I also test the confounding effects of firm characteristics, address several potential threats to identification and discuss measurement issues.

Orthogonality of tax and monetary shocks  One of the biggest concern related to the identification strategy is that federal tax reforms may influence monetary policy innovations. This paper uses *exogenous* changes in federal funds rate and *exogenous* and unanticipated changes in tax reforms where original sources (Romer and Romer, 2009, 2004) address general endogeneity concerns. However, it is still necessary to address orthogonality of monetary policy with respect to tax policy.

To verify monetary policy shocks are not endogenous to the Romer and Romer (2009) tax reforms, I perform Granger causality test using aggregate data. Table H.1 provides the test results suggesting Romer monetary policy shocks are orthogonal to the tax reforms. Similarly, Table H.2 ensures that exogenous set of tax reforms are not Granger caused by monetary policy shocks as well. The specifications include alternative versions with different aggregate controls, none provides evidence on endogeneity of the two policy measures. Furthermore, Figure D.1 plots the distribution of monetary policy shocks across tax regimes. Appendix D, Figure D.1 suggests that monetary innovations have sufficient randomness and mean-zero distribution in the neutral tax regime. The contractionary and expansionary regimes also have comparable left-skewed distribution of monetary shocks.\(^26\)

Next, one may also be worried that the income groups that received tax changes might be predicted from the political party in power. Regarding the tax scheme specific anticipation effects, I match the tax reforms in Table C.1 to respective political parties. Out of three tax cuts, two are legislated under Republican presidents and one is legislated under Democratic president.\(^27\) Out of two tax increases, Deficit Reduction Act of 1984 is legislated under Libertarian rule under Reagan and Omnibus 1993 has passed under Democratic president.

\(^26\)The negative shock in the expansionary regime in Figure D.1 belongs to year 1981, which is controlled in the regressions due to unusual policy variation of Volker era.

are also no conventions on the income range that receives a statutory rate change. For example, Deficit Reduction Act of 1984 - despite being legislated under Libertarian president - has increased the statutory taxes by 5 percentage points for large firms with income in between $1 and $1.4 million. Thus, there is sufficient randomness in the specifics of exogenous tax shifts and preferences of political parties.

**Baseline robustness checks**  One of the main assumptions in my empirical strategy is that it allocates firms to a certain tax treatment using last year’s taxable income which may overlook potential income responses. In the baseline regressions, I restrict my sample to firms who continue to stay in the treated income bracket for two years around the policy change. The results in Figure H.5.1 re-estimates the baseline specification when firms stay in the treated income brackets for three years around the policy change. The results confirm the baseline findings that tax shifts account for a considerable degree of heterogeneity in firms’ responses to monetary innovations. Note that the movement of taxable income per se is not crucial as long as the firm stays in the same bracket.

Second, the baseline analysis sets an upper bar of firms in each regime as 5 years. This is guided by the largest gap year within the exogenous reforms. It also captures persistence feature of tax reforms and ensures that average firm life across regimes are comparable. In Figure H.6.1 and Figure H.6.2, I change the maximum regime life of a firm to 8 years. Comparison with the baseline charts suggest that the results are robust to regime length as well.

Next, I explore the possibility that the baseline estimates could be prone to omitted variable bias and test alternative financial variables that might explain the differences in responses. First, Figure H.4.1 re-estimates equation 3 with additional controls on leverage and liquidity ratio of firms. The results are quite robust to additional controls.

Following Ottonello and Winberry (2020), I also test whether heterogeneity in other observable firm characteristics can drive the main results. Figure H.8.1-H.8.3 in Appendix H re-estimates the main results using specification 6 where monetary shocks are interacted with various other firm characteristics. In each case, the coefficient on monetary and tax regime interaction remains robust suggesting that the main results are not driven by asset growth, leverage or sales growth differences. In other words, these alternative channels of monetary policy do not offset the corporate tax channel I explore.

Next, I re-estimate the baseline analysis on the full set of tax reforms: exogenous and
The role of firm characteristics

This part explores the role of specific firm characteristics within the baseline findings. First, I group firms based on their cross-sectional characteristics using size (using number of employees), leverage and liquidity, and explore whether certain groups are more sensitive to indirect effects of taxes on monetary outcomes.

Figure H.11.1 - H.11.2, Figure H.11.3 - H.11.4 and Figure H.11.5 - H.11.6 provides estimates of employment, investment and sales by firm size. The results suggest that the average response observed in Figure 4 is generally similar across firms of different sizes, with the exception that small firms within contractionary regime respond most to monetary policy.

I also analyze responses based on liquidity and leverage rates of firms. Figure H.11.8 shows that high liquidity firms facing tax changes have a large and significant response to monetary policy on employees. On the investment results, there is no clear distinction of results across groups. On sales, high liquidity firms have an interesting response. Even within the neutral regime, high liquidity firms respond to monetary policy more than low liquidity group. The group similarly respond most to indirect effects of taxes on monetary policy.

28 As a robustness, I re-estimate the specification with quartile of doses. Figure H.10.1-H.10.3 shows that the results are robust to alternative dose cutoffs.

29 This is reassuring since a big portion of contractionary regime firms are large firms (See Figure E.1).
Last, I analyze firms with different leverage groups. Figure H.11.13 - H.11.14, Figure H.11.15 - H.11.16 and Figure H.11.17 - H.11.18 suggest that the response of monetary policy on employees, investment and sales is most significant in low leverage group.

Taken together, the relationship between tax changes and monetary effectiveness is largely common across different firm characteristics. However, I find characteristics such as being small, holding high liquidity and low leverage to play a role in enhancing indirect effects of taxes on monetary effectiveness.

**Measurement Error** There can be two measurement related concerns in this study. These are related to definition of taxable income and tax avoidance of firms. One of the key features of my research design is to use the taxable income variable to be able to sort the firms into tax brackets and actually use the time-series variation of marginal tax rate changes across different income brackets. Hence, the exact measure of taxable income is less of a concern as long as the firm is approximately matched to the right tax bracket.

Second, it is well documented that firms may engage in a variety of behavioral responses to minimize the tax burden (Rego, 2003). This type of measurement error would be highest for taxpayers with higher income as they may have greater access to avoidance opportunities. This is a less of a concern for my analysis since the treatment effects are based on the taxable income brackets the firms are in. Hence, even though the firm might not have a taxable income of $14,000, but say $12,000, it will be allocated to the same tax regime as long as the numbers are within the same taxable income brackets. In addition, since the taxable income brackets for large income firms are vast, large firms have less chance of mismeasured treatment effects.

### 4 The Model

This section builds a medium-size New Keynesian model featuring capital, corporate taxes and Rotemberg (1982) type price rigidities. The purpose of the model is to lay out how corporate tax shifts can effect the transmission channels of monetary policy. The model is populated by identical infinitely-lived households, continuum of monopolistically competitive intermediate goods firms, a final goods firm and government. The time is discrete and the planning horizon is infinite.
4.1 Households

Households purchase consumption goods, provide labor services to the productive sector and save with bonds. A representative infinitely-lived household is seeking to solve the following dynamic optimization problem:

$$\max_{C_t, N_t, B_t, w_t} E_t \sum_{t=0}^{\infty} \beta^t \left\{ \ln C_t - \theta \frac{N_t^{1+\chi}}{1+\chi} \right\} \quad \text{s.t.}$$

$$P_tC_t + Q_tB_t \leq B_{t-1} + W_tN_t + \Pi_t + T_t$$

where $C_t$ is the final goods consumption. $N_t$ denotes hours of employment, $W_t$ is the nominal wage and $P_t$ is the price of final good. The $\chi$ is the inverse of Frisch elasticity and $B_t$ is the stock of one-period nominally riskless savings household purchases. Each bond pays one unit at maturity and its price is $Q_t$. $T_t$ is government transfers and $\Pi_t$ is the dividend distribution from the ownership of firms. The consumption index, $C_t$, is given by

$$C_t \equiv \left( \int_0^1 C_t(i)^{1-\frac{1}{\epsilon}} di \right)^{\frac{1}{\epsilon-1}}$$

where $C_t(i)$ is the quantity of good $i$ consumed by the household in period $t$. The representative household has to solve two problem: allocation of spending across goods and allocation of spending across time. The solution to households problem is standard and is provided in Appendix I. The first order conditions bring the optimality conditions on consumption-savings and labor supply decision:

$$\theta N_t^{1+\chi}C_t = \frac{W_t}{P_t} = w_t \quad (4)$$

$$Q_t = \beta E_t C_t \frac{1}{C_{t+1}} \frac{1}{1+\pi_{t+1}} \text{ for } t = 0, 1, 2, ... \quad (5)$$

where $\pi_{t+1} = \frac{P_{t+1}}{P_t} - 1$ is the net inflation rate and $w_t = \frac{W_t}{P_t}$ is real wages. Equation 4 can be interpreted as the competitive labor supply condition, determining the quantity of labor

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30 Note that $N_t$ can be interpreted as the number of household members employed as in Galí (2009).
31 $Q_t$ is equal to inverse of gross nominal interest rate.
32 The dividends received by households are just the sum of profits from the intermediate good producers. Since the final good firms is competitive, they earn no profit.
supplied as a function of the real wage, given the marginal utility of consumption (which is a function of consumption only). Workers do not have any market power, hence they take the wage as given.\footnote{Last, equation \ref{equation:real-interest-rate} can also be used to determine the implied real interest rate in linear form as: \[ r_t \equiv i_t - E_t\{\pi_{t+1}\} \]}

### 4.2 Production

The production is split into two sectors: final and intermediate good sectors. There is a representative competitive final goods firm that aggregates intermediate inputs according to a CES technology. This generates a downward sloping demand for each intermediate good and grants the pricing power to intermediate producers. The intermediate firms produce output using capital and labor and are subject to price rigidities.

