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Young Firms and Monetary Policy Transmission

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Abstract

We investigate the role of business dynamism in the transmission of monetary policy by exploitingthe variation in firm demographics across U.S. states. Using local projections, we find that a larger fraction of young firms significantly mutes the effects of monetary policy on the labor market and personal income over the medium term. The firm entry rate and the employment share of young firms are key factors underpinning these results, which are robust to a battery of robustness tests. We develop a heterogeneous-firm model with age-dependent financial frictions that rationalizes the empirical evidence.

JEL Classification Numbers: E52, J11, M13.

Keywords: firm demographics, business dynamism, monetary policy, local projections, U.S. states.

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Contents

1 Introduction

In 1990, young firms (those aged 5 years or younger) accounted for about 43 percent of all firms in the United States. This number has steadily declined, reaching about 30 percent in 2018. The reduction in the number of young firms is a key feature of the secular decline of business dynamism in the U.S. economy (Akcigit and Ates, 2020). A rich research agenda aims to understand both its causes (Gutiérrez and Philippon, 2019; Akcigit and Ates, 2019) and consequences (Decker et al., 2016).

Surprisingly, however, there is still limited research on how this dramatic shift in firm demographics, and business dynamism more generally, has affected the propagation of aggregate shocks in the U.S. economy. In this paper, we aim to fill this gap by zooming in on the effects of declining business dynamism on the transmission of monetary policy shocks. We present compelling empirical evidence that an economy with a higher fraction of young firms is less responsive to monetary policy. To rationalize this finding, we construct a heterogenous firm model with financial frictions in which young firms face an external financing constraint due to insufficient credit history. This key friction is borne out in the data on small business in the U.S. and, in our model, renders the capital stock of financially constrained firms less responsive to monetary policy.

Our empirical analysis relies on measures of business dynamism at the state level constructed using the newly released and redesigned Business Dynamics Statistics (BDS), which is the publicly available version of the U.S. Census Bureau Longitudinal Business Database. These measures are combined with monetary policy shocks identified using high-frequency event studies. With this data in hand, we exploit the heterogeneity in the share of young firms across U.S. states, as well as over time, for identification purposes and control for a wide set of state-level and aggregate variables, both observable and unobservable. Our approach consists of estimating impulse response functions to monetary policy shocks using local projections à la Jordà (2005).

In our baseline specification, we explore how the share of young firms affects the response of state-level personal income, wages, and employment to monetary policy shocks. We find that firm demographics do matter. The effects of monetary policy become weaker as the share of young firms increases. The estimates are economically significant. Following a 25 basis point monetary policy tightening, personal income is 1 percentage point higher after 6 quarters in states with a one standard deviation higher share of young firms, all else equal. The impact of firm demographics is also quite persistent, remaining significant up to 3 years out. We obtain similar results for wages and employment, although the effects are slightly different in terms of magnitude and persistence.

We proceed by assessing the robustness of our empirical findings across several dimensions. First, we check if the role of firm demographics in shaping the propagation of monetary policy shocks changes when we include different, but closely related, measures of business dynamism.[1] Second, we provide compelling evidence that our main findings are not the results of a spurious correlation between firm and population demographics.[2] Third, we show that the effects of the share of young firms on monetary policy transmission are essentially unchanged when controlling for the sectoral composition of business activity, state-specific time trends and unobservable characteristics, and outlier states. Finally, we conclude our battery of robustness checks by assessing the sensitivity to using different monetary policy shock series and find that our main results are largely unaffected.

We then investigate some of the drivers of our main results. The share of young firms reflects the entry rate of new firms, the survival rate of young firms, and the overall growth rate of existing businesses. Considering these variables separately, we find that the impact of the entry rate on the transmission of monetary policy closely resembles that of the share of young firms in terms of magnitude, persistence, and statistical significance. This suggests that the number of startups entering the market, rather than their survival rate or the growth in the stock of firms, is a key driver of the effects of firm demographics on monetary policy transmission. Alternatively, a larger share of young firms can result from a higher fraction of workers employed by these firms, a smaller relative size of young firms, or both. In this case, we show that the employment share by young firms has a very similar impact to that of the share of young firms on monetary policy transmission, while the relative size of young firms plays a minor role.

In the final part of the paper, we develop a model in which some young firms do not have

[1]For instance, Haltiwanger et al. (2013) find that young firms tend to be smaller, have higher exit rates, and exhibit higher rates of job destruction and job creation, meaning they are characterized by a higher job reallocation rate.

[2]Recent studies also show that population demographics matter for the transmission of monetary policy shocks (for instance, see Hopenhayn et al., 2018).

access to external financing due to insufficient credit history. This friction reflects the findings in the Federal Reserve Banks' Small Business Credit Survey (SBCS, Federal Reserve Banks (2017)), which show that insufficient credit history is the main reason behind young firms' financing shortfalls relative to older firms that are comparable along multiple dimensions, including size and riskiness. We model this key friction in an economy that features entry and exit of firms that are subject to idiosyncratic productivity shocks and face a borrowing constraint when issuing debt.

Calibrating the model to parameters widely used in the literature and matching key moments of firm demographics, we find that the effects of an increase in the risk-free interest rate on consumption, employment, and wages are smaller as the fraction of young firms increases. This result is driven by young firms with no access to credit. When the risk-free interest rate decreases, firms will find it optimal to raise their capital stock by issuing debt. However, some young firms can only rely on dividends to fund their investment, limiting their response to a reduction in the interest rate.

The lack of access to credit also plays a key role when the interest rate increases. In response to a temporary rate hike, young firms that cannot issue debt reduce their capital stock by less than their unconstrained peers, since they anticipate that they may not be able to borrow in the future to increase their investment once rates start decreasing down to the initial level. In short, the lack of access to external financing renders aggregate investment, and in turn other macroeconomic variables, less sensitive to changes in interest rates.

The paper is organized as follows. We give a brief overview of the relevant literature in Section 2. Section 3 presents the data and empirical methodology. Section 4 discusses the empirical findings and their robustness. Section 5 explores potential channels behind our main results. Section 6 develops a model to interpret the empirical findings. Section 7 concludes.

2 Literature Review

A large body of evidence highlights the importance of firm dynamics for the propagation of aggregate shocks (Davis et al., 1998; Moscarini and Postel-Vinay, 2012; Fort et al., 2013; Clementi and Palazzo, 2016; Gourio et al., 2016; Adelino et al., 2017; Sedláček and Sterk, 2017; Crouzet and Mehrotra, 2020). More recently, Clementi et al. (2019) show that firm demographics played a key role in the slow recovery that followed the Great Recession. Similarly to this study, we explore the effects of firm dynamics and demographics on aggregate fluctuations. Differently, our focus is on the propagation of monetary policy shocks.

Our work also contributes to the literature on the role of firm age in the transmission of monetary policy. Recent efforts exploit firm-level data to better understand how firm age affects the transmission of monetary policy. Bahaj et al. (2019) use U.K. data to reconcile the transitory effect of monetary policy shocks on employment at the macro level, with the more persistent effects on individual firm employment, highlighting firm age and leverage as important factors. Cloyne et al. (2018) use data on publicly listed firms in the U.S. and find that younger corporations paying no dividends are more responsive to monetary policy with respect to investment and borrowing decisions. Similarly to these studies, we also explore how the effects of monetary policy depend on firm age, but our paper differs in at least three crucial dimensions. First, our dataset covers all employer firms in the U.S., including private and startup firms. Second, we exploit variation across time and U.S. states, with the precise goal of understanding how an important dimension of the decline in U.S. business dynamism–the shrinking fraction of young firms–has affected the transmission of monetary policy to several key macroeconomic variables. Third, we study the drivers of the observed shift in firm demographics and rationalize these findings by developing a model with heterogeneous firms.

Recent studies highlight the importance of population demographics for the transmission of monetary policy shocks. Berg et al. (2019) find that the consumption of households whose head is older than 65 years react more to monetary policy shocks than that of young and middle-aged households, while Leahy and Thapar (2019) find that the response of personal income and employment to monetary policy is weaker in U.S. states with a larger share of middle-aged people. In our work, we provide evidence that also another demographic dimension, namely firm demographics, matters. The literature also documents a close connection between population demographics and business dynamics (Liang et al., 2018; Robb and Robinson, 2014; Karahan et al., 2019; Pugsley and Sahin, 2019). In our analysis, we address the close connection between population and firm demographics and show that the two variables have an independent effect on the propagation of monetary policy shocks.

Finally, our paper contributes to the large literature on how financial frictions shape macroeconomic fluctuations, which is reviewed in Brunnermeier et al. (2012), by exploring the implications of young firms' access to credit on the propagation of monetary policy shocks.[3] Our heterogeneous-firm model with age-dependent financial frictions captures the well known fact that young firms are more likely to be financially constrained (e.g., Beck et al., 2006) and that these constraints negatively affect their growth (e.g., Beck et al., 2005).

3 Data and Empirical Strategy

To perform our empirical analysis, we construct a dataset that combines measures of business dynamism at the state level, monetary policy shocks identified at high-frequency, and macroeconomic variables at both the state and U.S. level. This section describes the different data sources, discusses the identification strategy that motivates our empirical analysis, and illustrates the empirical methodology adopted to investigate the role of firm demographics in the transmission of monetary policy.

3.1 Data Description

We rely on three main data sources. The first is the Business Dynamics Statistics (BDS), which is the publicly available version of the U.S. Census Bureau Longitudinal Business Database. The most recent release of the BDS includes all employer firms with at least one employee over the period 1978-2018 and covers 98 percent of private employment.

Thanks to its vast coverage, the BDS is an ideal dataset to study firm demographics and business dynamism compared to other data sources commonly used. For instance, Compustat does not include private firms, thus leaving out a significant fraction of business, in particular startups.[4] Other data sources, such as the U.S. Business Employment Dynamics (BED) database, only report

[3] Another strand of the literature studies how financial frictions affect business dynamism and in particular firm entry (among many others, see Lelarge et al., 2010).

[4] As documented in Dinlersoz et al. (2018), Compustat covers 6,600 U.S firms between 2000 and 2013, amounting to only 0.13 percent of all firms in the economy.

information on establishments, that are single physical locations of business activity, for instance a factory. Because multiple establishments may belong to the same firm, using the BDS firm-level data allows us to correctly measure business dynamism that is associated with the evolution in firm demographics rather than in establishment creation or destruction by existing firms. This is important because economic decisions that are relevant for our analysis, such as the hiring and firing of workers, are likely to be made at the firm rather than the establishment level.

The BDS is available at an annual frequency and reports the information available in March of each year. The dataset reports information on: number of firms, corresponding age, number of establishments, employees, jobs created, and jobs destroyed. Crucial to our analysis, the data is available by state and industry.[5] There are, of course, a number of limitations to the BDS data. First, it does not include data on firms' balance sheets nor information on credit market access. Second, the data is only available at the state rather than the firm level.

The BDS allows us to compute a broad set of variables that capture different dimensions identified by the literature as relevant for firm demographics and, more broadly, business dynamism at the state and industry level (Akcigit and Ates, 2020). The variation in business demographics is measured by the share of firms belonging to different cohorts. In particular, we divide businesses into three different age groups: (i) startups, or entrants, if less than one year old, (ii) young if 5 years old or younger, including startups, and (iii) mature if 6 years old or older.[6] We then compute the share of startups (or entry rate), young firms, and mature firms, as a fraction of total firms in each state and year. We also measure the firm exit rate and associated survival rate for each age group. By taking the overall exit rate at the state level and subtracting it from the entry rate, we obtain the net birth rate. Labor dynamics are captured using the share of employment, net and gross job creation, and job destruction rates by age group. In each year and state, we also compute the job reallocation rate, defined as the sum of the job creation and destruction rates in excess of the net job creation rate. Finally, we measure the average size of every cohort and track its growth over time.

[5] When considering state-level data, we collect data for the 50 states plus the District of Columbia.

[6] An important caveat is that the firm birth year is unknown if it took place before 1978, meaning that the number of young firms could be underestimated over the period 1978-1983. However, this feature of the data does not affect our analysis because it does not cover those years.

Table 1. Summary Statistics of Business Dynamism Variables

	Mean	St. Dev.	Min	Max	N
Share of young firms	0.362	0.067	0.179	0.574	2,091
Firm entry rate	0.095	0.024	0.048	0.204	2,091
Firm exit rate	0.079	0.013	0.049	0.154	2,091
Share of micro firms	0.849	0.025	0.701	0.902	2,040
Share of small firms	0.969	0.012	0.914	0.991	2,040
Job reallocation rate	0.270	0.045	0.167	0.482	2,091
Employment share by young firms	0.143	0.042	0.047	0.297	2,091

Notes: Summary statistics of firm demographics and business dynamism obtained form the BDS for the period 1978 - 2018. The sample is at annual frequency and includes the 50 U.S. states and the District of Columbia. Young firms are aged 5 and under. Entry firms are startups (age 0), while exiting firms are those ceasing activity. Job reallocation is the sum of jobs created and destroyed by firms in the sample, net of their difference (i.e., the net job creation) in absolute value. Micro (small) firms have less than 20 (500) employees. Shares and rates at time t are computed using the average of the number of firms (employment in the case of the job reallocation rate and the employment share of young firms) for times t and $t-1$, following Davis et al. (1998).

Table 1 reports the summary statistics of the key variables constructed using the BDS. In our empirical analysis, we normalize measures of business dynamism by dividing them by the corresponding unconditional standard deviation to facilitate the interpretation of the relevant coefficients, as explained in Section 3.3.

Monetary Policy Surprises

The second main component of our dataset consists of time-series of several different U.S. monetary policy shocks. To identify such shocks, we adopt the high-frequency, event-study approach that is used in a vast and still growing literature.[7] The advantage lies in the possibility to isolate the unanticipated component of the change in the monetary policy stance, thus addressing the endogeneity issues that arise when studying the effects of monetary policy on macroeconomic and financial conditions.

This methodology was first proposed by Cook and Hahn (1989) and further developed by Gürkaynak et al. (2005) and Gorodnichenko and Weber (2016), which we follow when constructing our measures of monetary policy shocks. First, we retrieve the change over a tight (15 minutes before

[7] Among others, see Gertler and Karadi (2015).

and after) or wide (15 minutes before and 45 minutes after) window around Federal Open Market Committee (FOMC) announcements of a set of interest rates at several maturities, namely rates implied by current and three-month ahead Fed Funds futures contracts, 3-month to 1-year Eurodollar futures rates, and yields on 2-year government bonds.[8] Following Ottonello and Winberry (2020), we aggregate these surprises up to the quarterly frequency to match that of the state-level macroeconomic variables. To this end, we weigh these high-frequency shocks ϵ_i by the number of days left between the FOMC announcement and the end of the quarter and then construct our quarterly shock ϵ_t as a moving average using the following formula:

$$\epsilon_t = \sum_{i \in t} \frac{d_t - d_{fomc}}{d_t} \epsilon_i + \sum_{i \in (t-1)} \frac{d_{fomc}}{d_t} \epsilon_i \ , \tag{1}$$

where t denotes the quarter, d_t is the number of days in quarter t, and d_{fomc} denotes the day of the FOMC announcement in quarter t. This adjustment accounts for two different factors. First, the day of the FOMC meetings vary across quarters, as they typically happen every six weeks. Second, monetary policy shocks are expected to have larger or smaller effects in any one quarter depending on their timing within the quarter, as agents in the economy may need time to react to the shock. Accordingly, equation (1) assigns a higher weight to surprises observed at the beginning of the quarter and to surprises that happened at the end of the previous quarter. We also compute the simple sum of surprises in each quarter as a robustness test. A positive value of the measure of ϵ_t from equation (1) corresponds to a contractionary monetary policy shock.

On top of changes in rates implied by futures contracts and yields on government bonds, we also consider the monetary policy surprises constructed by Nakamura and Steinsson (2018) using a principal component analysis aimed to capture the effects of "forward guidance." Table 2 shows the moments of the different series of monetary policy surprises in our dataset. A few observations are noteworthy. With the exception of the Nakamura and Steinsson (2018) shocks, the moments are

[8] We consider both scheduled and unscheduled announcements. Although Faust et al. (2004) argue that inter-meeting policy decisions are more likely to deliver unanticipated news about the state of the economy rather than on monetary policy stance, the results in Gorodnichenko and Weber (2016) and Nakamura and Steinsson (2018) are robust to the inclusion of surprises from unscheduled announcements. Our findings also are robust to considering exclusively FOMC scheduled announcements.