**Final Good Producer**

The final goods producers is perfectly competitive and aggregates the intermediate goods into a final good for consumption using a CES technology:

\[
Y_t \equiv \left( \int_0^1 Y_t(i)^{1-\frac{1}{\epsilon}} di \right)^{\frac{\epsilon}{\epsilon - 1}}
\]

where \(\epsilon\) is the constant elasticity of substitution and \(\epsilon > 1\) between different intermediate goods, \(i \in [0, 1]\).\footnote{As standard, the cost minimization problem of the final good producers implies that the demand for the intermediate good \(i\) is given by: \[ Y_t(i) = \left( \frac{P_t(i)}{P_t} \right)^{\frac{1}{1-\epsilon}} Y_t \text{ for all } i \in [0, 1] \]

where \(P_t(i)\) is the price of the intermediate good \(i\). This suggests that relative demand for good \(i\) is a function of its relative price, \(\epsilon\) price elasticity of demand and aggregate output, \(Y_t\). We can also reach the aggregate price index from the zero profit condition: \(P_t \equiv \left( \int_0^1 P_t(i)^{1-\epsilon} di \right)^{\frac{1}{1-\epsilon}}\)
where $A_t$ represents the level of technology, assumed to be common to all firms and to evolve exogenously over time. All firms face an identical isoelastic demand schedule given, and take the aggregate price level $P_t$, aggregate consumption index $C_t$ and wage level, $W_t$, as given. Following Rotemberg (1982), each monopolistic firm faces a quadratic cost of adjusting nominal prices, measured in terms of the final good:

$$Adj_P(i) = \psi \left( \frac{P_t(i)}{P_{t-1}(i)} - 1 \right)^2 Y_t$$

where $\psi$ is the degree of nominal price rigidities. Firms own the capital stock and generate more capital through investment. The capital accumulation process is subject to convex capital adjustment costs. Capital accumulates according to:

$$K_{t+1}(i) = I_t(i) - \frac{\phi}{2} \left( \frac{I_t(i)}{I_{t-1}(i)} - 1 \right)^2 + (1 - \delta)K_t(i) \quad (7)$$

Investment is financed out of dividends, and for simplicity we assume that the firm issues no intertemporal debt. The dividend payout is then

$$\Pi_t = (Y_t - w_tN_t)(1 - \tau_t) - I_t$$

Note that the corporate taxes is levied on the accounting profits of the firm which is the object explored in the empirical section. The firm $i$ will aim to maximize the value of future profits discounted by the stochastic discount factor of the household, $E_t \beta^{(1 + \lambda)/\lambda} = Q_t$. Each period the firm maximizes profits subject to two constraints. $q_t$ is the multiplier on the accumulation equation (since the units of the firm’s problem are in real terms, $q_t$ has the interpretation of reflecting how many goods the firms would give up for an additional unit of installed capital). $MC_t^i(i)$ measures how much nominal costs change if the firm produces an additional unit of its good. First order conditions are:

$$N_t(i) : \quad W_t(1 - \tau_t) = MC_t^i(i)[(1 - \alpha)A_tK_t(i)^\alpha N_t(i)^{-\alpha}]$$

where $MC_t^i = MC_t \ast Price$ and $MC_t$ is the real marginal cost and $w$ is the real wage. Hence, the labor demand equation becomes:

$$w_t(1 - \tau_t) = MC_t(i)[(1 - \alpha)A_tK_t(i)^\alpha N_t(i)^{-\alpha}]$$
mapping real wage into the quantity of labor demanded, given the level of technology and capital.

\[ I_t(i) : \quad 1 = q_t \left[ 1 - \phi \left( \frac{I_t(i)}{I_{t-1}(i)} - 1 \right) \right] + \beta \frac{\lambda_{t+1}}{\lambda_i} q_t + \beta E_t \frac{\lambda_{t+1}}{\lambda_i} \left[ \phi \left( \frac{I_{t+1}(i)}{I_{t-1}(i)} - 1 \right) \right] \quad (8) \]

\[ K_{t+1}(i) : \quad q_t = \beta E_t \frac{\lambda_{t+1}}{\lambda_i} \left\{ q_{t+1}(1 - \delta) + MC_{t+1}(i) (A_{t+1} a) K_{t+1}(i)^{a-1} N_{t+1}(i)^{1-a} \right\} \]

\[ P_t(i) : \quad \frac{1}{P_t} \left[ (1 - \epsilon) (\frac{P_t}{P_{t-1}(i)})^\epsilon Y_t(1 - \tau_l) - \psi (\pi_l(i)) \frac{1}{P_{t-1}(i)} P_t Y_t \right] - \frac{MC^n_t(i)}{P_t} \left[ \frac{-\epsilon P_t(i)^{-\epsilon-1}}{P_t^{-\epsilon}} Y_t \right] + \beta E_t \frac{\lambda_{t+1}}{\lambda_i} \left[ \psi (\pi_{t+1}(i)) (\pi_{t+1}(i) + 1) P_{t+1} \frac{Y_{t+1}}{P_t(i)} \right] = 0 \]

where \( \pi_l(i) = \frac{P_t(i)}{P_{t-1}(i)} - 1 \). By imposing symmetry and simplifying, we can reach the steady state markups:

\[ (1 - \epsilon) Y_t(1 - \tau_l) - \psi \pi_l(\pi_l + 1) Y_t + \beta E_t \frac{\lambda_{t+1}}{\lambda_i} \left[ \psi \pi_{t+1}(\pi_{t+1} + 1) Y_{t+1} \right] = -\epsilon MC_t(i) Y_t \quad (9) \]

where equation 9 is the counterpart of a New Keynesian Phillips curve relating nominal variables to the real economy. Under steady state:

\[ P = MC^n \frac{\epsilon}{(\epsilon - 1)} \frac{1}{(1 - \tau)} \quad (10) \]

where \( \frac{\epsilon}{(\epsilon - 1)} \) is the conventional flexible price markup, \( M \). The equation suggests that optimal price would be a fixed mark-up over nominal marginal cost and existence of taxes shows up like an increase in steady state mark up.

The market-clearing conditions are standard. Since the firm issues no intertemporal debt, then the household can not have any stock of savings. Note that from investment first order condition (equation 8) it is clear that \( q = 1 \) in steady state, where there is no adjustment costs. Labor market clearing requires that the sum of labor used by firms equals the total labor supplied by households, e.g. \( \int_0^1 N_l(i) \, di = N_l \). There is no market for capital, since firms own
the capital stock. Goods market clearing conditions is:

\[ Y_t = C_t + I_t + \frac{\psi}{2} (\pi_t)^2 Y_t \]  

(11)

4.3 Government

The government sets tax policy and an independent monetary authority, the Central Bank, conducts the monetary policy. The government is assumed to hold a balance budget and distribute the corporate tax returns to households as lump-sum transfers. Tax policy follows the following rule:

\[ \tau_t = (1 - \rho) \tau_{\text{ss}} + (\rho \tau_{t-1} + s_t \epsilon_{\tau,t}) \]  

(12)

Monetary policy sets the nominal interest rate according to the following Taylor (1993) rule:

\[ i_t = \rho i_{t-1} + (1 - \rho) \phi_{\pi} \pi_t + s_i \epsilon_{i,t} \]  

(13)

where \( \phi_{\pi} > 1 \) and \( \epsilon_{i,t} \) is an exogenous stochastic disturbance in the nominal interest rate, which follows a white noise process with zero mean and finite variance. A positive realization of \( \epsilon_{i,t} \) is interpreted as a contractionary monetary policy shock, leading to a rise in nominal interest rate. Note that this rule implies a countercyclical monetary policy where central bank increases the nominal interest rates when inflation is positive. Combining the above conditions and imposing symmetry leads the set of equilibrium conditions provided in Appendix I.

4.4 Model Results

This section discusses a simulation exercise which compares the effects of monetary policy in two economies with differing preceding tax interventions. Output, investment, capital and hours worked are variables of interest and units are interpreted as percent deviations from the steady state. The calibration parameters closely follow Galí (2009), Burnside et al. (2004) and Miao and Ngo (2019) and are provided in Appendix I Table I.1. I use a second order approximation to capture the level effect of an initial tax shock on the subsequent monetary policy shock.\(^{35}\) The aim is to test whether an economy with persistent preceding tax interventions shows a differentiated response to monetary policy.

\(^{35}\)In first order approximation, the initial condition, the sequence of shocks, their sign and size does not matter.
Figure 7a plots the impulse responses of the blue and red economy in which the red economy receives a 50 basis points increase in corporate tax rate at time $t = 1$, blue economy does not receive a tax shock. The responses to tax shocks start at time $t = 1$ and are presented with boxed lines. At time $t = 10$, both economies receive 25 basis point contractionary monetary policy shock. The object of interest is the shaded area that is the difference between the boxed ($\tau$) and the solid ($MP + \tau$) lines, capturing the effects of monetary policy in each economy. Comparing shaded areas of the two economy shows that the economy that received a preceding tax increase has a larger response to monetary policy shock than the economy with stable taxes.

![Figure 7a](image1.png)

(a) Total effect ($\tau$+MP)

![Figure 7b](image2.png)

(b) Effect of monetary policy

Figure 7: Impulse responses to monetary policy shock following contractionary tax shifts.

Note: The monetary policy shocks are 25 basis points (0.25 ppt) increase to steady state nominal interest rate and 50 basis points (0.5 ppt) increase to steady state corporate tax rate ($\tau_{ss} = 0.20$).

In order to visualize the effect more clearly, Figure 7b plots the gap between solid line ($MP + \tau$) and the boxed ($\tau$) line which is the total effect of monetary policy in each economy. Figure 7b shows that the effects of monetary policy is larger in an economy that faces a

36The choice of 10 quarter is guided by half life of 5 year regime length used in empirical section.
preceding contractionary tax shock. The main mechanism follows as persistent contractionary tax policy lowers the net present value of projects and leads firms to downsize capital subject to adjustment costs. When monetary policy hits during this transition, firms re-optimize their investment path as a response to the transitory change in funding cost. However, due to decreasing returns to capital, the elasticity to monetary policy may be higher in transition with a lower level of capital.

Figure 8: Impulse responses to monetary policy shock following expansionary tax shifts.

Note: The monetary policy shocks are 25 basis points (0.25 ppt) increase to steady state nominal interest rate and 50 basis points (0.5 ppt) increase to steady state corporate tax rate (\(\tau_{ss} = 0.20\)).

Last, I compare the effects of monetary policy when an economy faces a preceding expansionary tax shock. Figure 8b bottom panel shows the impulse responses to monetary policy shocks where the dashed (red) economy receives an expansionary tax shock at time \(t = 1\) and contractionary monetary shock at time \(t = 10\). Similarly, the blue economy only receives a contractionary monetary shock at time \(t = 10\). Comparison of the two impulse responses suggest that effectiveness of monetary policy is reduced if monetary innovations are preceded
by a persistent tax cut.

Overall, these results support the empirical findings such that a preceding contractionary tax policy amplifies the impact of monetary shocks and a preceding expansionary tax policy reduces the impact of monetary shocks. Although the theoretical model does not lay out cross-sectional features of taxes, the output of the model rationalizes the empirical findings of this paper. As for robustness, the results suggest that amplification effect varies with the timing of the monetary policy shock. The sooner the monetary policy shock hits, the larger is the amplification. Similarly, the adjustment costs also have a role in propagating the effect on investment and capital, such that with lower adjustment costs the total effect of monetary policy is larger on investment and capital. (See Appendix I Figure I.3.1 and I.3.2)

**Alternative Mechanisms** An alternative mechanism accounting for these results might be that changes in liability rates alter the tightness of financial constraints of firms. In an environment with capital market imperfections, borrowers’ balance sheet conditions (Gertler and Gilchrist, 1994; Bernanke and Gertler, 1989; Kiyotaki and Moore, 1997; Calomiris and Hubbard, 1990) play a significant role in access to credit. As tax shifts changes the balance sheet conditions of firms, we may see tax policy to contribute to financial propagation mechanism. The impact of tax policy can be seen both directly and indirectly. First, an increase in tax rate would weaken the balance sheet by lowering cash flows. Second, it may also lower the value of collateral assets through the decline in net worth. As highlighted in Gertler and Gilchrist (1994), monetary policy already operates through these two effects. Hence, in a model with financial frictions, tax policy can potentially amplify these two channels.

Also at a general equilibrium level, corporate tax changes can affect aggregate demand and savings through household balance sheet channels. By increasing corporate taxes, tax policy would lower dividend payouts and decrease asset prices which may affect household wealth. The fall in household wealth would dampen the aggregate demand and savings which can result in the fall of funds for firms. Hence, while not directly testable in my current setup, tax policy may influence the wealth effect based channels in monetary transmission.\(^{37}\)

\(^{37}\)See Mishkin (2007) for a survey of this literature.
5 Conclusion

This paper provides the first empirical evidence on how tax policy dynamics influence the transmission of monetary policy. Using a unique feature of the US corporate tax code, tax narrative accounts and detailed firm-level data, I document that changes in tax policy alter the average impact of monetary policy shocks and lead to heterogeneous effects. Specifically, I estimate investment, employment and sales responses to monetary policy changes allowing the effects to vary based on the firm-level tax treatment. Overall, my findings document that accounting for the dynamics of tax system may explain sizable variation in monetary effectiveness.

The results of this paper are particularly important for three reasons. First, this study is the first paper evaluating the impact of monetary policy conditional on underlying tax structures. This is quite different than the earlier approaches adopted in the monetary transmission literature that mainly uses firm characteristics to explain heterogeneous effects of monetary policy. Second, this paper is the first attempt to evaluate the intersection of two main policy tools in an applied setting with micro-data. In this regard, these findings provide a practical rule-of-thumb to the design of stabilization policy and also contribute to our understanding of the scope of monetary policy within an underlying tax system. Last, the findings of this paper are particularly relevant to understand the muted effects of monetary policy observed in last decades (Boivin et al., 2010). Taken together, my analysis provides an insight on how the historical downward trend in corporate taxes may have contributed to weaker effects of monetary policy as documented in recent decades. Moreover, the results of this paper brings the possibility of future work questioning the role of downward trend in taxes on the gradual decline of interest rates in the United States.
References


A Data appendix

Firm level variables I use annual version of Compustat from 1969 to 2006 in all regressions. Compustat provides high-quality information on balance sheet and income statement components of publicly traded C corporations in North America. Detailed variable definitions of Compustat can be accessed through Wharton Research Data Services for the United States.

Table A.1 provides the variable names and respective codes in Compustat. Leverage is the ratio of short and long term debt to total assets. Liquidity ratio is the ratio of cash and short-term investments \( (che) \) to total assets. Tobins’Q is defined as total assets at market value\(^{38}\) over total assets at book value following Cloyne et al. (2019). Dividend variable is used as an indicator on whether the firm has paid cash dividends in the previous year. \( aqc \) represents the cash outflow or funds used to acquisition of a company. All variables in level are deflated using the aggregate GVA deflator. I explain the variables used in taxable income definition in the next page in detail.

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<td>(che \ast 100/ at)</td>
</tr>
<tr>
<td>Tobins’ Q</td>
<td>((at + prcc_f \ast csho - ceq + txditc)/ at)</td>
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<tr>
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<tr>
<td>Acquisitions</td>
<td>(aqc/ at)</td>
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</table>

Table A.1: Variable Definitions

I drop firms in finance, insurance, real estate and public administration sectors. Following Ottonello and Winberry (2020), I also exclude firms with acquisitions accounting for more than 5% of total assets. I drop firms which are in the panel for less than 5 years. I exclude firms within the finance, insurance, real estate (FIRE) and public administration sectors. I also drop the first and last year observations of firms as these years lead to natural build-up or depletion of companies assets and may lead to bias.

Sample Restrictions The baseline trimming excludes firms with i) top 1 percent of leverage ratio; ii) top and bottom 1% of real sales growth; iii) Tobin’s Q ratio greater than 4; iv) acquisitions are more than 5% of total assets. Trimming is done by year. In order to address volatility of taxable income, I drop firms who jump more than one neighboring income bracket after a tax reform. I also drop firms who switch to non-treated income bracket after a tax reform.

Macro Time Series Data The one-year risk free is the 1-Year Treasury Contract Maturity Rate from FRED series GS1. The GVA (gross value added) deflator series is Price Index (Business : Nonfarm) from FRED (data series is B358RG3Q086SBEA).Top statutory rate is from IRS historical Table 13.


\(^{38}\)Note that \(prcc_f\) refers to closing price of the fiscal year. \(csho\) is common shares outstanding\(^{39}\). \(ceq\) is common/ordinary equity and \(txditc\) is deferred taxes and investment tax credit.