Table 2. Summary Statistics of Monetary Policy Shocks

	Mean	St. Dev.	Min	Max	N
3m ahead Fed Funds	-0.032	0.083	-0.428	0.122	5,916
3m ahead Fed Funds (sum)	-0.032	0.093	-0.435	0.170	5,916
Current month Fed Funds	-0.021	0.056	-0.321	0.124	5,916
3m Eurodollar deposit	-0.030	0.083	-0.466	0.104	7,089
2y Treasury yield	-0.015	0.078	-0.329	0.184	5,610
Nakamura-Steinsson	0.000	0.065	-0.268	0.146	3,978

Notes: Summary statistics of monetary policy shocks identified using the event study approach described in Section 3.1. The data on the Fed Fund futures rates, the 3-month Eurodollar deposits, and the yield on the 2-year on-the-run Treasury are obtained using tick-by-tick data. The corresponding change is computed for all FOMC announcements over a tight window (30 minutes), except for the current month futures for which a wide window (60 minutes) is used. The changes are aggregated at the quarterly frequency using equation (1) or by simply summing them (if specified). The data is available from 1990q1 for Fed Funds futures, 1978q1 for Eurodollar deposits, and from 1991q3 for Treasury yields. The series of Nakamura-Steinsson shocks is taken from Nakamura and Steinsson (2018).

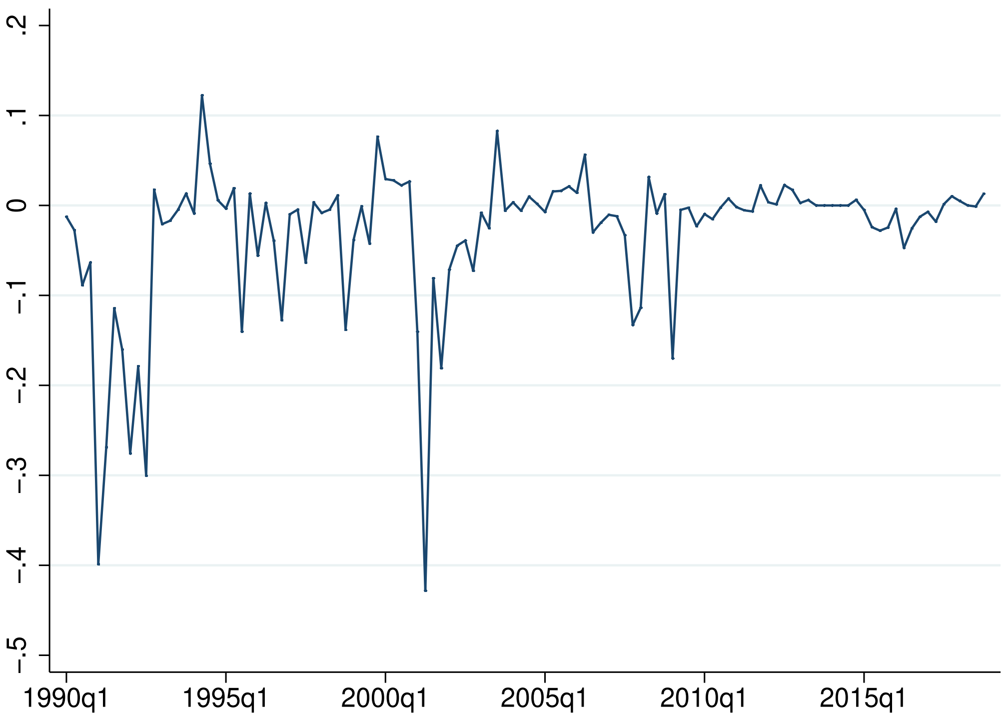
very similar across different measures of surprises on short-term rates, independently of the type of futures (on Fed Funds or Eurodollar deposits) and of whether they are smoothed using a moving average.[9] On the contrary, the number of observations varies significantly because the data on Eurodollar futures is available beginning in 1984, while Fed Funds futures have been traded since 1990, and Nakamura and Steinsson (2018) shocks are only available for the period 1995-2013.

Our baseline measure of monetary policy surprises is the change of the 3-month ahead Fed Funds futures over a tight window of 30 minutes, while using the other measures to test the robustness of the benchmark results. This choice is driven by three main considerations. First, compared to the spot-month Fed Funds futures, a longer horizon allows us to capture surprises relative to both conventional monetary policy and near-term forward guidance. This is particularly important because policy rates were at the zero lower bound for a large part of the period following the Global Financial Crisis.[10] Second, the longer is the horizon of the contract, the less sensitive is the implied rate to small surprises, for instance due to delays in press releases after unscheduled meeting. Third, a tight window reduces the risk of confounding factors affecting the measurement of monetary policy

[9]Differently from the other measures in Table 2, Nakamura and Steinsson (2018) shocks are constructed using a principal component decomposition.

[10]As a reference, in the period 2008q3-2018q4, the 3-month and current month Fed Funds futures have a similar mean (0.07 versus 0.05), but the standard deviation of the former is almost twice that of the latter (0.29 and 0.16, respectively).

Figure 1. Monetary Policy Shocks



Notes: Time series of the rate implied by the 3-month ahead Fed Funds futures. The rate is obtained by computed the variation over a 30-minute window around FOMC announcements since 1990q1. High-frequency changes are aggregated at the quarterly frequency using equation (1).

surprises relative to a wide window. Figure 1 shows the time series of surprises in the 3-month ahead Fed Funds futures over a tight window and smoothed using equation (1).

Macroeconomic and Financial Variables

Finally, we collect state-level macroeconomic and financial variables from different sources. In an ideal world, we would want data on GDP and prices at the state level. Unfortunately, data on state-level inflation are not produced, and while the Bureau of Economic Analysis (BEA) does produce state-level GDP, these series begin only in 2005. As a consequence, including state-level GDP would significantly reduce the time span covered by our study.

There is however a good alternative to GDP at the state level. The BEA produces statistics on nominal personal income at the state level. These data are available going back to 1948 and are almost identical to GDP (the correlation is 0.99 over the the period 2005-2018).

To compensate for the lack of data on inflation at the state level, we collect information on house prices. In particular, we use the index computed by the Federal Housing Finance Agency. This index is a broad measure of single-family house prices and is a weighted sales index.[11] Importantly, housing prices also influence the cost and availability of credit to firms, especially if small or young (Bahaj et al., 2019, 2020).

Given our focus on employer firms, we also study the effects on wages. In particular, we use data on total compensation from the Quarterly Census of Employment and Wages (QCEW). Besides its coverage, which is vast but excludes the unincorporated self-employed (which are also absent in the BDS), QCEW data on wages has the advantage of reporting total compensation, including bonuses, stock options, and other gratuities.

Despite the lack of data on real GDP, we can still study changes in economic activity by looking directly at labor market variables. Data on private state-level employment, unemployment, and labor force participation comes from the Bureau of Labor Statistics Local Area Unemployment Statistics (LAUS).[12] Importantly, all macroeconomic variables in our dataset are available at the quarterly frequency.

We also include information on state population demographics taken from the U.S. Census Bureau. Indeed, controlling for demographics allows for increased comparability across states with different population levels and dynamics. Moreover, there is a large and growing literature that identifies linkages between business dynamism and population dynamics, pointing to the need to study them jointly in order to provide robust results (among others, see Liang et al., 2018). Table 3 presents some descriptive statistics of the state-level macroeconomic and population demographic variables included in our dataset.

By combining variables on business dynamism, monetary policy shocks, and state-level controls,

[11]The data comes from mortgage transactions on single-family properties whose mortgages have been purchased or securitized by Fannie Mae or Freddie Mac.

[12]LAUS data come from the Current Population Survey (CPS), the household survey that is used as the official measure of the labor force. In fact, the BLS checks state monthly estimates to ensure consistency with national, monthly labor force estimates from the CPS.

Table 3. Summary Statistics of Macroeconomic Variables

	Mean	St. Dev.	Min	Max	N
Personal income	204,607	271,957	8,049	252,3626	5,916
Total Wages	211,520	282,541	6,837	255,3063	5,916
House price index	282	121	86	921	5,916
Employment	2,688	2,937	223	18,705	5,916
Unemployment	169	225	8	2,248	5,916
Population	5,770	6,488	454	41,268	5,916

Notes: Summary statistics of state-level variables for the period 1990q1 - 2018q4. The sample includes the 50 U.S. states and the District of Columbia. The sources of the data are: the BEA for personal income; the BLS for total wages (QCEW), employment and unemployment (LAUS); the Federal Housing finance Agency for the house price index;the U.S. Census Bureau for population. The data are at the quarterly frequency, except for population (annual). Personal income and wages are in USD millions, employment, unemployment and population are in thousands of people. All series, except for population, are seasonally adjusted.

we build a quarterly-frequency panel dataset that includes all 50 U.S. states plus the District of Columbia. The sample spans the period from 1990q1 to 2018q4 in our baseline analysis. This dataset relies on public data sources, making our results easy to replicate.

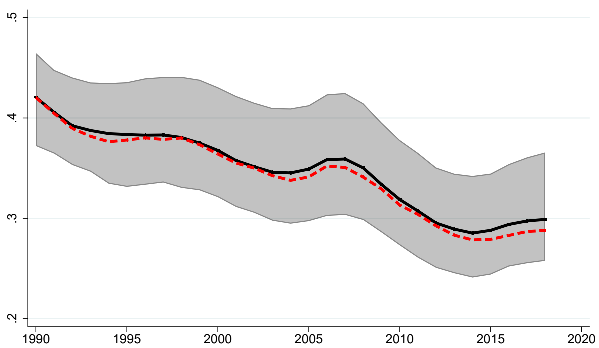
3.2 Declining Business Dynamism: a New Demographic Landscape

The purpose of our paper is to assess the effects of changes in firm demographics on the transmission of monetary policy. Our empirical strategy exploits variation in firm demographics across U.S. states and over time to guide our identification strategy. In this section, we document the heterogeneity in firm demographics across U.S. states and the secular shift toward older firms.

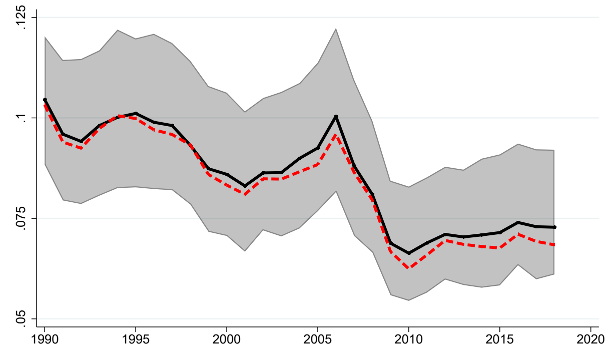
Figure 2 reports the time series evolution of the fraction of young firms, the fraction of startups (i.e., the entry rate), and the exit rate over the period 1990-2018. Panel (a) shows the steady decline in the fraction of young firms over the past 30 years, a trend that accelerated during, and in the aftermath of, the Global Financial Crisis. During the period 1990-2007, the fraction of young firms decreased by 0.34 percentage points per year on average, going from about 43.3 percent in 1990, to 37.5 percent in 2007. The decline accelerated dramatically in the following three years at about 1.3 percentage points per year, bringing the fraction of young firms to 33.5 percent in 2010. This acceleration was mostly driven by a collapse in the entry rate, with the share of startup firms falling

Figure 2. Evolution of U.S. Business Dynamism

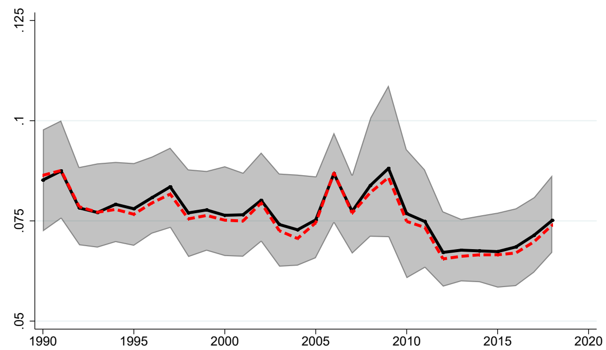
(a) Share of young firms



(b) Share of startups



(c) Firm exit rate



Notes: The solid black (dashed red) line shows the mean (median) of the share of young firms in panel (a), of the share of startups in panel (b), and of the exit rate in panel (c) in the U.S, from 1990 to 2018. The shaded areas correspond to the interval given by the 10^{th} and 90^{th} percentile of each considered variable.

from 8.8 percent in 2007 to 6.9 percent in 2010, as shown in panel (b). The exit rate seems to have played a limited role in the decline of the share of young firms. As panel (c) shows, the exit rate does not present a clear secular trend as is the case for the fraction of young and startup firms.

We also report the median and the 10^{th}-90^{th} percentile interval around the share of young firms, together with the mean value. Two things are worth noting. First, there is substantial variation in business dynamism not only across time but also states. Second, the mean and median values are very close, indicating that our measures of business dynamism are not driven by outlier states.

Crucially, focusing solely on the share of young firms at the national level ignores the significant heterogeneity across states. Panel (a) in Figure 3 shows the distribution of young firms across U.S.

states at two points in time, corresponding to the beginning and end of our sample: 1990 and 2018. These maps illustrate the substantial variation across states in both years. They also confirm that there has been a significant and pervasive shift in firm demographics in the U.S. economy over the past 3 decades in most states (Hathaway and Litan, 2014). Two states had a fraction of young firms larger than 50 percent (Arizona and Florida) in 1990 , while in the two states at the bottom of the firm-age distribution (Iowa and North Dakota) the share of young firms was about 34 percent. In 2018, the highest share of young firms was observed in Nevada and was down to about 40 percent, while only 10 states had a fraction of young firms larger than 34 percent (Arizona, California, Colorado, Florida, Georgia, Nevada, Idaho, Texas, Utah, Washington). Turning again at the bottom of the distribution, in 2018 five states had a fraction of young smaller or equal than 25 percent (Connecticut, Ohio, Iowa, Vermont, and West Virginia). Overall, the cross-sectional standard deviation of the fraction of young firms is the same in 1990 and 2018.

This observed decline in our measure of firm dynamism is far from being uniform across U.S. states. As illustrated by the map in panel (b) of Figure 3, the change in the fraction of young firms from 1990 to 2018 varies significantly from one state to another. The decrease ranges from a negligible -0.05 percentage points in North Dakota to a considerable -22.6 percentage points in Vermont, where the share of young firms has basically halved over the past 30 years. In the following section, we describe how our empirical approach exploits the variation in firm demographics along both the time and cross-sectional dimensions for identification purposes.

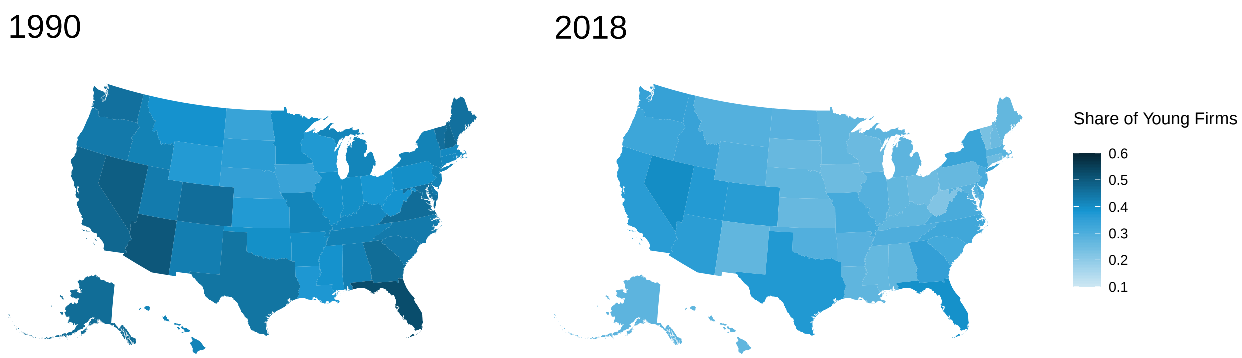
3.3 Empirical Strategy

To investigate how firm demographics affects the transmission of monetary policy, we adopt an empirical approach based on panel local projections à la Jordà (2005). Local projections can be used to produce impulse response functions (IRFs) over the medium run, allowing us to assess the persistence of monetary policy shocks, without imposing the kinds of restrictions on which VARs typically rely.[13]

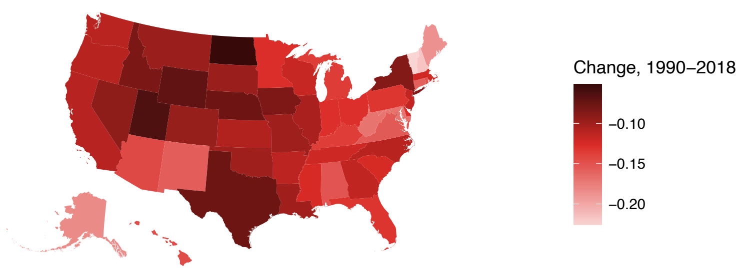
[13] For a discussion on the trade-off and differences between using VAR or local projection models to estimate IRFs, see Marcellino et al. (2006). In contrast to the conventional wisdom that that VARs are more efficient but less robust to misspecification than local projections, Plagborg-Møller and Wolf (2020) show that the two models estimate identical impulse responses.

Figure 3. Business Dynamism Across States and Over Time

(a) Share of young firms



(b) Change over the period 1990-2018



Notes: Share of young firms computed as the ratio of firms aged 5 and under to total firms in each U.S. state. The level of the share of young firms in 1990 (2018) is shown in the left (right) map in panel (a); the change in the share between 1990 and 2018 is shown in panel (b).

Specifically, we estimate several specifications of the following equation:

$$\log y_{s,t+h} = \beta_h(\epsilon_t \times z_{s,t-1}) + \phi_h z_{s,t-1} + \Gamma_h' X_{s,t} + \alpha_{s,h} + \delta_{t,h} + u_{s,t+h}\,, \tag{2}$$

where s and t denote state and time respectively, and $h \geq 0$ indexes the forecast horizon. The dependent variable is the log value of $y_{s,t}$, which captures changes in the business cycle; ϵ_t is the monetary policy shock, which is interacted with a measure of firm demographics, denoted by $z_{s,t}$. The remaining terms $\alpha_{s,h}$ and $\delta_{t,h}$ denote state and time fixed effects, respectively, while $X_{s,t}$ is a vector of additional controls at the state level, and $u_{s,t+h}$ is the residual.

The dependent variable, $y_{s,t}$, is either personal income, total wages, or employment. As explained in the previous section, data availability prevents us from considering state GDP and inflation, which are typically used to estimate the effects of monetary policy on the business cycle. It is important to note that, while personal income is highly correlated with GDP, the lack of state price indices means that it is expressed in nominal rather than real terms. This is in contrast to, for instance, employment.

The variable ϵ_t is the monetary policy surprise identified using high-frequency event studies. In our benchmark regressions, we choose the quarterly moving average of the shocks to the rate implied by the 3-month ahead Fed Funds futures contract, obtained using equation (1). A positive shock corresponds to an unexpected increase in interest rates and thus to a monetary policy tightening. Moreover, we normalize the size of the shock to 25 basis points. This is simply a re-scaling of the variable by a constant to aid interpretation of the results and does not affect its distribution. Finally, in our baseline specification, we use the share of young firms as the measure of firm demographics, $z_{s,t}$. In addition, and as discussed above, we construct several alternative measures of business demographics using the BDS dataset, which allow us to test the robustness of our findings and related mechanisms. We also normalize variables related to firm demographics (or business dynamism more in general) by dividing them by the corresponding standard deviation.

The main coefficient of interest, β_h, captures the impact of firm demographics on the transmission of monetary policy shocks to the economy, measured as the difference (in percentage points) in the response of the dependent variable over the horizon h. In particular, because of the normalization of the interaction variables, the coefficient β_h measures how a one standard deviation difference in the share of young firms alters the macroeconomic effects of a 25 basis point contractionary monetary policy shock.

The interpretation of the sign of β_h depends on the specific dependent variable considered. Given that a monetary policy tightening negatively affects economic activity and labor market conditions over the medium run (for instance, see Miranda-Agrippino and Ricco, 2020), a positive value for β_h implies that a higher share of young firms weakens the transmission of monetary policy, thus muting its effects. If the coefficient is negative, the opposite is true, and a higher share of young firms strengthens the transmission of monetary policy.

We include several state-level variables in the vector $X_{s,t}$, specifically: two lags of the log dependent variable, log personal income, log unemployment, and log house price index, and one lag of log population.[14] These covariates control for differences in the business cycle and population demographics across states. The inclusion of house prices among the explanatory variables serves a dual purpose: it acts as proxy for inflation and allows us to control for borrowing costs and financial frictions faced by firms, as shown in the literature (Bahaj et al., 2019, 2020). Finally, the set of dummies $\alpha_{s,h}$ and δ_t captures state and time fixed effects respectively, which control for both observable and unobservable permanent differences across states, as well as changes in aggregate conditions at the national level.

To deal with the potential endogeneity, all control variables, except for the monetary policy shocks, are lagged by at least one quarter.[15] Importantly, the choice to use lagged explanatory variables also alleviates concerns related to the recursiveness assumption. In other words, we avoid assuming that monetary policy does not affect the control variables contemporaneously, which would be the case if these variables were not lagged.[16]

To address concerns regarding serial correlation, heteroskedasticity, and potential correlation of errors across states, we follow Ramey and Zubairy (2018) and compute robust standard errors according to Driscoll and Kraay (1998) throughout the analysis, allowing for $h + 1$ lags of the dependent variable to be correlated, as in Jordà (2005).[17]

4 Empirical Results

We begin this section by presenting our baseline result that firm demographics, measured by the share of young firms, affects the transmission of monetary policy. We then assess the robustness of

[14] Population is included to control for state size. We include only one lag of the log state population because data on demographics is at annual frequency.

[15] When merging quarterly and annual data, we ensure that the timing is consistent. For instance, the BDS reflects data available in March of every year. Therefore, in equation (2), monetary policy shocks in the first quarter of each are interacted with the share of young firms from the previous year BDS. In the second, third, and fourth quarters, the interaction is with data from the current year BDS.

[16] See Ramey (2016) for further discussion about the relevance and implication of the recursiveness assumption.

[17] We also test for the robustness of our results to two-way clustering at both the state and quarter levels.

this finding across several dimensions, including: controlling for other related measures of business dynamism, investigating the role of population demographics, exploring the impact of outlier states, adding state-specific trends and unobservable characteristics, and evaluating the sensitivity to the use of different monetary policy shock series.

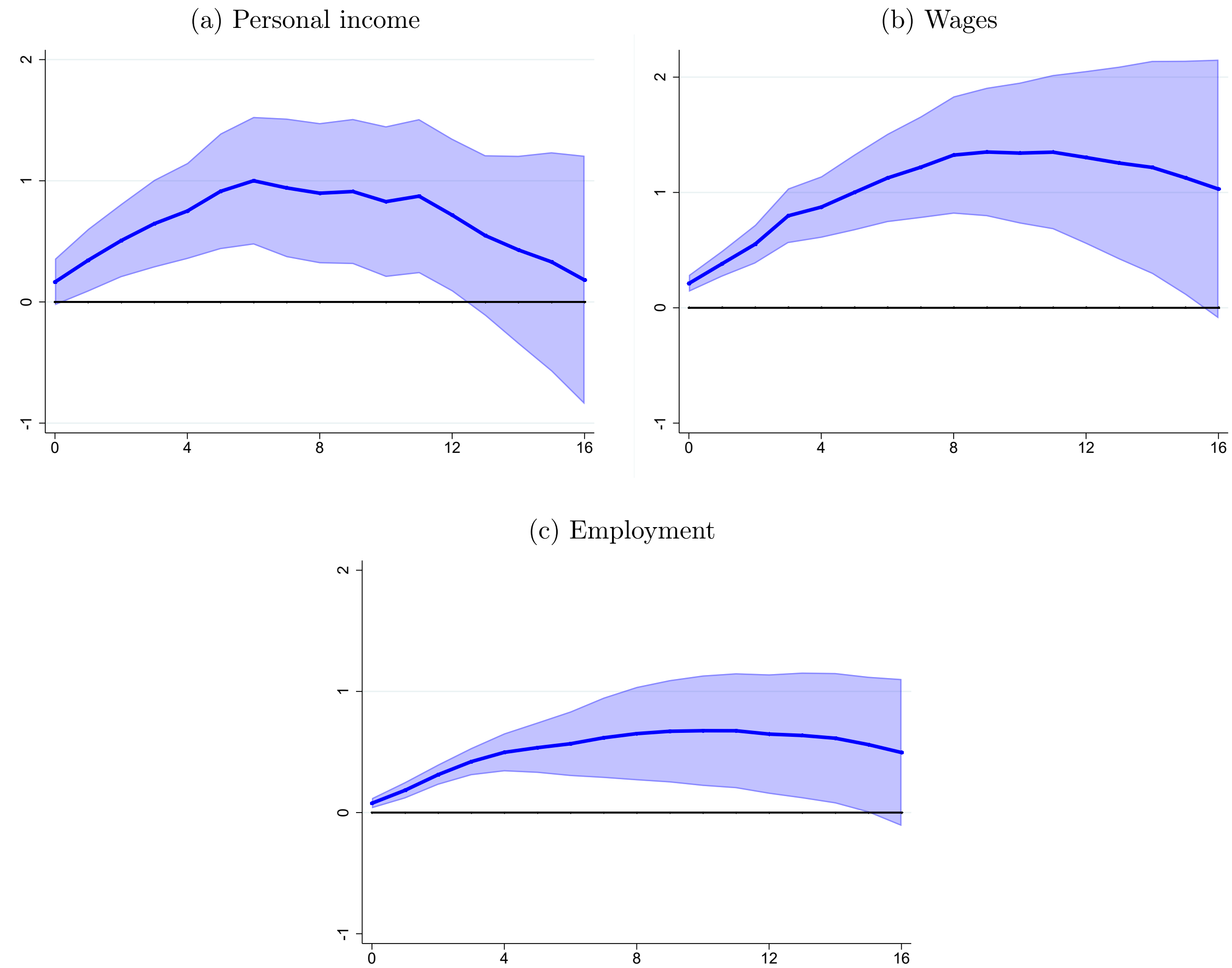
4.1 Baseline Results

In our baseline specification, we investigate how the share of young firms affects the response of state-level personal income, wages, and employment to a contractionary monetary policy shock. We define young firms as those that are 5 years old or younger, while the monetary policy shock is measured using 3-month ahead Fed Funds futures. We estimate the specification in equation 2 and report the corresponding results in Figure 4.

In each panel of Figure 4, we plot the estimated β_h coefficient at different horizons $h = 0, ..., 16$. We plot the response beginning in the quarter in which the monetary policy shock is observed and ending 16 quarters ahead. The considered forecast horizon places the analysis firmly in the short to medium term. The coefficient is normalized such that it represents the difference in the response of the dependent variable (in percentage points) to a 25 basis point tightening in a state whose share of young firms is one standard deviation above the mean. In other words, the estimates show how a one standard deviation increase in the fraction of young firms affects the response of the dependent variable to a positive 25 basis point monetary policy shock. Coefficients are reported using the solid blue lines and expressed in percentage points, while the shaded area is the 90 percent confidence interval obtained using Driscoll-Kraay errors. Panels (a), (b), and (c) in Figure 4 report the response of state-level personal income, wages, and employment respectively.

The main result from our baseline specification is that firm demographics do matter for the transmission of monetary policy and the effects are quite persistent. We find that the transmission of monetary policy to income, wages, and employment is weaker in states with more startups. In particular, all three interaction effects are positive and hump-shaped, and the coefficients remain significant for many quarters after the initial shock. This result indicates that monetary policy becomes less powerful when the share of young firms increases.

Figure 4. Business Dynamism and Monetary Policy Transmission



(a) Personal income

(b) Wages

(c) Employment

Notes: The solid blue lines show the coefficients on the interaction term between the monetary policy shock and the fraction of young firms. The size of the monetary policy shock is normalized to 25 basis points; the share of young firms is normalized by dividing it by its standard deviation. Coefficients are reported in percentage points over an horizon of 16 quarters. The shaded areas are 90 percent confidence intervals calculated using Driscoll-Kraay errors. All dependent variables are in log levels.

Panel (a) of Figure 4 shows that contractionary monetary policy shocks reduce personal income significantly less in states with a larger fraction of young firms. From a quantitative perspective, a 25 basis point monetary policy tightening reduces personal income by 1 percentage point less after 6 quarters in a state with a one-standard deviation higher share of young firms, all else equal. The effect of business dynamism remains significant out to 3 years. We obtain similar results when we use wages rather than personal income in panel (b). However, in this case the effect is quantitatively larger and more persistent. The coefficient reaches its peak after 9 quarters at 1.35 percentage points before decreasing, while remaining statistically significant for 15 quarters.

Panel (c) reports the response of state-level employment. As with personal income and wages, states with a higher fraction of young firms witness a smaller reduction in employment following a monetary policy tightening. A 25 basis point monetary policy tightening reduces employment by 0.75 percentage points less in states where the share of young firms is one standard deviation higher than the mean after 10 quarters, all else equal. This effect starts declining after 10 quarters, but it is still significantly different from zero until 15 quarters after the shock.

In order to extend our baseline quantitative assessment, we take a similar approach to that of Auerbach and Gorodnichenko (2012) and Tenreyro and Thwaites (2016). We split our sample into *young*-firm and *old*-firm states, defined according to the distribution of the share of young firms, and compare the IRFs in these two different groups of states estimating the following specification:

$$\begin{aligned} \log\, y_{s,t+h} = \beta_h^{low} D_{s,t}^{low} \epsilon_t + \beta_h^{high}(1 - D_{s,t}^{low})\epsilon_t + \gamma_h D_{s,t}^{low} + \psi_h(1 - D_{s,t}^{low}) \\ + \Gamma' X_{s,t} + \mu_h C_t + f(t) + \alpha_{s,h} + u_{s,t+h}\,, \end{aligned} \tag{3}$$

where $D_{s,t}^{low}$ is a dummy variable equal to 1 if state s is in the bottom half of the distribution of $z_{s,t-1}$ at time t (i.e., a *young*-firm state), and $f(t)$ is a cubic time trend. To estimate the effects of monetary policy on macroeconomic variables, we include the monetary policy shocks, ϵ_t, and drop the time fixed effects from the regression.[18] Instead, we add as explanatory variables a cubic time trend $f(t)$ and a vector of U.S.-level macro-financial controls, C_t, which includes: two lags of the log of personal consumption expenditure price index, log real GDP, log unemployment, and log Commodity Research Bureau spot commodity index and the level of the Fed Funds rate.

The coefficient β_h^{low} measures the impact of monetary policy shocks in the 25 states where the share of young firms is below the median value observed at the time of the shock. Symmetrically, β_h^{high} captures the transmission of monetary policy in the 26 states with the highest business

[18]Since we interact ϵ_t with D_t^{low} and $1 - D_t^{low}$, we do not include the monetary policy shocks in the regression to avoid multi-collinearity.

dynamism. We group states according to the distribution of z_t at each t rather over the whole distribution to account for unobservable aggregate conditions, which were previously controlled for via time dummies and could cause a bias in our estimates if omitted. Moreover, given the secular evolution in business dynamism presented in Section 3.2, considering the overall distribution would be almost equivalent to splitting the sample along the time dimension.

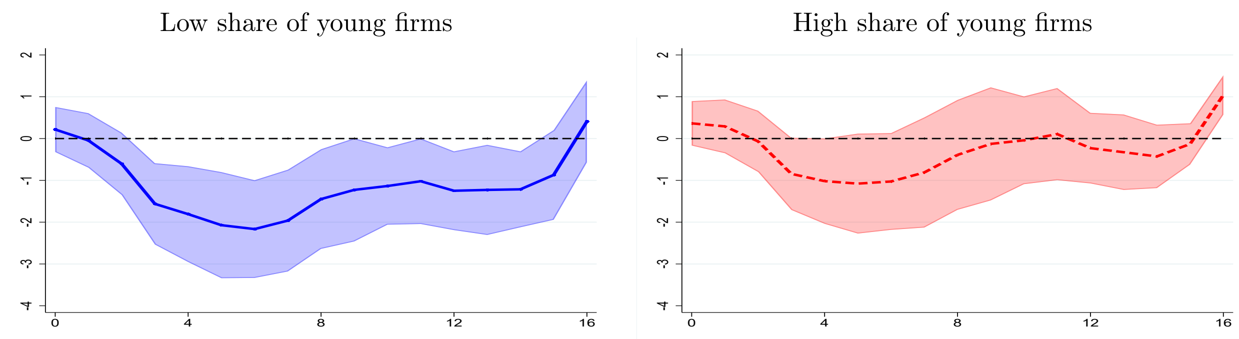
Figure 5 reports the IRFs in states with a high (dashed red line, right panels) and low (solid blue line, left panels) young firms' share, together with the corresponding confidence bands. Consistent with the vast literature on the topic, monetary policy shocks negatively affect personal income, wages, and employment over the medium term. However, these variables' response is significantly weaker in states with a higher fraction of young firms. In particular, the IRFs for states in the top half of the firm age distribution are statistically significant only for the response of employment, and in this case barely and only for few quarters (bottom right panel). On the contrary, the effects of monetary policy shocks in states where the fraction of young firms is relatively low are much stronger and lead to a significant fall in income, wages, and employment, with the U-shaped IRFs remaining negative and statistically significant up to 3 years after the shock.

Importantly, these findings allow us to better understand the magnitude of the benchmark estimates reported in Figure 4, and thus the importance of the role played by business dynamism in the transmission of monetary policy. For instance, a 25 basis point contractionary shock produces a fall in employment equal to about 1 percentage point after 10 quarters in states with a lower fraction of young firms, while the decrease is only 0.5 percentage points (and not statistically significant) in the other states.[19]

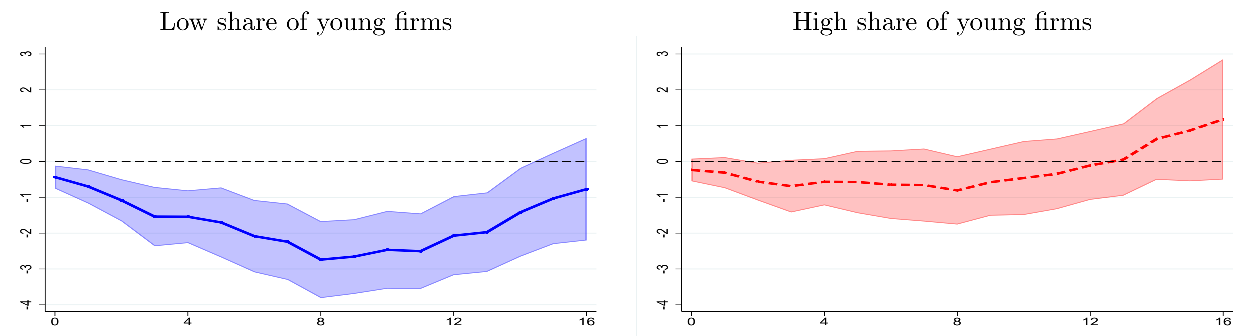
[19] It is worth noting that the response of personal income to monetary policy shocks is quantitatively consistent with the estimates of Leahy and Thapar (2019), who follow a similar approach. Other studies that focus on how the transmission of monetary policy varies across U.S. states include Carlino et al. (1999) and Fratantoni and Schuh (2003).