\(^{39}\)
Alternative definitions of taxable income

\[ TI = \text{Net Income} - \text{Interest Paid} - \frac{\sum_{n=t-3}^{t-1} \text{Tax Loss Carryforward}}{3} - \text{Depreciation and Depletion Expense} + \text{Special items} + \frac{\text{Income from extraordinary items}}{1 - mtr} \]  

(1)

\[ TI^{Graham} = \text{Net Income} - \frac{\text{Deferred tax expense}^{CF}}{mtr} + \text{Taxes paid} + \frac{\text{Minority interest}}{(1-mtr)} + \frac{\text{Income from extraordinary items}}{1 - mtr} \]  

(2)

\[ TI^{Blouin} = \text{EBIT} + \text{Interest on leases} - \frac{\text{Deferred tax expense}^{IS}}{mtr} + \text{Special items} + \frac{\text{Income from extraordinary items}}{1 - mtr} \]  

(3)

\( TI \) is the main definition employed in this paper that is constructed using the 1984 IRS corporate tax filings instructions (See Figure A.1 for the 1984 corporate tax return form) and the two main definitions in the literature from Blouin et al. (2010) and Graham (1996).

Net income is sum of operating (\( ebit \)) and nonoperating (\( npoi \)) income. Compustat \( ebit \) is sum of Sales (Net) minus Cost of Goods Sold (COGS) minus Selling, General and Administrative Expense (XSGA) minus Depreciation/Amortization (DP). It is also referred as Operating Income After Depreciation (OIADPQ). Income from extraordinary items is \( xido \), this item is deflated by one minus the top statutory rate following Blouin et al. (2010) and Graham (1996). Special items is \( spi \), depreciation expense is \( xdp \), depletion expense \( xdelp \), interest paid (net) is \( intpn \). According to the IRS instructions, firms are allowed to carry tax losses up to three years. Hence, carryforwards are calculated as the average of last three years tax loss carry forward (\( tlc_f \)). The capital gains are also part of the definition of taxable income, however since Compustat total capital gains (\( cgti \)) variable is genuinely missing, it is not part of the definition. Deferred tax liability is a tax that is assessed or is due for the current period but has not yet been paid, so I do not exclude it from the taxable income definition.

Note that the differences in the taxable income definitions also reflects the relative weight of a static versus dynamic definition of taxable income. Blouin et al. (2010) and Graham (1996) both focus on dynamic properties of taxable income in order to forecast taxable income over long periods of time and to proxy for the marginal tax rates. The definition also accounts for firms’ incentives to allocate income across time through carryforwards and allows for forward-looking behavior. However, the goal is to generate a taxable income definition closest to the actual reports, to the extent of data availability.
| Table A.2: Descriptive Statistics |

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|                  | B. Neutral Tax Regime |                  |                  |                  |                  |                  |                  |
|                  | count               | 148183           | 164131           | 164126           | 163365           | 163346           | 164131           | 163491.0         |
|                  | min                 | 0                | -124111          | 0                | -5878            | -9              | 0                | 0                |
| p5               | 0.5                | -52              | 0                | -1               | 0               | 1                | 0                |
| p50              | 3.8                | 86               | 25               | 25               | 850             | 1024             | 29.4             |
| mean             | 5.8                | 86               | 25               | 850              | 1024            | 29.4             | 23.4             |
| p95              | 24                 | 319              | 48               | 77               | 2840            | 3315             | 77.6             |
| max              | 1800               | 79671            | 53               | 27902            | 335086          | 750507           | 1140.0           |
| sd               | 27.8               | 1004             | 21               | 241              | 5657            | 7983             | 37.5             |

|                  | C. Contractionary Tax Regime |                  |                  |                  |                  |                  |                  |
|                  | count               | 7907             | 8251             | 8251             | 8241             | 8242             | 8251             | 8205             |
|                  | min                 | 0                | -5802            | 0                | -213             | 0                | 0                | 0                |
| p5               | 0.1                | -28              | 0                | -3               | 33              | 32               | 0                |
| p50              | 3.5                | 71               | 35               | 17               | 677             | 711              | 26.3             |
| mean             | 14.8               | 399              | 32               | 98               | 3104            | 3736             | 25.9             |
| p95              | 62.0               | 1812             | 38               | 425              | 12636           | 16520            | 57.7             |
| max              | 756.3              | 25566            | 51               | 7824             | 195805          | 304012           | 195.3            |
| sd               | 40.8               | 1281             | 11               | 323              | 9527            | 11492            | 19.3             |

<p>|                  | D. Expansionary Tax Regime |                  |                  |                  |                  |                  |                  |
|                  | count               | 31462.0          | 32960           | 32957           | 32910           | 32914           | 32960           | 32834.0          |
|                  | min                 | 0                | -9559            | 0               | -1713           | 0               | 0               | 0.0              |
| p5               | 0.1                | -9               | 0                | -1              | 4               | 4               | 0.0              |
| p50              | 1.4                | 9                | 40               | 2                | 128             | 101              | 27.2             |
| mean             | 9.2                | 126              | 35               | 37               | 1141            | 1249             | 28.5             |
| p95              | 42.0               | 566              | 46               | 146              | 4562            | 5154             | 64.7             |
| max              | 854.0              | 16471            | 51               | 8449             | 147848          | 184326           | 191.2            |
| sd               | 32.6               | 580              | 16               | 205              | 4942            | 5661             | 20.3             |</p>
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Table A.3: IRS Corporate Income Tax Brackets (1968-2016)
Figure A.1: IRS 1984 corporate tax return form (1120-A)
B Calculating dose of tax treatment

Figure B.1 presents an example calculation of average tax burden. Suppose at year t, a new tax legislation has decreased the statutory tax rates by 3 percentage points for the ($5,000, $10,000) taxable income bracket and by 2 percentage points for the ($10,000, $30,000) taxable income bracket. Firm A has $8,000 taxable income and firm B has $30,000 taxable income. Using the closest taxable income thresholds at $5,000 and $10,000 of taxable income, respectively, we can calculate the changes in liability for firm A and B can be calculated as $90 and $400, respectively. Next, in order to facilitate comparison across firms and time, I scale the liability changes with the lagged taxable income which leads 1.12 and 1.33 percent change in average tax burden of the firm A and B, respectively.

\[
\begin{align*}
\text{Statutory rate change: } & \Delta \text{ mtr} = 3\% & \Delta \text{ mtr} = 2\% \\
\Delta \text{ Liability: } & 3000 \times \frac{3}{100} = 90 & 20000 \times \frac{2}{100} = 400 \\
\Delta \text{ Tax burden: } & \frac{90}{8000} = 1.12\% & \frac{400}{30000} = 1.33\%
\end{align*}
\]

Figure B.1: Sketch of change in tax burden calculation.

Note: $5,000 and $10,000 correspond to taxable income thresholds. $8,000 is the actual taxable income of firm A and $30,000 is the actual taxable income of firm B. Statutory rate change reflects the changes in statutory tax rate in the relevant taxable income bracket. \(\Delta\) Liability shows the change in tax liability in the treated taxable income bracket. \(\Delta\) Tax burden calculates the changes in share of tax burden within the treated taxable income bracket.

\[\text{The liability change of firm A is } (8000 - 5000) \times \frac{3}{100} = 90 \text{ and the liability change of firm B is } (30000 - 10000) \times \frac{2}{100} = 400\]
## C List of tax reforms

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<th>Effective</th>
<th>Type</th>
<th>Persistence</th>
<th>Statutory rate changes</th>
<th>Exogenous</th>
<th>Years</th>
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</table>

Table C.1: List of tax reforms matching statutory rate changes

Notes: The list covers exogenous corporate tax reforms with statutory rate changes from 1969 to 2006. Following Mertens and Ravn (2012) anticipated tax liability changes with more than 90 days difference between the signing of the legislation and their implementation are classified as anticipated tax reforms. The baseline specification only includes tax changes categorised as exogenous and unanticipated. The anticipated reforms will be used for robustness. Source: Romer and Romer (2009), Mertens and Ravn (2012, 2013), Joint Committee of Taxation and IRS SOI files.
D Distribution of monetary shocks

Figure D.1: Histogram of monetary policy shocks across regimes (1969-2006)

Note: The figure plots distribution of Wieland and Yang (2020) monetary policy shocks across different tax regimes from 1969 to 2006. Neutral regime confirms the randomly distributed monetary policy shocks. The shocks in contractionary and expansionary regimes are also comparable in terms of having a right skewed distribution. The -0.5 in the expansionary tax regime corresponds to year 1981 and is controlled in the regressions with a year dummy.
E Distribution of firm characteristics by tax regime

Figure E.1: Firm characteristic decomposition by each tax regime.

Note: The figure plots the quartiles of real asset, real sales, leverage and investment in each regime. The quartiles is generated by year and histogram spans observations from 1969 to 2006.
F Average treatment effects across regimes

The average causal effects of monetary policy shocks estimated using local projection:

$$y_{jt+h} - y_{jt-1} = \alpha_j^{h} + \beta_j^{h} \Delta R_t + \Omega' (L) Z_{jt-1} + \epsilon_{jt+h} \text{ where } h = 0, \ldots, H,$$

(4)

(a) Employees (b) Real Sales

Figure F.1: Impulse responses to monetary policy shocks (1969-2006).
Note: The plots show impulse responses of employees and sales using Romer and Romer monetary policy shocks as instruments for 1 year treasury rate. Horizon is 4 years, lag is set to 2. Both specifications include a year dummy for 1981 and 2001. Standard errors are clustered by firm and year. Controls follow the baseline specification.