Figure 5. Effects of Monetary Policy in States with High and Low Business Dynamism

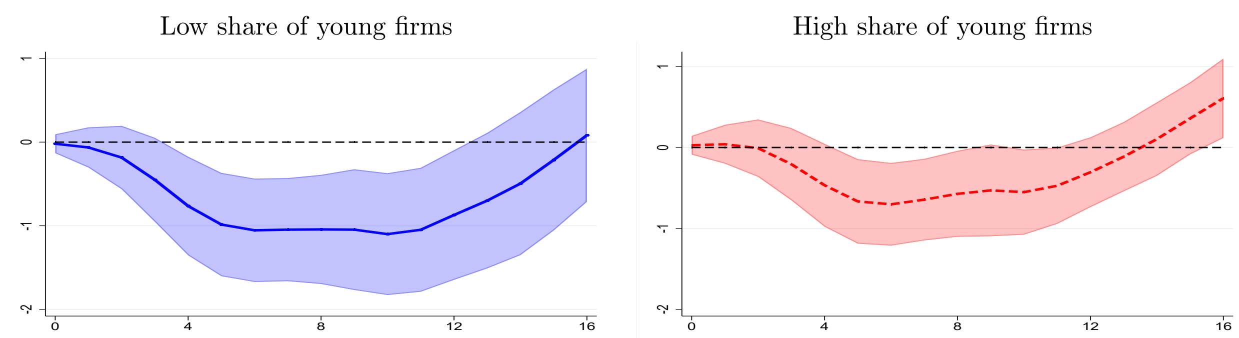
(a) Personal income



(b) Wages



(c) Employment



Notes: The solid blue lines in the left panels (dashed red lines in the right panels) show the coefficients on the interaction term between the monetary policy shock and a dummy equal to 1 for *young* (*old*) states. Young (old) states are defined as those with a share of young firms below (equal or above the median) in each quarter. The size of the monetary policy shock is normalized to 25 basis points. Coefficients are reported in percentage points over an horizon of 16 quarters. The shaded areas are 90 percent confidence intervals calculated using Driscoll-Kraay errors. All dependent variables are in log levels.

4.2 Alternative Measures of Business Dynamism

In this section, we perform several tests to gauge the robustness of our baseline results to considering different, but closely related, measures of business dynamism. Given the similar size and shape of results for personal income and wages, and that the latter is more directly affected by firm choices, we focus on the estimates for wages and employment only. We start by exploring if the role of firm demographics in shaping the propagation of monetary policy shocks changes when we include different, but closely related, measures of business dynamism.

Young firms also tend to be small. This implies a close link between firm demographics and the distribution of firm size. Moreover, since the seminal paper by Gertler and Gilchrist (1994), a vast literature has explored the role of firm size and age in the amplification of monetary policy shocks.[20] Therefore, in our first robustness test we add the share of small firms (i.e., firms with less than 500 employees) and its interaction with the monetary policy shock to the baseline specification in equation (2).

The results are presented in panel (a) in Figure 6, which shows the estimated coefficients on the interaction term between monetary policy shocks and the fraction of young firms (solid blue line) together with the coefficients on the interaction between monetary policy shocks and the share of small firms (dashed red line). Neither the magnitude nor the significance of baseline results are affected by conditioning on firm size. At the same time, the estimates show that the firm size distribution, as proxied by the share of small firms, has no significant effect on the transmission of monetary policy shocks. We also perform the same exercise using the share of micro (less than 20 employees), medium (between 500 and 999 employees), and large firms (1000 or more employees): we find that the results are very similar and we omit presenting them to conserve space.

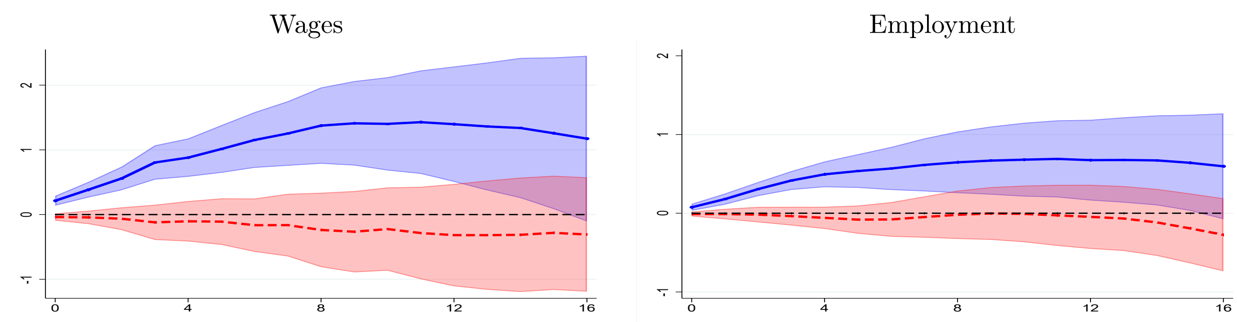
Evidence by Haltiwanger et al. (2013) suggests that young firms tend to have higher exit rates and exhibit higher rates of job destruction and job creation, meaning they are characterized by a higher job reallocation rate.[21] The relevance of the firm exit rate and job reallocation as proxies for the decline of business dynamism in the U.S. is also highlighted by Akcigit and Ates (2020).

[20] Among others, see Fort et al. (2013).

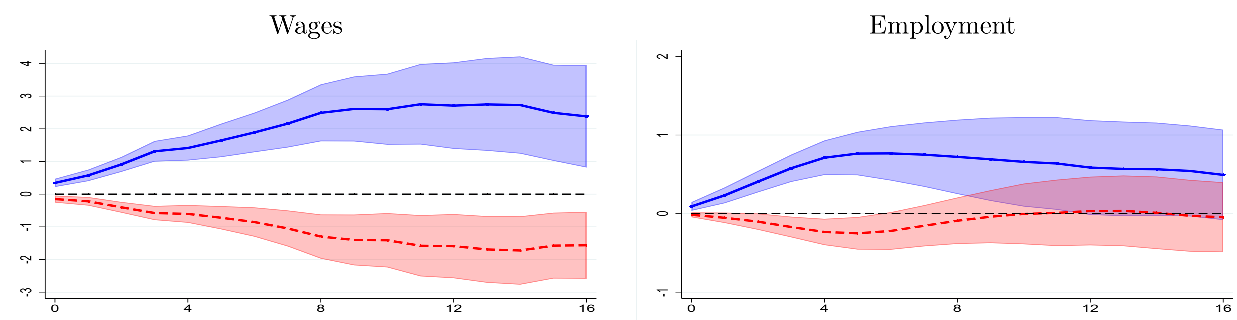
[21] In our sample, the correlation of the share of young firms with the exit rate and the job reallocation rate is 0.71 and 0.72, respectively.

Figure 6. Robustness: Other Measures of Business Dynamism

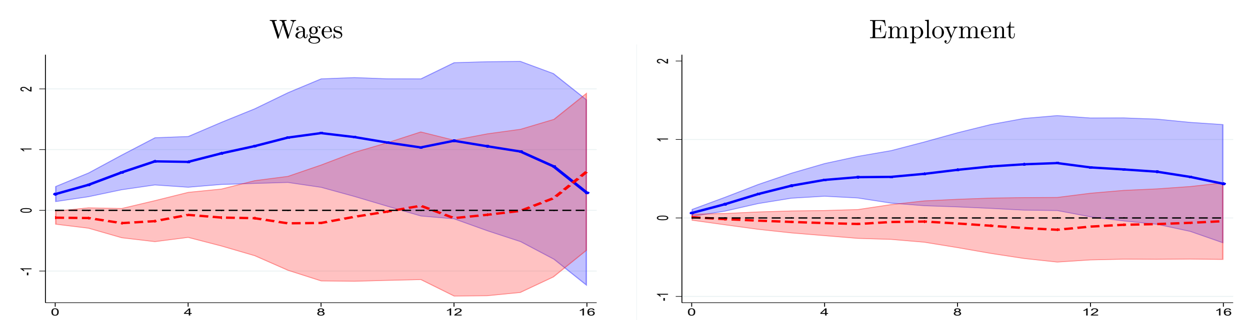
(a) Share of small firms



(b) Firm exit rate



(c) Job reallocation rate



Notes: The solid blue lines show the coefficients on the interaction term between the monetary policy shock and the fraction of young firms. The dashed red lines show the coefficients on the interaction term between the monetary policy shock and the share of small firms in panel (a), the firm exit rate in panel (b), and the job reallocation rate in panel (c). The size of the monetary policy shock is normalized to 25 basis points; the interacted variable is normalized by dividing it by its standard deviation. Coefficients are reported in percentage points and for 16 quarters. The shaded areas are 90 percent confidence intervals calculated using Driscoll-Kraay errors. All dependent variables (wages and employment) are in log levels.

To address concerns that the correlation between these measures of business dynamism and the fraction of young firms may drive our results, we augment the benchmark specification with the firm exit rate and its interaction with monetary policy shocks in panel (b), and with the job reallocation rate and the corresponding interaction with monetary policy shocks in panel (c) of Figure 6.

In contrast to the results from the share of small firms in panel (a), the exit rate significantly amplifies the transmission of monetary policy on wages, while it still has no effect for employment. Similarly to the share of small firms, the job reallocation rate has negligible effects. Despite these differences, our coefficients of interest keep their sign and magnitude in both robustness tests, except for the case of wages in panel (b) in which the coefficients become even larger. In terms of significance, the horizon over which the estimates are different from zero tends to shorten, but never falls below 10 quarters. The left figure in panel (b) is once again the exception, as the solid blue line is still highly above zero even after 16 quarters.

The overall picture that emerges from Figure 6 is that the effects of the share of young firms on the transmission of monetary policy shocks are not significantly altered when we control for other measures of business dynamism known to be correlated with the fraction of young firms. In addition, the alternative measures of business dynamism seem to play a negligible role in the transmission of monetary policy shocks vis-à-vis the share of young firms.

4.3 Population Demographics

As discussed in the introduction and literature review, recent studies document the role of population demographics for the transmission of monetary policy shocks. In light of this evidence, we assess the robustness of our main findings by augmenting the baseline specification with additional state-level measures of population demographics and their corresponding interactions with the monetary policy shock.[22] It is worth highlighting that we already include the lag of the (log) state population in the baseline specification.

In the first robustness exercise, we incorporate the findings by Hopenhayn et al. (2018), who connect the decline in U.S. business dynamism to a contemporaneous decrease in population growth,

[22] Consistent with the rest of the analysis, we normalize the additional control related to population demographics by dividing the variable by its standard deviation.

which in turn shifts the firm-age distribution towards older firms via a fall in the firm entry rate. We therefore include the state population growth rate and its interaction with monetary policy shocks among the explanatory variables.[23] Panel (a) in Figure 7 reports the estimated coefficients on the interaction terms between the monetary policy shock and the share of young firms (solid blue line) and between the monetary policy shock and the population growth rate (dashed red line). The baseline results for wages remain unchanged both quantitatively and qualitatively, while the estimates for employment become even larger and more statistically significant (peak response is around 1.4 percentage points and statistically different from zero over the entire forecast horizon). The coefficient on the interaction between monetary policy surprises and the population growth rate is never significantly different from zero when looking at the response of wages (left hand panels), while it points to a significant strengthening of the monetary policy transmission to employment (right hand panels).

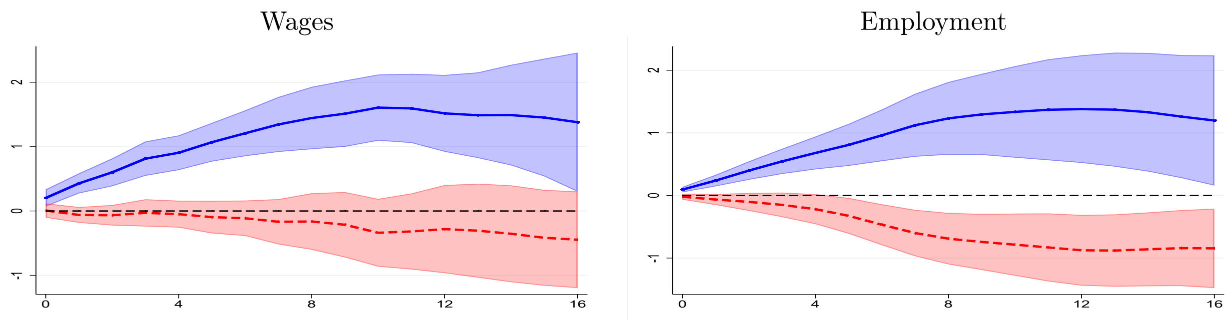
Next, we consider the work of Karahan et al. (2019) and Pugsley and Sahin (2019), who find that the fall in the working age population, defined as the fraction of people aged 25-54, is among the key drivers of the decline in firm entry in the U.S. economy. We therefore augment the baseline specification with the population share of workers of prime working age and its interaction with monetary policy shocks, and report the results in panel (b) of Figure 7. This exercise confirms the robustness of our findings. The impact of the share of young firms on monetary policy transmission is broadly unchanged, both in terms of magnitude and significance, when compared to Figure 4. At the same time, the population share of prime-age workers seems to matter more than the population growth rate because the corresponding coefficients become statistically different from zero towards the end of the horizon window.

In our final robustness test, we consider the role of middle-aged population in our main results. To this end, we include as a control the fraction of people aged between 40 and 64 years and its interaction with monetary policy shocks. Panel (c) of Figure 7 shows that despite the significant and negative correlation between the share of young firms and the fraction of middle-aged people across U.S. states, the effect of firm demographics on the transmission of monetary policy shocks is once

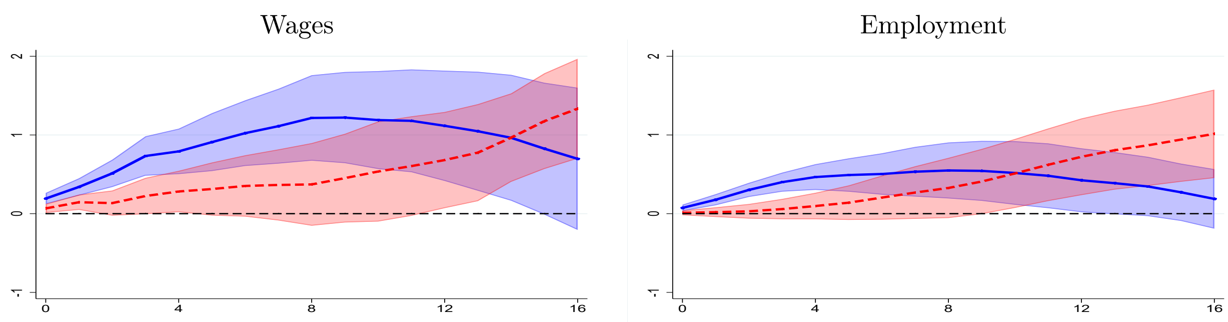
[23] To control for the state population growth rate, we include the difference between the first and second lag of the log population in the regression.

Figure 7. Robustness: Population Demographics

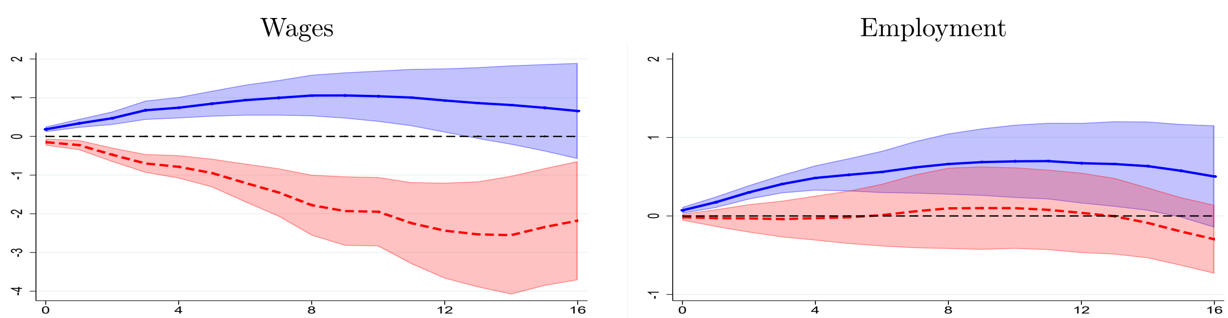
(a) Population growth



(b) Share of working-age population



(c) Share of middle-aged population



Notes: The solid blue lines show the coefficients on the interaction term between the monetary policy shock and the fraction of young firms. The dashed red lines show the coefficients on the interaction term between the monetary policy shock and the population growth rate in panel (a), the share of population aged 25-54 in panel (b), and the share of population aged 40-64 in panel (c). The size of the monetary policy shock is normalized to 25 basis points; the interacted variable is normalized by dividing it by its standard deviation. Coefficients are reported in percentage points and for 16 quarters. The shaded areas are 90 percent confidence intervals calculated using Driscoll-Kraay errors. All dependent variables (wages and employment) are in log levels.

again little changed when we add this additional control. It is worth noting that the inclusion of the fraction of people between 40 and 65 years generates a stronger response for wages, in accordance with the findings in Leahy and Thapar (2019). Differently from that study however, we find that the fraction of people between 40 and 65 years does not matter for the transmission of monetary policy to employment.

Take together, Figure 7 provides compelling evidence that our main findings are robust and not the results of a spurious correlation between firm and population demographics. Although these two variables are closely linked, the role of the share of young firms in influencing the transmission of monetary policy is largely unaffected by population demographics.

4.4 State Characteristics and Trends

In this section, we explore the robustness of our baseline results to the inclusion of additional state-level controls. First, we focus on the role of sectoral composition of firm activity, motivated by Galesi and Rachedi (2019) who show that the distribution of firms across sectors matters for the transmission of monetary policy. To this end, we exploit the available information in the BDS and include the share of manufacturing firms among the set of explanatory variables.

Panel (a) of Figure 8 presents results for the estimated coefficients on the interactions of monetary policy shocks and the share of young firms (solid blue line) as well as the interaction with the share of manufacturing firms (dashed red line). The baseline results are robust, both in terms of magnitude and statistical significance. On the contrary, the share of manufacturing firms only weakly mutes the transmission of monetary policy in the case of employment.[24]

More generally, a potential concern is that unobservable state characteristics may be driving our results. To test for this bias, we augment our benchmark specification with the interactions between monetary policy shocks and state fixed effects. Panel (b) of Figure 8 illustrates that our baseline results still hold and are, in some cases, even strengthened. The share of young firms continues to dampen monetary policy transmission, with the coefficients now larger and significant for about 12

[24] Very similar results are obtained when using the share of firms for each of the 9 broad sectors listed in the BDS: agriculture, forestry, and fishing; mining; construction; manufacturing; transportation, communication and public utilities; wholesale trade; retail trade; finance, insurance, and real estate; and services.

quarters in the case of wages or the entire horizon in the case of employment.

A related concern may be that secular changes occurring in specific states in the last 3 decades may be driving our results. To address this concern, we add a state-specific cubic time trend among the explanatory variables. The results are presented in panel (c) of Figure 8. It is worth emphasizing that we always include time dummies as covariates, meaning that we already control for trends that are common at the U.S. level. Focusing on the response of employment, the coefficient of interest is similar to what we obtain in the previous robustness exercises; however, in the case of wage, the interaction between the share of young firms and the monetary policy shock is only significant for the first 5 quarters and is smaller in size.

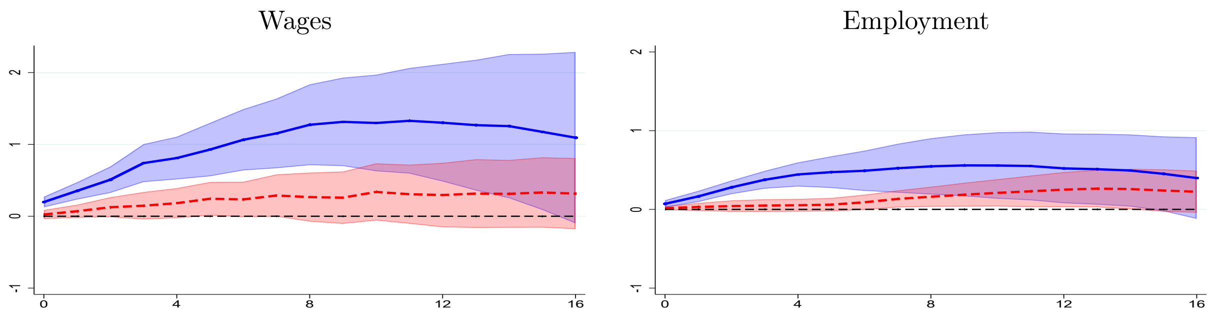
We also explore the possibility that our empirical findings are driven by outlier states. States greatly vary in terms of macroeconomic importance but are all given an equal weight in our panel estimation. We therefore perform two exercises: we first exclude in each quarter the five states with the lowest personal income and then the five with the highest. The baseline results continue to hold in both cases (panels (a) and (b) of Figure 11 in the Appendix). We also estimate specification (2) weighting observations by the state's relative size using personal income in each quarter. Again, we find that state size does not affect our baseline results.[25]

Finally we consider the role of credit availability and dynamics at the state level. To this end, we use data from the FDIC on the number of per capita bank branches and the growth rate of commercial and industrial bank loans in each state, and add these variables as controls to the benchmark specification. The estimates are not reported to conserve space as they are essentially identical to the baseline estimates, with only the confidence bands widening marginally.

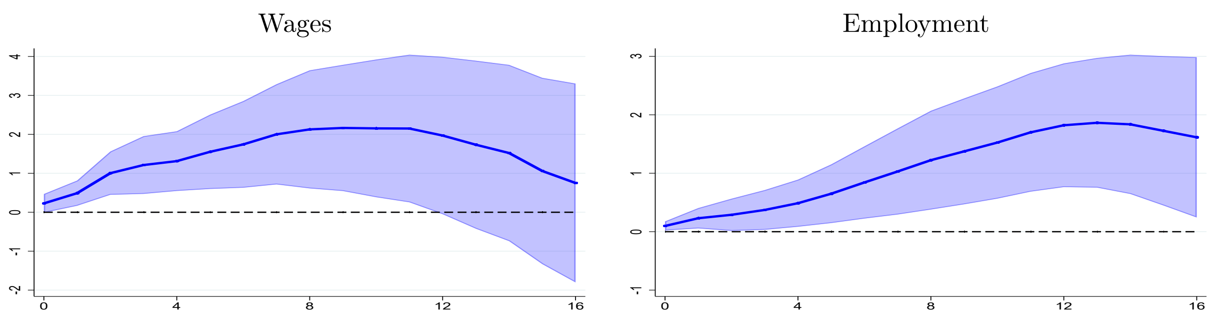
[25] Almost identical results are obtained when removing or weighing states based on their relative population rather than personal income. We omit presenting the corresponding figures to conserve space.

Figure 8. Robustness: State Trends and Characteristics

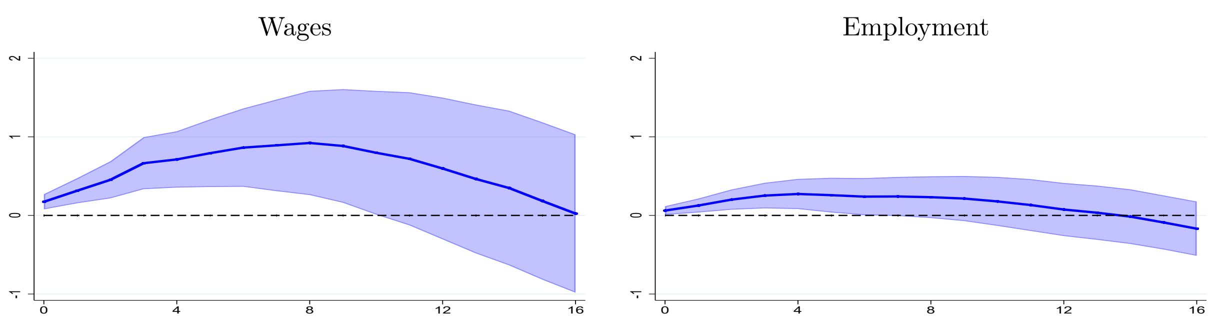
(a) Share of manufacturing firms



(b) Unobservable state characteristics



(c) State-specific trends



Notes: The solid blue lines show the coefficients on the interaction term between the monetary policy shock and the fraction of young firms. The dashed red lines in panel (a) show the coefficients on the interaction term between the monetary policy shock and the share of workers in the manufacturing sector. The benchmark specification (2) is augmented with the interaction between the monetary policy shock and the state fixed effect in panel (b), and a state-specific cubic time trend in panel (c). The size of the monetary policy shock is normalized to 25 basis points; the interacted variables are normalized by dividing it by its standard deviation. Coefficients are reported in percentage points and for 16 quarters. The shaded areas are 90 percent confidence intervals calculated using Driscoll-Kraay errors. All dependent variables (wages and employment) are in log levels.

4.5 Different Monetary Policy Shocks

The final set of robustness tests investigates the specific choice of monetary policy shocks. In particular, we address concerns that our baseline results may be driven by the size of the window used for the high-frequency identification, the inclusion of unscheduled FOMC meetings, or data availability in earlier periods.

We consider four alternative measures of monetary policy shocks. The first is the 3-month eurodollar deposit. Due to its long trading history, this measure allows us to extend our sample back to 1984. The second is the 2-year on-the-run Treasury yield, which allows us to study the effect of a change in the forward guidance component of monetary policy (for instance, see Hanson and Stein (2015)). The third is the change in the current month Fed Funds futures contract around a wide 60-minute window. This is a common choice in the literature (Gorodnichenko and Weber, 2016; Gürkaynak et al., 2005; Ottonello and Winberry, 2020). The final measure is the series of monetary policy shocks constructed by Nakamura and Steinsson (2018), which captures the effects of "forward guidance."[26] Importantly, this last measure only considers monetary policy surprises around scheduled FOMC meetings. To enhance comparability, we normalize all shock series to correspond to a 25 basis point tightening.

The results from this robustness exercise are shown in Figures 12 and 13, which are reported in Appendix A. The overall message is that our main result is robust to the choice of monetary shocks. One point worth noting here is that the fraction of young firms seems to matter less for the transmission of monetary policy shocks when we use the surprise in the 2-year on-the-run Treasury yield. In this case, the magnitude of the estimated coefficient becomes smaller and the significance disappears around 6 quarters after the initial shock.

[26] Specifically, Nakamura and Steinsson (2018) take the first principal component of the unanticipated change over a 30-minute window in five different interest rates at different maturities. They refer to this variable as the "policy news shock."

5 Possible Mechanisms

In the previous section we presented compelling evidence that higher business dynamism, measured by the fraction of young firms, weakens the effects of monetary policy. In this section, we discuss some possible drivers behind this result.

We start with a decomposition of the share of young firms. Recall that the fraction of young firms is given by:

$$Share\ of\ young_t = \sum_{i=0}^{5} \frac{N_t^i}{N_t^{tot}}\,, \tag{4}$$

where N_t^i is the number of business with age i in a given year t and N_t^{tot} denotes all the existing firms in the same year. The relative importance of each cohort i among young firms depends on the number of startups that were born in a given cohort and their survival rate. Indeed, the share of firms of age i at time t can be rearranged to yield:

$$\frac{N_t^i}{N_t^{tot}} = \frac{N_{t-i}^0}{N_{t-i}^{tot}} \times \frac{N_t^i}{N_{t-i}^0} \times \left(\frac{N_t^{tot}}{N_{t-i}^{tot}}\right)^{-1}\,. \tag{5}$$

Equation (5) shows that the share of firms of age i in year t is the product of the entry rate at time $t-i$ (N_{t-i}^0/N_{t-i}^{tot}), the survival rate of entrants from time $t-i$ to t (N_t^i/N_{t-i}^0), and the inverse of the overall growth rate of stock of firms in the economy (N_t^{tot}/N_{t-i}^{tot}).

As a result, the share of young firms may increase because (i) more startups entered the market in the previous 5 years, (ii) new entrants exited the market at a lower rate, and/or (iii) the growth rate in the overall number of firms decreased. To assess the relative importance of these three components in affecting the transmission of monetary policy, in our baseline specification (2) we replace the fraction of young firms with the average values of the entry rate, the startup survival rate, and the firm growth rate over the last 5 years.

Panel (a) of Figure 9 presents the estimated coefficients on the interaction terms between monetary policy shocks and the entry rate (solid blue line) and the survival rate (dashed red line), while the estimates for the growth rate of the stock of firms are reported separately in panel (b) to improve readability.

The effect of firm entry on monetary policy transmission to wages (left panels) is statistically significant for about 12 quarters with a peak value around 1 percentage point. In contrast, the effects of the survival rate or firm growth rate do not seem to matter for the transmission of monetary policy to wages, as seen by the weakly statistically significant coefficient estimates. The response of employment (right panels) also strongly depends on the entry rate, whose impact closely resembles that of the share of young firms in terms of magnitude, statistical significance, and persistence (e.g, panel (a) in Figure 4). Again, both the growth in the number of firms and the survival rate play a marginal role. All in all, the evidence from this decomposition suggests that the number of startups entering the market, rather then their survival rate or the growth in the stock of firms, plays a prominent role in muting the effects of monetary policy.

While equation (5) is useful to evaluate the role of different components of the share of young firms, there also are alternative decompositions that highlight the role of other factors. In particular, it is possible to decompose the share of young firms into the share of employment by young firms and their relative average size compared to that of all firms. Formally, we use the following decomposition:

$$Share\ of\ young_t = \frac{E_t^y}{E_t^{tot}} \times \frac{E_t^{tot}}{N_t^{tot}} \times \left(\frac{E_t^y}{N_t^y}\right)^{-1}, \tag{6}$$

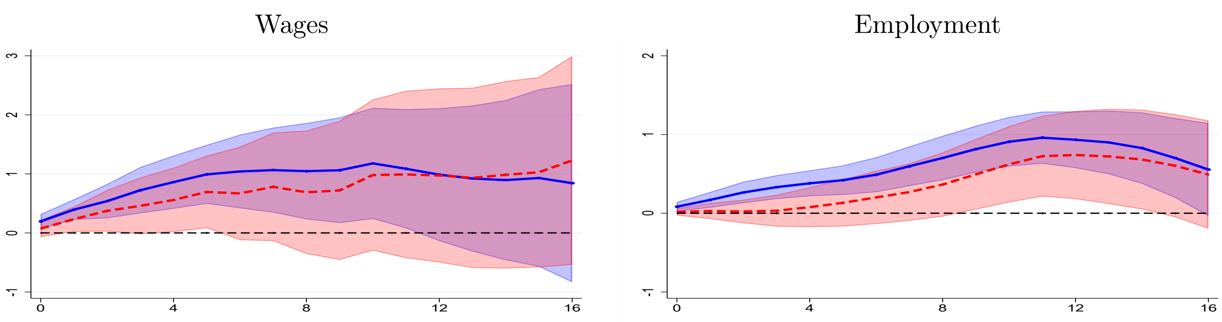
where E_t^y (N_t^y) denotes the number of workers employed by young firms (the number of young firms) in year t. The first term is the share of employees working in young firms, while the second term corresponds to the average size of all firms, defined as the number of employees per firm. The last term is the inverse of the average size of young firms. By taking logs, we can rewrite the above equation as:

$$\text{Log}(Share\ of\ young_t) = \text{Log}(Emp.\ share_{young}) - \text{Log}\left(\frac{Avg.size_{young}}{Avg.size_{tot}}\right), \tag{7}$$

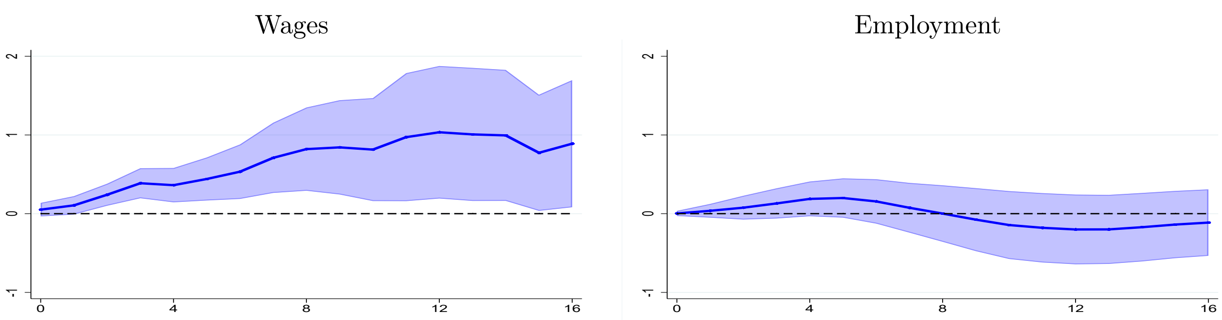
which shows how the log of the fraction of young firms is the difference of two components: the log of the employment share of these firms and the log of their relative size. This decomposition highlights how a large share of young firms can be associated with either a large fraction of workers

Figure 9. Decomposition of the Share of Young Firms

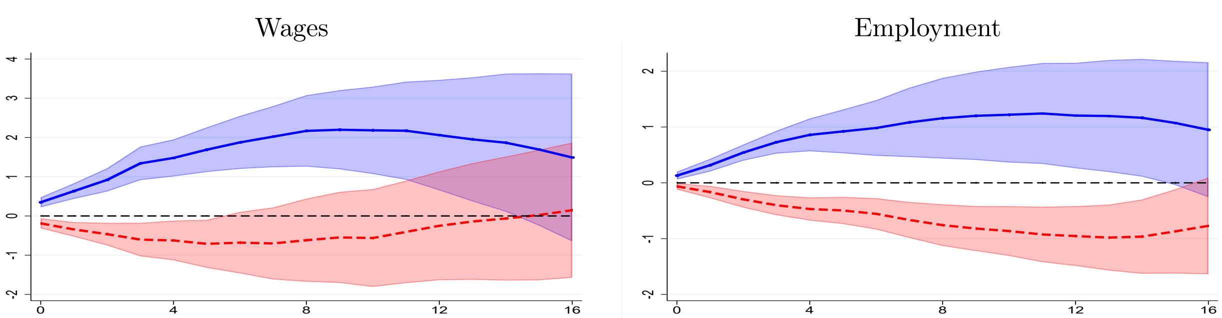
(a) Entry and survival rates of startups



(b) Growth in the number of firms



(c) Employment share and relative size



Notes: The solid blue (dashed red) lines show the coefficients on the interaction term between the monetary policy shock and the average share (survival rate) of startups over the previous 5 years in panel (a); between the shock and the average share growth of firms of startups over the previous 5 years in panel (b); between the shock and the employment share (relative size with respect to all firms) of young firms in panel (c). The size of the shock is normalized to 25 basis points; the interacted variables are normalized by dividing them by their standard deviation. Coefficients are reported in percentage points and for 16 quarters. The shaded areas are 90 percent confidence intervals calculated using Driscoll-Kraay errors. All dependent variables are in log levels.

employed by young firms, or a small relative size of young firms, or both. In other words, as the number of young firms increases, they will employ a higher number of workers, if their size remain constant. At the same time, an increase in the number of young firms will result in these firms being smaller if their overall employment is unchanged.