(a) Employees (b) Real Sales

Neutral Regime

(a) Employees (b) Real Sales

Contractionary Regime

(a) Employees (b) Real Sales

Expansionary Regime

Figure F.2: Impulse responses to monetary policy shocks by regime (1969-2006).
G Histogram of tax burden changes

Figure G.1: Histogram of changes in tax burden (dose)

Note: This figure plots the histogram of tax burden changes across the sample. The dose is calculated as change in tax liability over taxable income. Negative doses are from expansionary tax changes and positive doses are from contractionary tax changes. The gray thresholds show the mean dose of each regime on points -0.031 and 0.0067. The highest expansionary tax shock changes a firm’s share of tax liabilities by 6 percent.

Figure G.2: Histogram of changes in tax burden (dose) by regime bins

Note: This figure plots the histogram of tax burden changes across the sample. The dose is calculated as change in tax liability over lagged taxable income. Negative doses are from expansionary tax changes and positive doses are from contractionary tax changes. The dark shades reflect higher dose treatments. The gray thresholds show the mean dose of each regime on points -0.031 and 0.0067. For instance, if a firm receives tax dose lower than -0.031, it is labeled as receiving a high expansionary tax treatment.
H Robustness

H.1 Less parametric specification

\[ \Delta_h \log(y_{j,t+h}) = \alpha_j^{h,r} + \beta_j^{h} \cdot \Delta R_t + \beta_j^{h \cdot r} \cdot \Delta R_t \cdot \mathbb{1} \{ \Delta \tau_j^t \} \cdot |Dose_{j,t}| + \delta_j^{h,r} \cdot |Dose_{j,t}^r| \]

\[ + \theta_j^{h,r} + \Omega_j^{(L)} \cdot Z_{j,t-1}^r + \epsilon_{j,t+h} \]

(5)

Figure H.1.1: Impulse responses of employees using specification 5.

Figure H.1.2: Impulse responses of capital expenditures using specification 5.

Figure H.1.3: Impulse responses of sales using specification 5.
H.2 Baseline specification with standard errors by dose

Figure H.2.1: Impulse responses of number of employees to monetary shocks (by dose).

(a) Dose -4%

(b) Dose -2%

(c) Dose 0%

(d) Dose 2%

Note: The plots show impulse responses of employees using IV-LP. Horizon is 4 years, lag is set to 2. The time span is 1969-2006. Standard errors are clustered by firm and year. Dose = 0% is equal to neutral regime plot. Shaded areas show 95% (light gray) and 90% (dark gray) confidence intervals.
Figure H.2.2: Impulse responses of number of investment to monetary shocks (by dose).

Note: The plots show impulse responses of investment using IV-LP. Horizon is 4 years, lag is set to 2. The time span is 1969-2006. Standard errors are clustered by firm and year. $Dose = 0\%$ is equal to neutral regime plot. Shaded areas show 95\% (light gray) and 90\% (dark gray) confidence intervals.
Figure H.2.3: Impulse responses of number of sales to monetary shocks (by dose).

Note: The plots show impulse responses of sales using IV-LP. Horizon is 4 years, lag is set to 2. The time span is 1969-2006. Standard errors are clustered by firm and year. Dose = 0% is equal to neutral regime plot. Shaded areas show 95% (light gray) and 90% (dark gray) confidence intervals.
H.3 Baseline specification in details

Figure H.3.1: Impulse responses of number of employees to monetary shocks.

(a) Neutral Regime (\(\hat{\beta}^h\))

(b) \(\hat{\beta}^h + \hat{\Gamma}^h\)

(c) \(\hat{\Gamma}^h\)

(d) \(\hat{\theta}^h\)

Note: The plots show impulse responses of employees using IV local projection regressions with Romer and Romer (extended) monetary policy shocks instrumenting 1 year government bond rate. Horizon is 4 years, lag is set to 2. The time span is 1969-2006. Standard errors are clustered by firm and year. \(Dose = 0\%\) is equal to neutral regime plot. Shaded area in panel (a) shows 95% confidence intervals. Shaded areas in panel (c) show 90% and 95% confidence intervals.
Figure H.3.2: Impulse responses of log investment to monetary shocks.

Note: The plots show impulse responses of investment using IV local projection regressions with Romer and Romer (extended) monetary policy shocks instrumenting 1 year government bond rate. Horizon is 4 years, lag is set to 2. The time span is 1969-2006. Standard errors are clustered by firm and year. Dose $= 0\%$ is equal to neutral regime plot. Shaded area in panel (a) shows 95% confidence intervals. Shaded areas in panel (c) show 90% and 95% confidence intervals.
Figure H.3.3: Impulse responses of log sales to monetary shocks.

(a) Neutral Regime ($\hat{\beta}_h$)

(b) $\hat{\beta}_h + \hat{\Gamma}_h$

(c) $\hat{\Gamma}_h$

(d) $\hat{\theta}_h$

Note: The plots show impulse responses of employees using IV local projection regressions with Romer and Romer (extended) monetary policy shocks instrumenting 1 year government bond rate. Horizon is 4 years, lag is set to 2. The time span is 1969-2006. Standard errors are clustered by firm and year. Dose $= 0\%$ is equal to neutral regime plot. Shaded area in panel (a) shows 95% confidence intervals. Shaded areas in panel (c) show 90% and 95% confidence intervals.
H.4 Additional controls

Figure H.4.1: Impulse responses of employees using additional controls in equation 3.

(a) Neutral Regime ($\hat{\beta}^h$)

(b) Total effects by dose ($\hat{\beta}^h + \hat{\Gamma}^h$)

Note: The plots show impulse responses of employees using IV local projection regressions with Romer and Romer (extended) monetary policy shocks instrumenting 1 year government bond rate. Horizon is 4 years, lag is set to 2. The time span is 1969-2006. The control variables are change in log employees, change in log sales, real asset growth, real investment growth, log real assets, top statutory tax rate, an indicator variable for dividends paid, leverage ratio and liquidity ratio. Standard errors are clustered by firm and year. Dose = 0% is equal to neutral regime plot. Dashed line in panel (a) shows 95% confidence intervals.

Figure H.4.2: Impulse responses of investment using additional controls in equation 3.

(a) Neutral Regime ($\hat{\beta}^h$)

(b) Total effects by dose ($\hat{\beta}^h + \hat{\Gamma}^h$)

Note: The plots show impulse responses of investment using IV local projection regressions with Romer and Romer (extended) monetary policy shocks instrumenting 1 year government bond rate. Horizon is 4 years, lag is set to 2. The time span is 1969-2006. The control variables are change in log employees, change in log sales, real asset growth, real investment growth, log real assets, top statutory tax rate, an indicator variable for dividends paid, leverage ratio and liquidity ratio. Standard errors are clustered by firm and year. Dose = 0% is equal to neutral regime plot. Dashed line in panel (a) shows 95% confidence intervals.
H.5 Additional Taxable Income Restrictions

Figure H.5.1: Impulse responses of employees using additional income restrictions in equation 3.

- **Neutral Regime** ($\hat{\beta}^h$)
- **Total effects by dose** ($\hat{\beta}^h + \hat{\Gamma}^h$)

Note: The plots show impulse responses of employees using IV local projection regressions with Romer and Romer (extended) monetary policy shocks instrumenting 1 year government bond rate. Horizon is 4 years, lag is set to 2. The time span is 1969-2006. The control variables are change in log employees, change in log sales, real asset growth, real investment growth, log real assets, top statutory tax rate and an indicator variable for dividends paid. Standard errors are clustered by firm and year. Dose = 0% is equal to neutral regime plot. Shaded area in panel (a) shows 95% confidence intervals.

Figure H.5.2: Impulse responses of investment using additional income restrictions in equation 3.

- **Neutral Regime** ($\hat{\beta}^h$)
- **Total effects by dose** ($\hat{\beta}^h + \hat{\Gamma}^h$)

Note: The plots show impulse responses of investment using IV local projection regressions with Romer and Romer (extended) monetary policy shocks instrumenting 1 year government bond rate. Horizon is 4 years, lag is set to 2. The time span is 1969-2006. The control variables are change in log employees, change in log sales, real asset growth, real investment growth, log real assets, top statutory tax rate and an indicator variable for dividends paid. Standard errors are clustered by firm and year. Dose = 0% is equal to neutral regime plot. Shaded area in panel (a) shows 95% confidence intervals.
H.6  Extended regime length

Figure H.6.1: Impulse responses of employees using extended regime length in equation 3.

(a) Neutral Regime ($\hat{\beta}^h$)  
(b) Total effects by dose ($\hat{\beta}^h + \hat{\Gamma}^h$)

Note: The plots show impulse responses of employees using IV local projection regressions with Romer and Romer (extended) monetary policy shocks instrumenting 1 year government bond rate. Horizon is 4 years, lag is set to 2. The time span is 1969-2006. The control variables are change in log employees, change in log sales, real asset growth, real investment growth, log real assets, top statutory tax rate and an indicator variable for dividends paid. Standard errors are clustered by firm and year. Dose = 0% is equal to neutral regime plot. Shaded area in panel (a) shows 95% confidence intervals.