We proceed by incorporating the insights from equation (7) into our analysis. First, we construct the first two variables on the right hand side (the log of the employment share of young firms and the log of of their relative size) using data from the BDS. Next, we add these variables to the baseline specification in place of the share of young firms and report the estimates in Panel (c) of Figure 9.

The employment share by young firms (solid blue line), has a very similar role to the share of young firms in terms of effects on monetary policy transmission. The same conclusion does not apply to the relative average size (dashed red line), which is barely significant for the response of wages, while being negative and significant in the case of employment. Importantly, the signs of both coefficients are consistent with what one would expect from equation (7).

To mitigate concerns related to the high correlation (0.87) between the two variables on the right-hand side of equation (7), we regress the log of the share of young firms on the log of their employment share. The residuals from this regression (with the opposite sign) can be interpreted as the proportion of the relative average size of startups and all firms that is orthogonal to the employment share of young firms. The results (not reported) confirm the previous findings: the relative average size of young firms plays a minor role compared to their employment share.

Overall, the empirical evidence presented in this section provides support for two main results. First, among the components that make up the share of young firms, the entry rate is the main driver in explaining the muted response of the economy to monetary policy shocks. Considering two states with the same share of young firms, this finding implies that monetary policy is likely to be less effective in the state where the fraction of startups is higher than in the one where startups exit the economy at a slower pace. Second, the transmission of monetary policy becomes weaker as the share of employees in young businesses increases, while the relative size of young firms plays a marginal role in weakening the effects of monetary shocks.

6 Model

We develop a heterogeneous firm model to interpret the empirical evidence presented in Section 4. Consistent with data from surveys, we incorporate the fact that young firms are more likely to face external financing shortfalls because of their insufficient credit history. By embedding this mechanism in a model with firm entry and exit, we study how firm demographics and financial frictions affect the transmission of monetary policy. We begin by presenting evidence on the importance of firm credit history in obtaining external financing, we then describe the theoretical framework and briefly turn to its parameterization, and finally discuss the main results from the model.

6.1 The Role of Credit History

Our empirical findings clearly suggest that a higher share of young firms weakens the effects of monetary policy shocks on key macroeconomic variables. These results speak to the large literature that uses firm characteristics–such as age, size, and leverage–as proxies for financial constraints. However, as argued by Dinlersoz et al. (2018), these studies rely on datasets that do not report firm age, like the Quarterly Financial Report for Manufacturing Corporations (QFR), or do not include private firms, like Compustat. Importantly, our empirical analysis also provides evidence that the relative size of young firms with respect to incumbents does not matter for the transmission of monetary policy. In contrast, the entry rate seems to play a key role.

Overall, our results point towards the existence of firm-specific characteristics that are common among startups and makes them less responsive to monetary policy. To investigate such characteristics, we exploit data from the Federal Reserve Banks' Small Business Credit Survey (SBCS) (Federal Reserve Banks (2017)), which is conducted by the 12 Federal Reserve Banks and covers firms with fewer than 500 employees. It is worth noting that the SBCS covers employer firms, as in the BDS. To improve comparability between the datasets, we group firms using the same thresholds for age (5 years) and size (500 employees).[27]

[27] The 2017 report on startups is based on the 2016 SBCS and comprises 10,303 responses from employer firms in 50 states and the District of Columbia. Responses from firms 5 years old and younger were 2,159. Since the definition of startup was different in previous rounds of the survey (less than 3 years old), reports published prior to 2017 are not comparable.

According to the report, 69 percent of young firms that applied for credit faced a financing shortfall, meaning they obtained less than the amount they sought. Crucially, the SBCS also asks for the reasons behind credit denial. The lack of sufficient credit history is by far the most reported reason: 47 percent of young firms that experienced financing shortfall cite it versus only 13 percent of small firms older than 5 years. The gap is large and statistically different at the 95 percent level.[28]

It is worth emphasizing that the role of credit history in determining firms' access to credit does not depend on their riskiness. Looking at firms with a low credit score, 50 percent of young firms cite insufficient credit history as a reason for credit denial, compared to only 11 percent for mature firms. The corresponding share for medium- and high-credit-score firms is 47 and 15 percent, respectively. In both cases, the difference is statistically significant.

Another potential friction is lack of sufficient collateral. Collateral is often cited in the literature as an important driver of firms' access to credit. Indeed, 30 percent of young firms in the SBCS report this as a reason for credit denial, but so do 31 percent of mature small firms.

Overall, the empirical evidence from the SBCS suggests credit history plays an important role in explaining the difficulties experienced by young firms in accessing credit. This result seems not to be driven by differences in firm size, riskiness, or availability of collateral. By construction, insufficient credit history is linked to firm age, while independent of other firm characteristics, thus representing a friction that speaks to our empirical findings.

6.2 Theoretical Framework

Our model is in discrete time and with an infinite horizon. The economy consists of infinitely lived households and firms that are subject to idiosyncratic productivity shocks and face a constant death probability. The available sources of financing are profits and risk-free debt. We abstract from aggregate uncertainty.

[28]The methodology used in the SBCS adopts a balanced half sample approach to determine the standard errors around summary statistics.

6.2.1 Firms

In each period t there is a unitary mass of price-taking firms, who produce a homogeneous numeraire good. Because all firms are ex-ante identical, we focus on a single firm's problem first and then describe aggregation at the end of the section. Firms' production technology is given by:

$$y_t = z_t k_t^{\alpha} \ell_t^{\nu} \,, \tag{8}$$

where z_t denotes idiosyncratic productivity, k_t and ℓ_t are capital and labor, respectively, and $\alpha+\nu < 1$ so returns are decreasing in scale. Firm productivity follows the log-AR(1) process:

$$\log z_t = \rho \log z_{t-1} + u_t \,, \tag{9}$$

with $u_t \sim N(0, \sigma^2)$. We approximate this process using a Markov process with the conditional distribution given by $H(z_{t+1}|z_t)$ such that z_t takes values in the interval $[\underline{z}, \overline{z}]$.

Firms hire labor at wage w_t, which shows some degree of rigidity due to frictions in labor markets. We abstract from microfounding these frictions and assume staggered wage setting, which is widely used in the literature (see Blanchard and Galí, 2007). In particular, a fraction γ of workers cannot reset their wage, implying that $w_t = \gamma w_{t-1} + (1-\gamma) w_t^*$, where w_t^* is the wage that would arise in a frictionless labor market at time t.

Firms also invest in capital, whose price is equal to q_t. As is standard, capital is predetermined one period ahead and depreciates at constant rate δ. When investing, firms incur convex adjustment costs $\psi(k_{t+1}/k_t - (1-\delta))^2$, which is functional form commonly used in the literature.[29] Without adjustment costs, our model would imply excessive sensitivity of investment to variations in productivity shocks, which is at odds with the empirical evidence.

At the beginning of each period, a mass of new firms enters the economy. These startups receive an initial capital k_0 from the household and draw idiosyncratic productivity z_t from the invariant distribution $\mu^{ent}(z) \sim \log N\left(-m\frac{\sigma}{(1-\rho^2)^{-2}}, \frac{\sigma^2}{1-\rho^2}\right)$, with m capturing the difference in average pro-

[29] For instance, see Cooper and Haltiwanger (2006).

ductivity between startups and incumbents.[30] At the end of the period, a share $\pi_D \in (0,1)$ of all firms exits the economy and their undepreciated capital is returned to households. To maintain the total mass of firms constant over time, we assume that the number of startups and exiting firms are equal in each period.

As a result of firm entry and exit dynamics, there are two groups of firms in each period: (i) young firms (including startups) and (ii) mature firms. Young firms are aged 0 to 2 periods. In other words, they are the sum of new entrants and startup firms that have entered the market in the two last periods and did not exit (that is, they did not receive the death shock). A fraction $\lambda \in [0,1]$ of startups cannot borrow today, which reflects their lack of credit history. Moving forward, and conditional on survival, only a fraction λ of these firms continues to have insufficient credit history, while $(1-\lambda)$ of them gains access to the external funding. On the contrary, all mature firms can borrow.

To fund their capital investment k_{t+1}, firms can use their internal funds or issue risk-free debt b_{t+1}, if they can borrow. Given that it is not possible to issue new equity, dividends must be positive, that is $d_t \geq 0$. Firms also face two types of constraints when borrowing. First, the amount of debt must satisfy a no default condition as it is considered risk-free. Second, there exists a collateral constraint, meaning that debt cannot exceed some fraction $\chi \geq 0$ of the firm's capital.[31]

6.2.2 Capital Good Producer

The price of capital, q_t, is determined by the profit maximization problem of a representative capital good producer. Capital is produced using the technology given by $\Phi\left(I_t/K_t\right)K_t$, where I_t and K_t are aggregate investment and aggregate capital stock at time t, respectively. By taking the first order conditions, the price of capital is given by:

$$q_t = \left(\frac{I_t/K_t}{I^{SS}/K^{SS}}\right)^{1/\Phi} \tag{10}$$

[30]The choice to have startups with a lower productivity than incumbents is consistent with findings in Foster et al. (2016) and modeling assumption in Clementi and Palazzo (2016).

[31]A collateral constraint is widely used in the literature and debt is often set equal to a fixed fraction of capital since the seminal paper by Kiyotaki and Moore (1997).

where SS denotes the value in steady state.

6.2.3 Households

There is a continuum of infinitely lived households of unitary mass. Households have identical preferences over consumption and leisure given by:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\log(c_t) - \phi \frac{\ell_t^{1+\theta}}{1+\theta} \right) , \tag{11}$$

where β is the discount factor, ϕ measures labor disutility, and θ is the inverse Frisch elasticity.[32] The representative household supplies labor and lends to firms. Since the representative household owns all firms, she also receives all dividends, provides capital to startups, and obtains capital from exiting firms. The representative household's optimal choice of labor supply is denoted by $\ell^S(w_t, c_t)$.

6.2.4 Timing

Timing in a single period t runs as follows.

(i) A mass π_D of new firms enters the economy.

(ii) Every firm draws an idiosyncratic productivity realization. Mature and young firms' draw their productivity from the conditional distribution $H(z_t|z_{t-1})$, while new entrants' distribution is given by $\mu^{ent}(z_t)$.

(iii) Young firms draw their credit history shock: with probability $(1-\lambda)$ a startup firm can borrow, otherwise it cannot. Also, a fraction $(1-\lambda)$ of firms aged 1 and 2 that could not borrow in the previous period can now borrow. All firms aged 3 and over can borrow.

(iv) Firms hire labor, produce, and repay any outstanding debt b_t at the gross interest rate R^f.

(v) Firms receive an exogenous exit (or death) shock: with probability π_D, the firm leaves the economy, transferring its profits and undepreciated capital to the households.

[32] The Frisch elasticity of substitution measures the inter-temporal sensitivity of hours worked to the wage rate, given a constant marginal utility of wealth. See MaCurdy (1981).

(vi) All continuing firms purchase next period's capital k_{t+1}, financed through nominal debt b_{t+1} or through internal funds. All remaining resources are paid to households as dividends.

6.2.5 Value Functions

As we are looking for a stationary equilibrium in which aggregate and individual choices do not depend on time, we drop the time index t unless required for clarity. Profits in each period are given by

$$\pi(z,k) = \max_{\ell} \left\{ zk^{\alpha}\ell^{\nu} - w\ell \right\} , \tag{12}$$

thus, the choice of labor is static given a firm's productivity, capital, and the wage. We denote the firm's policy function for labor as $\ell^{D}(z,k)$.

The assumption that debt is risk free involves a borrowing constraint, as firms need to be able to fully repay debt and the associated interest payments in every state of the world. Given the timing assumptions described above, firms must repay their outstanding debt after producing but before issuing new debt. Formally, this implies that there exists a threshold for debt $\bar{b}_{t+1}$ such that:

$$\pi(\underline{z},k') + (1-\delta)q'k' - R^{f}\bar{b}(k') = 0\,. \tag{13}$$

The value function for a mature firm that can borrow, with productivity z, capital k, and outstanding debt b today is given by

$$\begin{aligned} V(z,k,b) = \pi_D \Big(\pi(z,k) + (1-\delta)qk - R^f b \Big) + (1-\pi_D) \max_{k'} \Bigg\{ & \pi(z,k) - R^f b \\ - \psi\left(\frac{k' - (1-\delta)k}{k}\right) - qk' + b' + \beta \sum_{z'} V(z',k',b')H(z'|z) & \Bigg\} \end{aligned} \tag{14}$$

subject to

$$\pi(z,k) - R^f b - \psi\left(\frac{k' - (1-\delta)k}{k}\right) \geq 0 \quad \text{and} \quad b' \leq \min\{\chi k, \bar{b}(k')\} \quad .$$

Equation (14) states that the firm exits with probability π_D, in which case it gets the current period production and undepreciated capital, net of debt expenses. If the firm does not exit, it chooses new capital k' and debt b' to maximize its continuation value, while subject to the non-negativity constraint for dividends. The choice of debt must satisfy two constraints: (i) it cannot exceed the threshold which would make it risky, given by equation (13), and (ii) cannot be larger than a fixed fraction of the firm's current capital. The firm takes expectations over next period's value V given the conditional distribution for productivity, H. We denote the policy function for capital as $k'(z,k,b)$ and for debt as $b'(z,k,b)$. For brevity, the value function of young firms are reported in Appendix B, while the distribution of firms is described in Appendix C.

An equilibrium consists of a set of value functions $V(z,k,b)$; policy functions $\ell^D(z,k)$, $k'(z,k,b)$, $b'(z,k,b)$; a distribution of firms $\mu(z,k,b)$; and prices such that: (i) firms optimize, (ii) households optimize, (iii) firm distribution is stationary, and (iii) all markets clear.[33]

6.2.6 Solving for Debt

Before proceeding with the parametrization and numerical solution of the model, we study the financing decisions of firms and sensitivity to changes in the interest rate. In particular, we show that the inability to borrow due to insufficient credit history hinders the growth of young firms and makes them less responsive to monetary policy, consistent with our empirical findings.

The problem of a firm with access to credit is given by the Bellman equation (14). By combining the first order conditions with respect to k_{t+1} and b_{t+1}, it is possible to show that the optimal choice for capital, k^*_{t+1}, satisfies:

$$\mathbb{E}_t z_{t+1}\alpha(k^*_{t+1})^{\alpha-1}\ell^{\nu}_{t+1} = R^f \,, \tag{15}$$

which compares the marginal benefit of borrowing to fund investment with the marginal cost of debt, which is the risk-free rate.[34] The above equation implies that it is optimal for firms to increase investment through debt issuance until the expected marginal return on capital is equal to the risk-free rate. However, not every firm can choose k^*_{t+1} due to the presence of the borrowing constraint.

Firms can be grouped into three categories depending on their debt policy. First, there are

[33] For more details, see Appendix D.
[34] For simplicity, we consider the case in which q_t is constant and equal to 1.

unconstrained firms that can select k^*_{t+1} and fund this choice entirely via internal funds by cutting their dividends to a non-negative value. For this reason, unconstrained firms are indifferent between any choice for debt, as long as $b_{t+1} \leq \bar{b}(k^*_{t+1})$.[35]

The second category of firms includes businesses that can achieve k^*_{t+1} but require external funding to do so. Relative to the previous group, these firms do not have enough dividends to finance their optimal investment policy. Therefore, firms in this category choose the amount of investment that satisfies equation (15), using all their internal funds and borrow the remainder, $b_{t+1} = k^*_{t+1} - d_t$.

Finally, there are constrained firms that are prevented from choosing the optimal level of capital because they do not have enough internal resources and cannot borrow as much as firms in the second group. One reason for this may be that these businesses lack sufficient collateral, implying that $b_{t+1} = \chi k_t$. Another possibility that applies exclusively to young firms is the lack of access to credit due to to insufficient credit history, implying $b_{t+1} = 0$.

Given this categorization, it is possible to study the effects of a change in the risk-free rate for each type of firm. For instance in response to a temporary interest rate cut, firms will find it optimal to increase their investment, according to equation (15). If all business were unconstrained or could borrow without restrictions, capital would immediately jump to the new optimal level within one period. In our model however, as the share of firms whose debt issuance is constrained increases, the effects of a reduction in the risk-free rate weaken. Taken to the extreme, in an economy in which no firm has access to credit, additional investment could not exceed the amount of dividends, significantly muting the impact of monetary policy.

Considering a temporary increase in the risk-free rate, firms will decrease their capital stock and thus borrowing constraints are unlikely to bind. However, lack of access to credit still plays a key role in muting the response of young firms' investment. Knowing that the interest rate will return to its previous level, firms anticipate that their optimal level of capital will increase after the initial fall. Firm that cannot borrow also anticipate that they not be able to issue debt to fund higher investment. As a result, these young firms find it optimal to reduce their capital stock less than

[35] When solving the model, we set $b_{t+1} = \chi k_t$ without loss of generality.

firm with access to external financing. Overall, the lack of access to credit mutes the response of firms' investment to temporary changes in the risk-free rate in both directions.

6.3 Parametrization

After explaining the key model intuition and mechanism, we turn to its calibration, illustrating the values assigned to parameters and describing the statistics in the data that the model aims at matching.

Table 4 reports the fixed parameters which we take from the literature. To match the quarterly frequency considered in our empirical analysis, we set $\beta = 0.99$. The parameters that govern the idiosyncratic shock for startups and other firms are those reported in Ottonello and Winberry (2020). Regarding the production function, we assume decreasing returns to scale and set $\alpha = 0.21$ and $\nu = 0.64$. The rate of capital depreciation is set equal to 0.025, while the cost of producing capital is captured by setting $\Phi = 4$, following Bernanke et al. (1999). We choose the adjustment cost parameter $\psi = 1.08$, as in Gourio and Miao (2010). The parameter on the degree of rigidity in real wage adjustment, $\gamma = .71$, reflects the empirical findings by Barattieri et al. (2014) and is needed to produce a co-movement between wages and employment, as observed in the data. We choose $\theta = 1.8$ such that the Frisch elasticity of labor supply is equal to 0.54, consistent with the range of estimates in Chetty et al. (2011).

The remaining parameters are calibrated to match specific moments in the data. Table 5 reports our choices and the targets. The disutility of labor, measured by ϕ, is chosen to generate an employment rate of about 70 percent, which is the average value observed over the period 1990-2018 covered by our empirical analysis. We set the parameter that governs the tightness of the collateral constraint to target the leverage ratio of 0.46, which is reported by Dinlersoz et al. (2018). As discussed in Section 6.1, the share of young firms that experience financing shortfalls due to insufficient credit history is equal to 0.47, that is 34 percentage points larger than in the case of mature firms. Given that in the model all mature firms can borrow, we choose $\lambda = 0.53$ so that 34 percent of young firms cannot issue debt since they lack credit history. Finally, we choose two parameters to match key moments related to firm demographics, computed using BDS data.

Table 4. Fixed Parameters

Description	Parameter	Value
Preferences and production		
Discount factor	β	0.99
Inverse Frisch elasticity	θ	1.8
Exponent on capital	α	0.21
Exponent on labor	ν	0.64
Capital production	Φ	4
Depreciation rate	δ	0.025
Productivity		
Shock persistence	ρ	0.9
Shock standard deviation	σ	0.03
Startups productivity	m	3.12
Frictions		
Adjustment costs	ψ	1.08
Wage rigidity	γ	0.71

Notes: Parameters exogenously fixed in the calibration. The Frisch elasticity of labor supply is taken from Chetty et al. (2011). The value of the parameter controlling capital production is from Bernanke et al. (1999). All the parameters related to firm (both startups and incumbents) idiosyncratic productivity come from Ottonello and Winberry (2020). The parameter on investment adjustment costs is taken from Gourio and Miao (2010). The wage rigidity parameter is taken from Barattieri et al. (2014). All the remaining parameter values are standard.

Specifically, the entry rate is set such that the share of young firms equals 0.34, while the initial capital of startups allows us to match the share of employment by young firms (0.13).

6.4 Results

Using the model and the calibration described above, we study the economic effects of a change in the risk-free rate.[36] Consistent with the empirical analysis, we consider an increase in the interest rate R^f of 25 basis points, which decays back to zero following a deterministic decaying process.[37] Given that there is no aggregate uncertainty, the transition paths from and to the steady state are

[36] The change in the risk-free rate is simulated by changing the discount factor because in equilibrium $R^f \times \beta = 1$.

[37] The decay rate equals 0.5 and implies that the interest rates returns to its steady state value within about 6 quarters. This speed of re-absorption is widely chosen in the literature (see Kaplan et al., 2018; Ottonello and Winberry, 2020)

Table 5. Fitted Parameters

Description	Parameter	Value	Target moment	Target value
Borrowing constraint	χ	0.82	Leverage ratio	0.46
Exogenous death rate	π_D	0.13	Share of young firms	0.33
Initial capital	k_0	0.97	Employment by young firms	0.13
Credit history	λ	0.53	Young firms with no credit history	0.34
Disutility of labor	ϕ	1.51	Employment rate	0.71

Notes: calibrated parameters and corresponding targets. The value of the leverage ratio comes from Dinlersoz et al. (2018). The share of young firms and their employment share are computed using BDS data. The share of young firms that face financing shortfall because of insufficient credit history is taken from the SBCS. The employment rate is expressed as a ratio of the population aged 15-64 and provided by the BLS.

computed under perfect foresight.

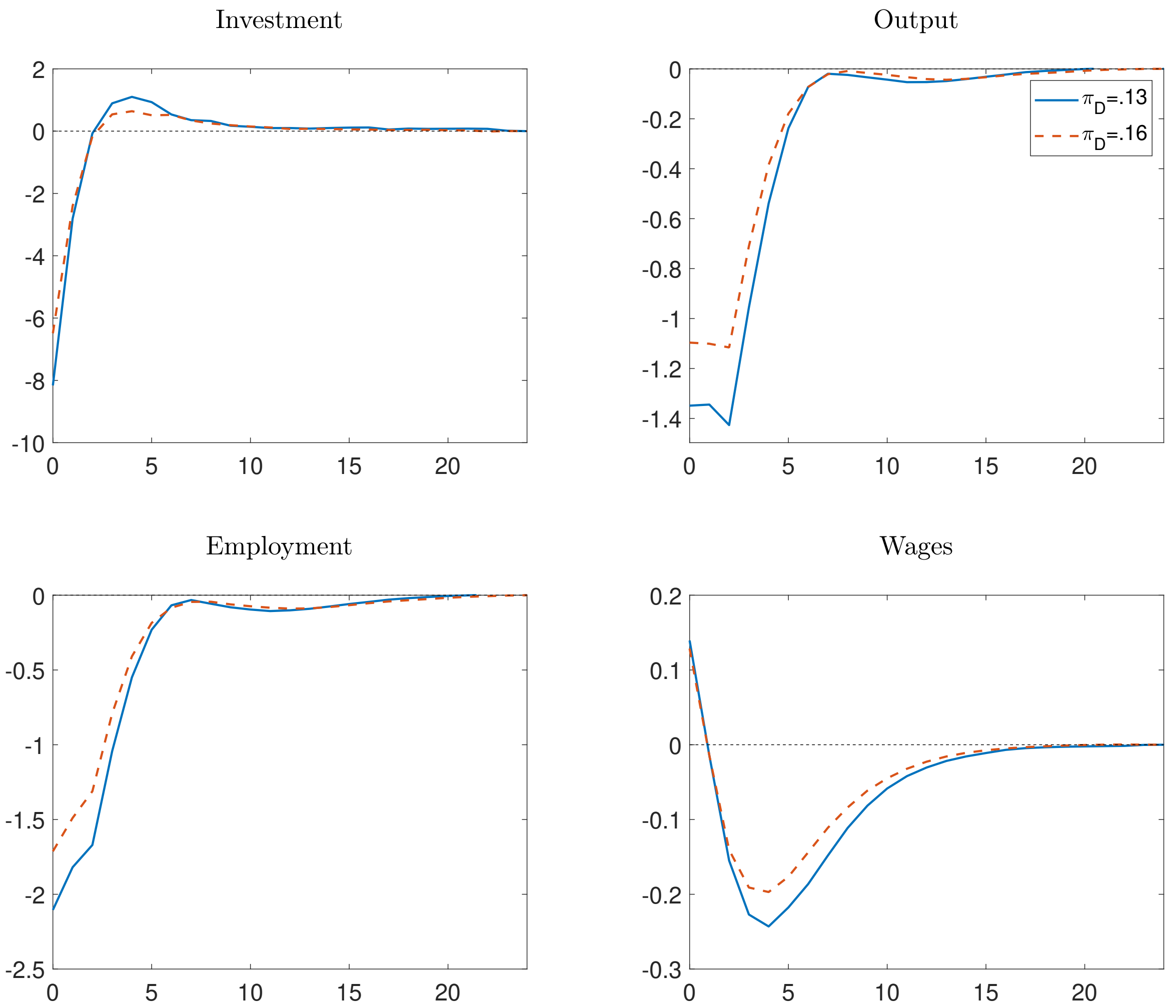
Figure 10 plots the response of four key macroeconomic variables, namely investment, output, wage, and employment (solid blue line). Importantly, consumption and wages are expressed in real terms. When hitting the economy in steady state, the shock to the interest rate generates a contraction in investment. Given the lower level of capital, the marginal productivity of labor reduces the demand for labor and therefore the level of wages.[38] The combined decrease in capital and employment results in a fall in output.

To assess the importance of young firms for the transmission of monetary policy, we study the effects of the same change in the risk-free rate in an economy with a higher share of young firms. In particular, we increase the entry rate so that in steady the share of young firms is now equal to 40 percent, which is one standard deviation higher than its median value over the period 1990-2018. The dashed red lines in Figure 10 report the results of this exercise. The macroeconomic effects of a temporary increase in the risk-free rate are now smaller, suggesting that a higher share of young firms mutes the impact of the interest rate shock.

From a qualitative perspective, the model is consistent with the empirical evidence presented in previous sections. Quantitatively, the role of the share of young firms in the transmission of monetary policy is captured by the distance between the solid blue and the dashed red lines in

[38] Wages initially increase because firms cut investment and pay out more dividends, decreasing the marginal utility of consumption of households and thus in their labor supply.

Figure 10. Responses to an Increase in the Risk-free Rate



Notes: The sold blue lines plot the response of investment, output, employment, and wages to a 25bps temporary increase in the risk-free interest rate under the baseline calibration described in Tables 4 and 5. The dashed red lines plot the responses when the entry rate is calibrated such that the share of young firms is 40 percent in the steady state.

Figure 10. In the case of output and employment, the difference amounts to about 0.4 percentage points. While the model is not developed to match the quantitative effects in our empirical findings, the difference in response between the two economies accounts for a significant share of the estimated coefficient reported for personal income and employment in Figure 4. On the contrary, the model's results are more distant from the empirical evidence when looking at the response of wages. A higher

share of young firms weakens the effects of a rate hike on real wage by 0.05 percentage points. These results point to a need for a richer model to better capture the response of labor market variables to monetary policy shocks. Importantly, similar results in terms of shape and magnitude, but with the opposite sign, are obtained when considering a decrease in the interest rate. As explained above, in this case the presence of firms with no access to debt limits the response of investment, in turn dampening the change in consumption, wages, an employment.

7 Conclusions

The secular decline in business dynamism has profoundly changed the productive landscape of the U.S. economy over the past 3 decades. This new landscape has implications for the transmission of aggregate shocks, as shown by a vast and growing literature.

Importantly, existing studies have largely overlooked how business dynamism may alter the propagation of monetary policy shocks. We contribute to filling this gap in the literature by exploiting the variation in firm demographics across U.S. states in order to isolate one dimension that seems to be particularly relevant for the effectiveness of monetary policy, namely the share of young firms. Using local projection estimates, we show that a larger fraction of young firms significantly mutes the effects of monetary policy on the labor market and personal income over the medium term.

The results are robust to a series of robustness tests that incorporate key findings in other studies. We also provide evidence that the weakening in the transmission of monetary policy works via two key channels: the entry rate and the share of employment by young firms.

Finally, we develop a heterogeneous firm model to interpret the empirical results. By incorporating the fact that young firms are more likely to face external financing shortfalls because of their insufficient credit history, the model generates responses to monetary policy that are consistent with the empirical evidence.

These findings have important policy implications, especially in light of the likely impact of the Covid-19 crisis on firm demographics. The magnitude of the recession and the possibility of a prolonged recovery may significantly affect business dynamism, including the entry rate and age structure of firms. In turn, these developments in firm demographics could alter the transmission of monetary policy, potentially affecting the central bank's ability to provide the needed monetary accommodation.

In future work we plan to extend the empirical analysis to other countries to study whether our results apply at the international level. We also intend to further develop our theoretical framework to provide additional insights into our empirical findings and better support policy-makers' decisions. A richer model that includes risky firms with endogenous exit would allow us to assess more precisely the role that different frictions play in explaining our empirical results. By embedding a New Keynesian block into our theoretical framework, we could study how firm demographics affect monetary policy transmission to prices. Ultimately, we would be able to address the still open question of why young firms respond less to monetary policy shocks and how to optimally incorporate this result into central bank decision-making.

References

Adelino, M., S. Ma, and D. Robinson (2017). Firm age, investment opportunities, and job creation. *The Journal of Finance 72*(3), 999–1038.

Akcigit, U. and S. T. Ates (2019). What happened to us business dynamism? Working paper 25756, National Bureau of Economic Research.

Akcigit, U. and S. T. Ates (2020). Ten facts on declining business dynamism and lessons from endogenous growth theory. *American Economic Journal: Macroeconomics Forthcoming*.

Auerbach, A. J. and Y. Gorodnichenko (2012). Measuring the output responses to fiscal policy. *American Economic Journal: Economic Policy 4*(2), 1–27.

Bahaj, S., A. Foulis, and G. Pinter (2020). Home values and firm behavior. *American Economic Review 110*(7), 2225–70.

Bahaj, S., A. Foulis, G. Pinter, and P. Surico (2019). Employment and the collateral channel of monetary policy. Bank of England working papers 827, Bank of England.

Barattieri, A., S. Basu, and P. Gottschalk (2014). Some evidence on the importance of sticky wages. *American Economic Journal: Macroeconomics 6*(1), 70–101.

Beck, T., A. Demirgüç-Kunt, L. Laeven, and V. Maksimovic (2006). The determinants of financing obstacles. *Journal of International Money and Finance 25*, 932–952.

Beck, T., A. Demirgüç-Kunt, and V. Maksimovic (2005). Financial and legal constraints to growth: does firm size matter? *Journal of Finance 60*, 137–177.

Berg, K. A., C. C. Curtis, S. Lugauer, and N. C. Mark (2019). Demographics and monetary policy shocks. Working Paper 25970, National Bureau of Economic Research.

Bernanke, B. S., M. Gertler, and S. Gilchrist (1999). The financial accelerator in a quantitative business cycle framework. *Handbook of macroeconomics 1*, 1341–1393.

Blanchard, O. and J. Galí (2007). Real wage rigidities and the new keynesian model. *Journal of Money, Credit and Banking 39*, 35–65.

Brunnermeier, M. K., T. M. Eisenbach, and Y. Sannikov (2012, May). Macroeconomics with financial frictions: A survey. Working Paper 18102, National Bureau of Economic Research.

Carlino, G., R. DeFina, et al. (1999). Do states respond differently to changes in monetary policy.

Business Review 2, 17–27.

Chetty, R., A. Guren, D. Manoli, and A. Weber (2011). Are micro and macro labor supply elasticities consistent? a review of evidence on the intensive and extensive margins. *The American Economic Review 101*(3), 471–475.

Clementi, G. L. and B. Palazzo (2016). Entry, exit, firm dynamics, and aggregate fluctuations. *American Economic Journal: Macroeconomics 8*(3), 1–41.

Clementi, G. L., B. Palazzo, and P. Wu (2019). Firm demographics and the great recession. Working paper.