Figure H.6.2: Impulse responses of investment using extended regime length in equation 3.

(a) Neutral Regime ($\hat{\beta}^h$)  
(b) Total effects by dose ($\hat{\beta}^h + \hat{\Gamma}^h$)

Note: The plots show impulse responses of investment using IV local projection regressions with Romer and Romer (extended) monetary policy shocks instrumenting 1 year government bond rate. Horizon is 4 years, lag is set to 2. The time span is 1969-2006. The control variables are change in log employees, change in log sales, real asset growth, real investment growth, log real assets, top statutory tax rate and an indicator variable for dividends paid. Standard errors are clustered by firm and year. Dose = 0% is equal to neutral regime plot. Shaded area in panel (a) shows 95% confidence intervals.
H.7 Baseline with endogenous and exogenous tax reforms

Figure H.7.1: **Impulse responses of employees using full set of tax reforms in equation 3.**

(a) **Neutral Regime** ($\hat{\beta}_h$)

(b) **Total effects by dose** ($\hat{\beta}_h + \hat{\Gamma}_h$)

Note: The plots show impulse responses of employees using IV local projection regressions with Romer and Romer (extended) monetary policy shocks instrumenting 1 year government bond rate. Horizon is 4 years, lag is set to 2. The time span is 1969-2006. Full set of tax reform (both endogenous and exogenous) are used in firm grouping. The control variables are change in log employees, change in log sales, real asset growth, real investment growth, log real assets, top statutory tax rate and an indicator variable for dividends paid. Standard errors are clustered by firm and year. Dose = 0% is equal to neutral regime plot. Shaded area in panel (a) shows 95% confidence intervals.

Figure H.7.2: **Impulse responses of investment using full set of tax reforms in equation 3.**

(a) **Neutral Regime** ($\hat{\beta}_h$)

(b) **Total effects by dose** ($\hat{\beta}_h + \hat{\Gamma}_h$)

Note: The plots show impulse responses of investment using IV local projection regressions with Romer and Romer (extended) monetary policy shocks instrumenting 1 year government bond rate. Horizon is 4 years, lag is set to 2. The time span is 1969-2006. Full set of tax reform (both endogenous and exogenous) are used in firm grouping. The control variables are change in log employees, change in log sales, real asset growth, real investment growth, log real assets, top statutory tax rate and an indicator variable for dividends paid. Standard errors are clustered by firm and year. Dose = 0% is equal to neutral regime plot. Dashed line in panel (a) shows 95% confidence intervals.
H.8 Heterogeneity in other observable firm characteristics

This part shows that the heterogeneous effects of monetary policy are not driven by firm characteristics such as sales growth, asset growth or leverage. I expand the baseline specification as:

\[
\Delta_{h}\log(y_{j,t+h}) = \alpha_{j}^{h} + \beta_{t}^{h}R_{t} + \Gamma_{t}^{h}Dose_{j,t} + \beta_{y}^{h}\Delta R_{t}s_{j,t} + \theta^{h}\text{Dose}_{j,t} + \Omega'(L)Z_{j,t-1} + \epsilon_{j,t+h}
\]

where \(s_{jt}\) is lagged real sales growth, lagged leverage and lagged real asset growth. In each case, the coefficient on monetary and tax regime interaction remains robust. Hence, firm-level characteristics that may be correlated with tax regimes or monetary effectiveness do not drive the heterogeneous responses in tax regimes.

Figure H.8.1: Impulse responses of employees using equation 6 with lagged asset growth.

(a) Neutral Regime \((\hat{\beta}^{h})\)

(b) Total effects by dose \((\hat{\beta}^{h} + \hat{\Gamma}^{h})\)

(c) \(\hat{\Gamma}^{h}\)

(d) \(\hat{\beta}^{h}_{y}\)

Note: The plots show impulse responses using IV local projection regressions with using equation 6 where \(s_{t}\) is lagged real asset growth. Firms are allowed to stay in a regime for a maximum of 5 years. Horizon is 4 years, lag is set to 2. The time span is 1969-2006. The control variables are change in log employees, change in log sales, real asset growth, real investment growth, log real assets, top statutory tax rate and an indicator variable for dividends paid. The specification include a year dummy for 1981 and 2001 as dependent variable. Standard errors are clustered by firm and year.
Figure H.8.2: Impulse responses of employees using equation 6 with lagged sales growth.

(a) Neutral Regime ($\hat{\beta}^h$)

(b) Total effects by dose ($\hat{\beta}^h + \hat{\Gamma}^h$)

(c) $\hat{\Gamma}^h$

(d) $\hat{\beta}^h_y$

Note: The plots show impulse responses of equation 6 where $s_t$ is lagged sales growth. Horizon is 4 years, lag is set to 2. The time span is 1969-2006. The control variables are change in log employees, change in log sales, real asset growth, real investment growth, log real assets, top statutory tax rate and an indicator variable for dividends paid. The specification include a year dummy for 1981 and 2001 as dependent variable. Standard errors are clustered by firm and year.
Figure H.8.3: Impulse responses of employees using equation 6 with lagged leverage ratio.

(a) **Neutral Regime** ($\hat{\beta}_h$)

(b) **Total effects by dose** ($\hat{\beta}_h + \hat{\Gamma}_h$)

(c) $\hat{\Gamma}_h$

(d) $\hat{\beta}_y$

**Note:** The plots show impulse responses using IV local projection regressions with using equation 6 where $s_t$ is lagged leverage ratio. Firms are allowed to stay in a regime for a maximum of 5 years. Horizon is 4 years, lag is set to 2. The time span is 1969-2006. The control variables are change in log employees, change in log sales, real asset growth, real investment growth, log real assets, top statutory tax rate and an indicator variable for dividends paid. The specification includes a year dummy for 1981 and 2001 as dependent variable. Standard errors are clustered by firm and year.
H.9 Impact of liability changes on estimates

\[ \Delta h \log(y_{j,t+h}) = \alpha_j^{h,r} + \theta^{h,r} + \beta^{h,r} \Delta R_t \mathbb{1}\{\Delta r_{j,t}^{'}\} + \Omega'(L)^{h,r} Z_{j,t-1}^r + \epsilon_{j,t+h} \]  

(7)

where r denotes regime-dose dummy bins: Expansionary low, Expansionary high, Contractionary low, Contractionary high and Neutral regime.

Figure H.9.1: Impulse responses of number of employees using equation 7.

Note: The plots show impulse responses of number of employees using IV local projection regressions with Romer and Romer (extended) monetary policy shocks instrumenting 1 year government bond rate. Horizon is 4 years, lag is set to 2. The time span is 1969-2006. The control variables are change in log employees, change in log sales, real asset growth, real investment growth, log real assets, top statutory tax rate and an indicator variable for dividends paid. Standard errors are clustered by firm and year.
Figure H.9.2: Impulse responses of investment using equation 7.

Note: The plots show impulse responses of investment using IV local projection regressions with Romer and Romer (extended) monetary policy shocks instrumenting 1 year government bond rate. Horizon is 4 years, lag is set to 2. The time span is 1969-2006. The control variables are change in log employees, change in log sales, real asset growth, real investment growth, log real assets, top statutory tax rate and an indicator variable for dividends paid. Standard errors are clustered by firm and year.
Figure H.9.3: Impulse responses of log real sales using equation 7.

Note: The plots show impulse responses of log real sales using IV local projection regressions with Romer and Romer (extended) monetary policy shocks instrumenting 1 year government bond rate. Horizon is 4 years, lag is set to 2. The time span is 1969-2006. The control variables are change in log employees, change in log sales, real asset growth, real investment growth, log real assets, top statutory tax rate and an indicator variable for dividends paid. Standard errors are clustered by firm and year.
H.10 Impact of liability changes using quartiles of dose

Figure H.10.1: Impulse responses of number of employees using equation 7.

(a) Neutral regime

(b) Quartile 4

(c) Quartile 3

(d) Quartile 2

(e) Quartile 1

Note: The plots show impulse responses of number of employees using IV local projection regressions with Romer and Romer (extended) monetary policy shocks instrumenting 1 year government bond rate. Horizon is 4 years, lag is set to 2. The time span is 1969-2006. The control variables are change in log employees, change in log sales, real asset growth, real investment growth, log real assets, top statutory tax rate and an indicator variable for dividends paid. Standard errors are clustered by firm and year. Quartile 1 corresponds to $-0.06 < \text{dose} < -0.028$ (e.g., high dose tax cut group), Quartile 2 corresponds to $-0.028 \leq \text{dose} < -0.013$, Quartile 3 corresponds to $-0.013 \leq \text{dose} < -0.003$, Quartile 4 corresponds to $-0.003 \leq \text{dose}$. 

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Figure H.10.2: Impulse responses of investment using equation 7.

(a) Neutral regime

(b) Quartile 4

(c) Quartile 3

(d) Quartile 2

(e) Quartile 1

Note: The plots show impulse responses of investment using IV local projection regressions with Romer and Romer (extended) monetary policy shocks instrumenting 1 year government bond rate. Horizon is 4 years, lag is set to 1. The time span is 1969-2006. The control variables are change in log employees, change in log sales, real asset growth, real investment growth, log real assets, top statutory tax rate and an indicator variable for dividends paid. Standard errors are clustered by firm and year. Quartile 1 corresponds to $-0.06 < dose < -0.028$ (e.g. high dose tax cut group), Quartile 2 corresponds to $-0.028 \leq dose < -0.013$, Quartile 3 corresponds to $-0.013 \leq dose < -0.003$, Quartile 4 corresponds to $-0.003 \leq dose$.
Figure H.10.3: Impulse responses of sales using equation 7.

Note: The plots show impulse responses of investment using IV local projection regressions with Romer and Romer (extended) monetary policy shocks instrumenting 1 year government bond rate. Horizon is 4 years, lag is set to 1. The time span is 1969-2006. The control variables are change in log employees, change in log sales, real asset growth, real investment growth, log real assets, top statutory tax rate and an indicator variable for dividends paid. Standard errors are clustered by firm and year. Quartile 1 corresponds to \(-0.06 < \text{dose} < -0.028\) (e.g. high dose tax cut group), Quartile 2 corresponds to \(-0.028 \leq \text{dose} < -0.013\), Quartile 3 corresponds to \(-0.013 \leq \text{dose} < -0.003\), Quartile 4 corresponds to \(-0.003 \leq \text{dose}\).
H.11  Heterogeneity analysis

H.11.1  Marginal tax rate estimates on employment based on firm size

Figure H.11.1: Impulse responses of employees using LP-IV specification in equation 3.

Figure H.11.2: Impulse responses of employees using LP-IV specification in equation 3.

Note: The plots show impulse responses of employees using IV local projections. Horizon is 5 years, lag is set to 2. The time span is 1969-2006. Standard errors are clustered by firm and year. The left panel shows the impulse responses to monetary shock absent any tax intervention. The middle (right) panel shows the impulse responses to monetary shock for firms that received a tax hike (cut). Large (small) firms refers to firms with employment greater (less) than median company (906 employees).
H.11.2 Marginal tax rate estimates on investment based on firm size

![Graph showing impulse responses of investment using LP-IV specification in equation 3.](image)

Figure H.11.3: Impulse responses of investment using LP-IV specification in equation 3.

![Graph showing impulse responses of investment using LP-IV specification in equation 3.](image)

Figure H.11.4: Impulse responses of investment using LP-IV specification in equation 3.

Note: The plots show impulse responses of investment using IV local projection regressions with Romer and Romer (extended) monetary policy shocks instrumenting 1 year government bond rate. The time span is 1969-2006. Standard errors are clustered by firm and year. Large (small) firms refers to firms with employment greater (less) than median company (906 employees).
H.11.3 Marginal tax rate estimates on sales based on firm size

Figure H.11.5: Impulse responses of log real sales using LP-IV specification in equation 3.

Figure H.11.6: Impulse responses of log real sales using LP-IV specification in equation 3.

Note: The plots show impulse responses of log real sales using IV local projection regressions with Romer and Romer (extended) monetary policy shocks instrumenting 1 year government bond rate. The time span is 1969-2006. The control variables are change in log employees, change in log sales, real asset growth, real investment growth, log real assets, top statutory tax rate and an indicator variable for dividends paid. Standard errors are clustered by firm and year. Large (small) firms refers to firms with employment greater (less) than median company (906 employees).
H.11.4 Marginal tax rate estimates on employment based on liquidity

![High Liquidity Impulse Responses](image1)

![Low Liquidity Impulse Responses](image2)

Figure H.11.7: Impulse responses of employees using LP-IV specification in equation 3.

Figure H.11.8: Impulse responses of employees using LP-IV specification in equation 3.

Note: The plots show impulse responses of employees using IV local projections. Horizon is 5 years, lag is set to 2. The time span is 1969-2006. Standard errors are clustered by firm and year. The left panel shows the impulse responses to monetary shock absent any tax intervention. The middle (right) panel shows the impulse responses to monetary shock for firms that received a tax hike (cut). Large (small) firms refers to firms with employment greater (less) than median company (906 employees).
H.11.5 Marginal tax rate estimates on investment based on liquidity

![Figure H.11.9: Impulse responses of investment using LP-IV specification in equation 3.](image1)

![Figure H.11.10: Impulse responses of investment using LP-IV specification in equation 3.](image2)

Note: The plots show impulse responses of investment using IV local projection regressions with Romer and Romer (extended) monetary policy shocks instrumenting 1 year government bond rate. The time span is 1969-2006. Standard errors are clustered by firm and year. Large (small) firms refers to firms with employment greater (less) than median company (906 employees).
H.11.6 Marginal tax rate estimates on sales based on liquidity

Figure H.11.11: Impulse responses of log real sales using LP-IV specification in equation 3.

Figure H.11.12: Impulse responses of log real sales using LP-IV specification in equation 3.

Note: The plots show impulse responses of log real sales using IV local projection regressions with Romer and Romer (extended) monetary policy shocks instrumenting 1 year government bond rate. The time span is 1969-2006. The control variables are change in log employees, change in log sales, real asset growth, real investment growth, log real assets, top statutory tax rate and an indicator variable for dividends paid. Standard errors are clustered by firm and year. Large (small) firms refers to firms with employment greater (less) than median company (906 employees).
H.11.7 Marginal tax rate estimates on employment based on leverage

Figure H.11.13: Impulse responses of employees using LP-IV specification in equation 3.

Figure H.11.14: Impulse responses of employees using LP-IV specification in equation 3.

Note: The plots show impulse responses of employees using IV local projections. Horizon is 5 years, lag is set to 2. The time span is 1969-2006. Standard errors are clustered by firm and year. The left panel shows the impulse responses to monetary shock absent any tax intervention. The middle (right) panel shows the impulse responses to monetary shock for firms that received a tax hike (cut). Large (small) firms refers to firms with employment greater (less) than median company (906 employees).
H.11.8 Marginal tax rate estimates on investment based on leverage

Figure H.11.15: Impulse responses of investment using LP-IV specification in equation 3.

Figure H.11.16: Impulse responses of investment using LP-IV specification in equation 3.

Note: The plots show impulse responses of investment using IV local projection regressions with Romer and Romer (extended) monetary policy shocks instrumenting 1 year government bond rate. The time span is 1969-2006. Standard errors are clustered by firm and year. Large (small) firms refers to firms with employment greater (less) than median company (906 employees).
H.11.9 Marginal tax rate estimates on sales based on leverage

Figure H.11.17: Impulse responses of log real sales using LP-IV specification in equation 3.

Figure H.11.18: Impulse responses of log real sales using LP-IV specification in equation 3.

Note: The plots show impulse responses of log real sales using IV local projection regressions with Romer and Romer (extended) monetary policy shocks instrumenting 1 year government bond rate. The time span is 1969-2006. The control variables are change in log employees, change in log sales, real asset growth, real investment growth, log real assets, top statutory tax rate and an indicator variable for dividends paid. Standard errors are clustered by firm and year. Large (small) firms refers to firms with employment greater (less) than median company (906 employees).
H.12 Granger causality tests

This part provides a series of Granger causality tests confirming the Romer monetary shock series are uncorrelated to the exogenous tax reforms. Specifically, I regress annual monetary innovations on a set of lagged tax reform dates and aggregate variables including changes in real government spending, changes in total employees and changes in total public real debt. Lag length is 3 years.

\[
\text{Romer shocks} = c + \sum_{i=1}^{L} \beta_i x_{t-i} + v_i \tag{8}
\]

The null hypothesis is that Romer shocks are not predictable from the exogenous tax reforms. Table H.1 reports F statistics and p-values for the null hypothesis based on equation 8. All p-values are above 10 percent and mostly above 40 percent, hence we can not statistically reject the hypothesis of exogeneity of the monetary shocks to tax reforms. This suggests that studying tax changes around monetary policy innovations is suitable.

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* p < 0.05, ** p < 0.01, *** p < 0.001

Table H.1: Granger tests on monetary policy shocks

Note: All regressions spans from 1969 to 2006 and p-values are provided in parentheses. Specification (1) has exogenous tax reforms, changes in real GDP, changes in real government spending, changes in total employees and changes in total public real debt as left hand side variables. Specification (2) adds contemporaneous exogenous tax reforms to specification (1). Specification (3) has endogenous and exogenous tax reforms, changes in real GDP, changes in real government spending, changes in total employees and changes in total public real debt as left hand side variables.

In addition, I provide Granger causality tests confirming the exogenous tax reforms are uncorrelated to the monetary policy shocks. Specifically, I regress the tax reform dates on lagged annual monetary innovations and a set of aggregate variables including changes in real government spending and changes in real GDP.

\[
\text{Tax Reforms} = c + \sum_{i=1}^{L} \beta_i x_{t-i} + v_i
\]

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>L.resid_full</td>
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<td>-0.00833 (0.924)</td>
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<td>F</td>
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<td>2.771</td>
<td>1.765</td>
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* p < 0.05, ** p < 0.01, *** p < 0.001

Table H.2: Granger tests on tax reforms

Note: All regressions spans from 1969 to 2006 and p-values are provided in parentheses. Specification (1) regresses exogenous tax reforms on lags of monetary shocks. Specification (2) regresses exogenous tax reforms on lags of monetary shocks and changes in real GDP. Specification (3) regresses exogenous tax reforms on lags of monetary shocks, changes in real GDP and changes in real government spending.
I Model Appendix

Household’s problem:

\[ L = E_t \left\{ \ln C_t - \frac{\theta N_t^{\lambda}}{1 + \lambda} + \lambda_t \left( \frac{W_t N_t}{P_t} + \frac{\Pi_t}{P_t} + \frac{T_t}{P_t} + \frac{B_{t-1}}{P_t} - \frac{P_t C_t - Q_t B_t}{P_t} \right) \right\} \]

where \( P_t \equiv \left( \int_0^1 P_t(i)^{1-\epsilon} di \right)^{1/\epsilon} \) is the aggregate price index and \( C_t \) is the final goods consumption:

\[ C_t(i) = \left( \frac{P_t(i)}{P_t} \right)^{-\epsilon} C_t \text{ for all } i \in [0,1] \]

Hence, consumption expenditures can be expressed as the product of the price index times the quantity index as follows:

\[ P_t C_t = \int_0^1 P_t(i) C_t(i) di \]

Note that in addition to the flow budget constraint, the household is also subject to a solvency constraint that prevents it from engaging in Ponzi-type schemes.

\[ \lim_{T \to \infty} E_t \{ \Lambda_{t,T} \frac{B_T}{P_T} \} \geq 0 \text{ for all } t, \text{ where } \Lambda_{t,T} \equiv \beta^{T-t} U_{c,T} / U_{c,t} \]

The first order conditions:

\[ C_t : \quad \frac{1}{C_t} = \lambda_t \quad (9) \]

\[ N_t : \quad \theta N_t^{\lambda} = \lambda_t \frac{W_t}{P_t} \quad (10) \]

\[ B_t : \quad \frac{\lambda_t Q_t}{P_t} = \beta E_t \left( \frac{\lambda_{t+1}}{P_{t+1}} \right) \quad (11) \]

bring the optimality conditions on consumption-savings and labor supply decision:

\[ \theta N_t^{\lambda} C_t = \frac{W_t}{P_t} = w_t \quad (12) \]

\[ Q_t = \beta E_t \left( \frac{C_t}{C_{t+1}} \right) \frac{1}{1 + \pi_{t+1}} \quad \text{for } t = 0, 1, 2, \ldots \quad (13) \]

where \( \pi_{t+1} = \frac{P_{t+1}}{P_t} - 1 \) is the net inflation rate and \( w_t = \frac{W_t}{P_t} \) is real wages. Equation 12 can be interpreted as the competitive labor supply condition, determining the quantity of labor supplied as a function of the real wage, given the marginal utility of consumption (which is a function of consumption only). Workers do not have any market power, hence they take the wage as given.\(^4\)

---

\(^4\)Last, equation 13 can also be used to determine the implied real interest rate in linear form as:

\[ r_t \equiv i_t - E_t \{ \pi_{t+1} \} \]
Firms' problem:

\[ L = E_t \sum_{j=0}^{\infty} \beta^j \frac{\lambda_{t+j}}{\lambda_t} \left( \frac{1}{P_{t+j}} \left( P_{t+j}(i) Y_{t+j}(i) - W_{t+j} N_{t+j}(i) \right) (1 - \tau_t) - \frac{\psi}{2} \left( \frac{P_{t+j}(i)}{P_{t+j-1}(i)} - 1 \right)^2 P_{t+j} Y_{t+j} \right) - I_{t+j}(i) \]

- \frac{MC_{t+j}(i)}{P_{t+j}} \left[ \left( \frac{P_t(i)}{P_t} \right)^{-\epsilon} Y_t - A_t K_t(i)^\alpha N_t(i)^{1-\alpha} \right] + q_{t+j} \left[ I_{t+j}(i) - \frac{\phi}{2} \left( I_t(i) \frac{I_{t-1}(i)}{I_t(i)} - 1 \right)^2 + (1 - \delta) K_{t+j}(i) - K_{t+j+1}(i) \right] \]

subject to demand function that follows the Dixit Stiglitz model of imperfect competition,

\[ Y_t(i) = \left( \frac{P_t(i)}{P_t} \right)^{-\epsilon} Y_t = \left( \frac{P_t}{P_t(i)} \right)^\epsilon Y_t = \tilde{P}_t(i)^\epsilon Y_t \]

where \( Y_t(i) = A_t K_t(i)^\alpha N_t(i)^{1-\alpha} \) and \( \frac{P_t}{P_t(i)} = \tilde{P}_t(i) \).

Equilibrium conditions:

1. \[ \theta N_t^\alpha C_t = w_t \quad (14) \]
2. \[ \frac{1}{C_t} Q_t E_t (1 + \pi_{t+1}) = \beta E_t \frac{1}{C_{t+1}} \quad (15) \]
3. \[ MC_t (1 - \alpha) A_t K_t^\alpha N_t^{-\alpha} = w_t (1 - \tau_t) \quad (16) \]
4. \[ 1 = q_t \left[ 1 - \phi \left( \frac{I_t(i)}{I_{t-1}(i)} - 1 \right) \right] \frac{1}{I_t} + \frac{\lambda_{t+1}}{\lambda_t} q_{t+1} \left[ \phi \left( \frac{I_{t+1}(i)}{I_t} - 1 \right) - 1 \right] \quad (17) \]
5. \[ q_t = \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \left\{ q_{t+1}(1 - \delta) + MC_{t+1} A_{t+1} \alpha K_{t+1}^\alpha N_{t+1}^{-\alpha} \right\} \quad (18) \]

Phillips curve: \( (1 - \epsilon) (1 - \tau_t) - \psi \pi_t (\pi_t + 1) + \beta E_t \frac{C_t}{C_{t+1}} \left[ \psi \pi_{t+1} (\pi_{t+1} + 1) \frac{Y_{t+1}}{Y_t} \right] = -\epsilon MC_t(i) \quad (19) \)

Central Bank’s interest rate rule: \[ i_t = 0.7 i_{t-1} + 0.3 \ast \phi_t \pi_t + s_t \epsilon_{i,t} \quad (20) \]

\[ Y_t = A_t K_t^\alpha N_t^{1-\alpha} \quad (21) \]

\[ Y_t = C_t + I_t + \frac{\psi}{2} (\pi_t)^2 Y_t \quad (22) \]

\[ K_{t+1}(i) = I_t(i) - \frac{\phi}{2} \left( \frac{I_t(i)}{I_{t-1}(i)} - 1 \right)^2 + (1 - \delta) K_t(i) \quad (23) \]

\[ \tau_t = (1 - \rho_t) \tau_{t-1} + (\rho_t) \tau_{t-1} + \sigma_t \epsilon_{\tau,t} \quad (24) \]

\[ Q_t = \frac{1}{1 + i_t} \quad (25) \]
I.1 Calibration Details

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<th>Parameter</th>
<th>Description</th>
<th>Value</th>
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Table I.1: Quarterly Parametrization

Note: The calibration parameters closely follow Gali (2009), Burnside et al. (2004) and Miao and Ngo (2019).
I.2 Simulation of monetary policy shock in theoretical model

The figure I.2.1 shows a basic contractionary monetary policy exercise in my model using quarterly calibrated parameters in Table I.1. Figure I.2.1 plots the impulse responses of key aggregate variables to a 25 basis points contractionary monetary policy shock. All variables are expressed in percent deviation from their steady state level. Following a 25 basis points positive shock to interest rate, nominal interest rate increases by 0.15 points. Since the prices are sticky, this also increases the real interest rate. Output falls by approximately 0.3 percent on impact and slowly transitions to steady state six periods after the shock. Through the Euler equation, as interest rate increases households reoptimize the consumption path, lowering consumption contemporaneously. Consumption falls about 0.34 percent on impact. By standard notion of arbitrage, a higher real interest rate increases the required return on capital which makes firms invest less. Both investment and capital show a hump-shaped response where the peak effect for investment occurs three periods after the shock with a -0.1 percent fall in steady state investment. Capital reaches its peak effect about 10 periods after the shock, corresponding to a -0.025 percent fall in capital stock. Last, lower aggregate demand lowers hours worked.\footnote{In a model with intertemporal debt, we can also argue through the cost channel of monetary policy that the higher the interest rate, the more expensive it is to borrow. Hence, the firms would further lower the demand for factors of production and hence output.}

Figure I.2.1: Impulse response to 25 bps shocks to the nominal interest rate.
I.3 Comparison of capital adjustment costs ($\phi$)

Figure I.3.1: Impulse response to monetary policy with different capital adjustment costs ($\phi = 4$, Baseline)

Figure I.3.2: Impulse response to monetary policy with different capital adjustment costs ($\phi = 1$)
I.4 Testing share of capital

(a) $\alpha = 0.30$

(b) $\alpha = 0.70$

Figure I.4.3: Impulse responses to monetary policy following contractionary tax shifts.