Cloyne, J., C. Ferreira, M. Froemel, and P. Surico (2018). Monetary policy, corporate finance and investment. Working Paper 25366, National Bureau of Economic Research.

Cook, T. and T. Hahn (1989). The effect of changes in the federal funds rate target on market interest rates in the 1970s. *Journal of Monetary Economics 24*(3), 331–351.

Cooper, R. W. and J. C. Haltiwanger (2006). On the nature of capital adjustment costs. *The Review of Economic Studies 73*(3), 611–633.

Crouzet, N. and N. R. Mehrotra (2020). Small and large firms over the business cycle. *American Economic Review 110*(11), 3549–3601.

Davis, S., J. Haltiwanger, and S. Schuh (1998). *Job Creation and Destruction*. The MIT Press.

Decker, R. A., J. Haltiwanger, R. S. Jarmin, and J. Miranda (2016). Where has all the skewness gone? the decline in high-growth (young) firms in the us. *European Economic Review 86*, 4–23.

Dinlersoz, E., S. Kalemli-Ozcan, H. Hyatt, and V. Penciakova (2018). Leverage over the life cycle and implications for firm growth and shock responsiveness. Working Paper 25226, National Bureau of Economic Research.

Driscoll, J. C. and A. C. Kraay (1998). Consistent covariance matrix estimation with spatially dependent panel data. *Review of economics and statistics 80*(4), 549–560.

Faust, J., E. T. Swanson, and J. H. Wright (2004). Do federal reserve policy surprises reveal superior information about the economy? *The B.E. Journal of Macroeconomics 4*(1).

Federal Reserve Banks (2017). 2016 small business credit survey: Report on startup firms.

Fort, T. C., J. Haltiwanger, R. S. Jarmin, and J. Miranda (2013). How firms respond to business cycles: The role of firm age and firm size. *IMF Economic Review 61*(3), 520–559.

Foster, L., J. Haltiwanger, and C. Syverson (2016). The slow growth of new plants: Learning about demand? *Economica 83*(329), 91–129.

Fratantoni, M. and S. Schuh (2003). Monetary policy, housing, and heterogeneous regional markets. *Journal of Money, Credit and Banking*, 557–589.

Galesi, A. and O. Rachedi (2019). Services deepening and the transmission of monetary policy. *Journal of the European Economic Association 17*(4), 1261–1293.

Gertler, M. and S. Gilchrist (1994). Monetary policy, business cycles, and the behavior of small manufacturing firms. *The Quarterly Journal of Economics 109*(2), 309–340.

Gertler, M. and P. Karadi (2015). Monetary policy surprises, credit costs, and economic activity. *American Economic Journal: Macroeconomics 7*(1), 44–76.

Gorodnichenko, Y. and M. Weber (2016). Are sticky prices costly? evidence from the stock market. *American Economic Review 106*(1), 165–99.

Gourio, F., T. Messer, and M. Siemer (2016). Firm entry and macroeconomic dynamics: a state-level analysis. *American Economic Review 106*(5), 214–18.

Gourio, F. and J. Miao (2010). Firm heterogeneity and the long-run effects of dividend tax reform. *American Economic Journal: Macroeconomics 2*(1), 131–68.

Gürkaynak, R. S., B. Sack, and E. T. Swanson (2005). Do actions speak louder than words? the response of asset prices to monetary policy actions and statements. *International Journal of Central Banking 1*(1).

Gutiérrez, G. and T. Philippon (2019). The failure of free entry. Working paper 26001, National Bureau of Economic Research.

Haltiwanger, J., R. S. Jarmin, and J. Miranda (2013). Who creates jobs? small versus large versus young. *The Review of Economics and Statistics 95*(2), 347–361.

Hanson, S. G. and J. C. Stein (2015). Monetary policy and long-term real rates. *Journal of Financial Economics 115*(3), 429–448.

Hathaway, I. and R. Litan (2014). The other aging of america: The increasing dominance of older firms. Working paper, The Brookings Institution.

Hopenhayn, H., J. Neira, and R. Singhania (2018). From population growth to firm demographics: Implications for concentration, entrepreneurship and the labor share. Working Paper 25382, National Bureau of Economic Research.

Jordà, O. (2005). Estimation and inference of impulse responses by local projections. *American Economic Review 95*(1), 161–182.

Kaplan, G., B. Moll, and G. L. Violante (2018). Monetary policy according to hank. *American Economic Review 108*(3), 697–743.

Karahan, F., B. Pugsley, and A. Sahin (2019). Demographic origins of the startup deficit.

Kiyotaki, N. and J. Moore (1997). Credit cycles. *Journal of political economy 105*(2), 211–248.

Leahy, J. V. and A. Thapar (2019). Demographic effects on the impact of monetary policy. Working Paper 26324, National Bureau of Economic Research.

Lelarge, C., D. Sraer, and D. Thesmar (2010). Entrepreneurship and credit constraints: Evidence from a french loan guarantee program. In *International differences in entrepreneurship*, pp. 243–273. University of Chicago Press.

Liang, J., H. Wang, and E. P. Lazear (2018). Demographics and entrepreneurship. *Journal of Political Economy 126*(S1), S140–S196.

MaCurdy, T. E. (1981). An empirical model of labor supply in a life-cycle setting. *Journal of political Economy 89*(6), 1059–1085.

Marcellino, M., J. H. Stock, and M. W. Watson (2006). A comparison of direct and iterated multistep ar methods for forecasting macroeconomic time series. *Journal of econometrics 135*(1-2), 499–526.

Miranda-Agrippino, S. and G. Ricco (2020). The transmission of monetary policy shocks. *American Economic Journal: Macroeconomics Forthcoming*.

Moscarini, G. and F. Postel-Vinay (2012). The contribution of large and small employers to job creation in times of high and low unemployment. *American Economic Review 102*(6), 2509–39.

Nakamura, E. and J. Steinsson (2018). High frequency identification of monetary non-neutrality: The information effect. *The Quarterly Journal of Economics 133*(3), 1283–1330.

Ottonello, P. and T. Winberry (2020). Financial heterogeneity and the investment channel of monetary policy. *Econometrica Forthcoming*.

Plagborg-Møller, M. and C. K. Wolf (2020). Local projections and vars estimate the same impulse responses. *Econometrica Forthcoming*.

Pugsley, B. W. and A. Sahin (2019). Grown-up business cycles. *The Review of Financial Studies 32*(3), 1102–1147.

Ramey, V. A. (2016). Macroeconomic shocks and their propagation. In J. B. Taylor and H. Uhlig (Eds.), *Handbook of Macroeconomics*, Volume 2, pp. 71–162. Elsevier.

Ramey, V. A. and S. Zubairy (2018). Government spending multipliers in good times and in bad: evidence from us historical data. *Journal of Political Economy 126*(2), 850–901.

Robb, A. M. and D. T. Robinson (2014). The capital structure decisions of new firms. *The Review of Financial Studies 27*(1), 153–179.

Sedláček, P. and V. Sterk (2017). The growth potential of startups over the business cycle. *American Economic Review 107*(10), 3182–3210.

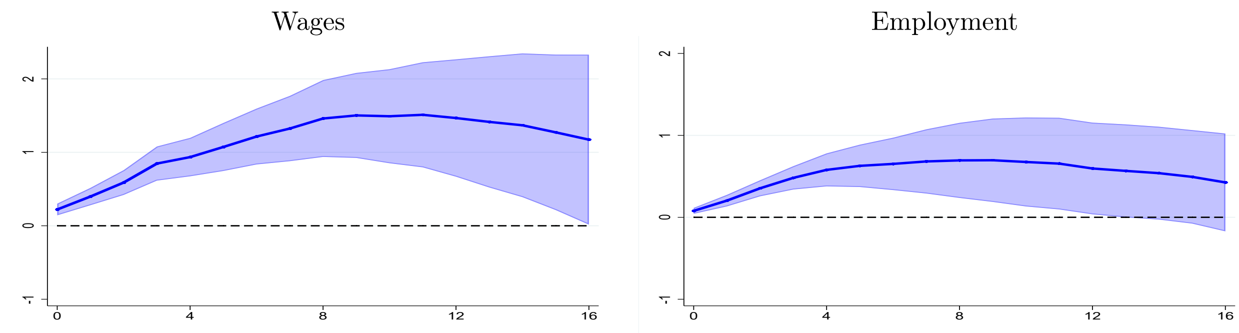
Tenreyro, S. and G. Thwaites (2016). Pushing on a string: Us monetary policy is less powerful in recessions. *American Economic Journal: Macroeconomics 8*(4), 43–74.

Appendices

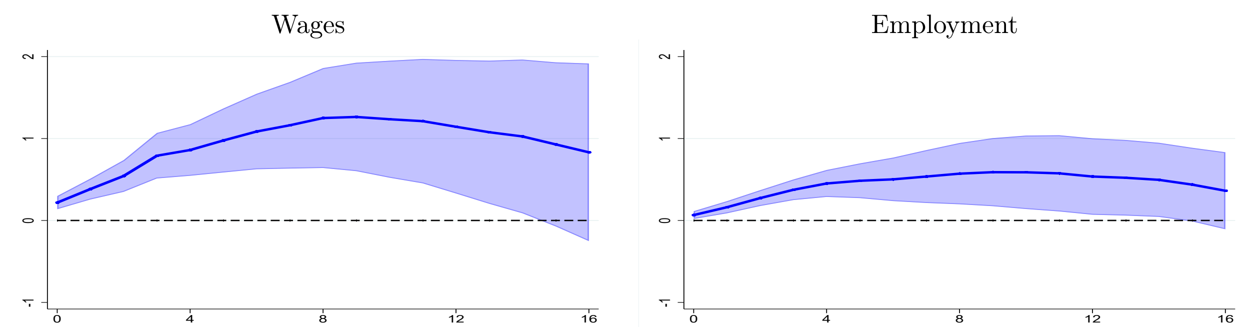
A Additional Robustness Exercises

Figure 11. State Size

(a) Small states

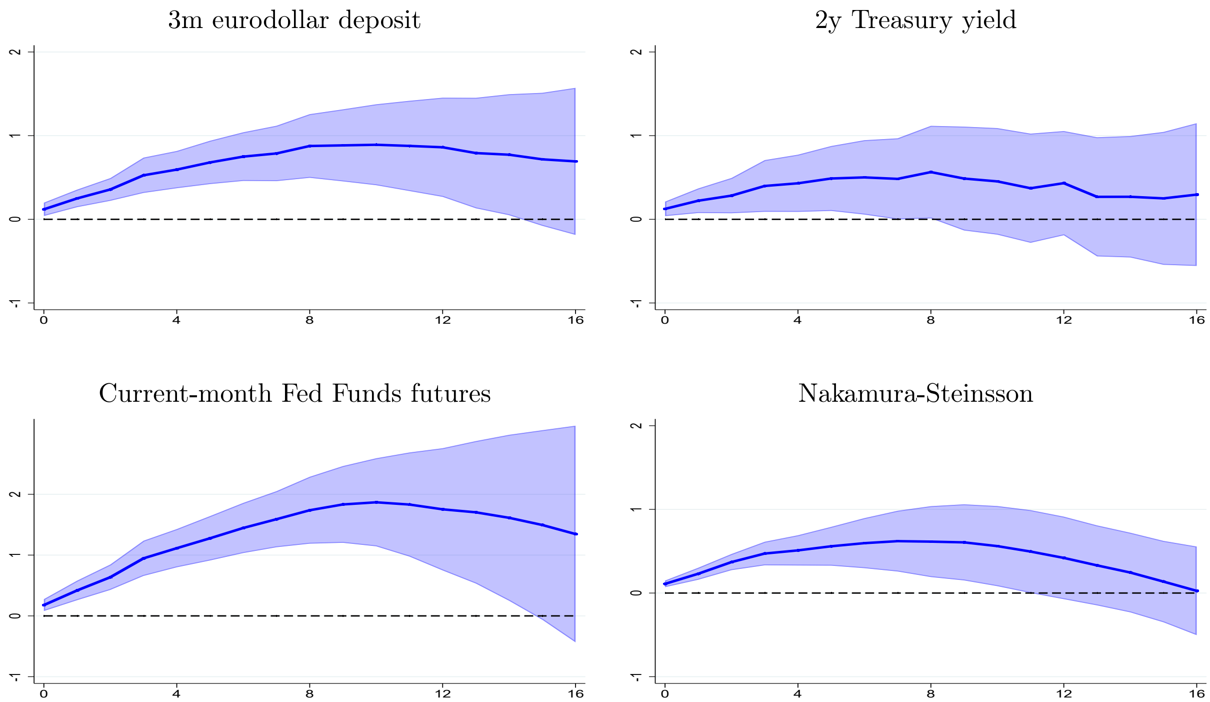


(b) Large states



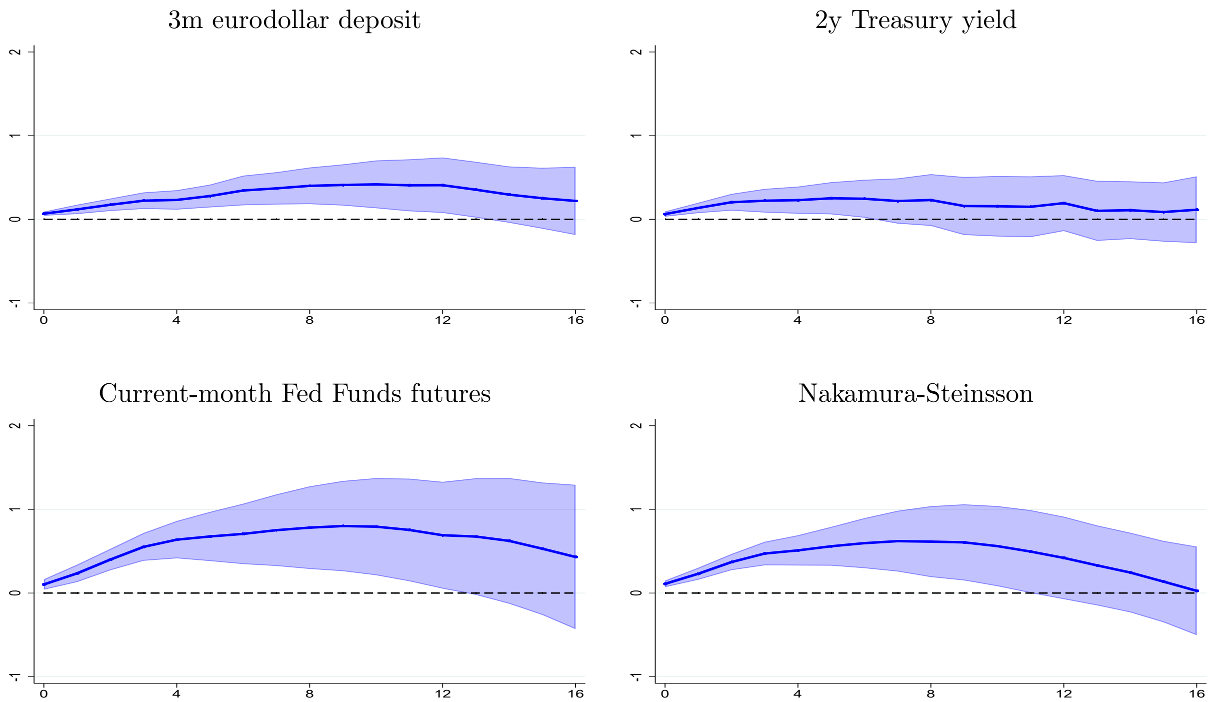
Notes: The solid blue lines show the coefficients on the interaction term between the monetary policy shock and the fraction of young firms. The 5 smallest and largest states in terms of personal income in each quarter are dropped from the sample in panel (a) and (b), respectively. The size of the monetary policy shock is normalized to 25 basis points; the interacted variable is normalized by dividing it by its standard deviation. Coefficients are reported in percentage points and for 16 quarters. The shaded areas are 90 percent confidence intervals calculated using Driscoll-Kraay errors. All dependent variables (wages and employment) are in log levels.

Figure 12. Alternative Monetary Policy Shocks: Wages



Notes: The solid blue lines show the coefficients on the interaction term between the fraction of young firms and different measures of monetary policy shocks. The various series of shocks are constructed using high-frequency event studies, as describes in section 3.1. The size of the monetary policy shock is normalized to 25 basis points; the share of young firms is normalized by dividing it by its standard deviation. Coefficients are reported in percentage points over an horizon of 16 quarters. The shaded areas are 90 percent confidence intervals calculated using Driscoll-Kraay errors. The dependent variable (wages) is in log levels.

Figure 13. Alternative Monetary Policy Shocks: Employment



Notes: The solid blue lines show the coefficients on the interaction term between the fraction of young firms and different measures of monetary policy shocks. The various series of shocks are constructed using high-frequency event studies, as describes in section 3.1. The size of the monetary policy shock is normalized to 25 basis points; the share of young firms is normalized by dividing it by its standard deviation. Coefficients are reported in percentage points over an horizon of 16 quarters. The shaded areas are 90 percent confidence intervals calculated using Driscoll-Kraay errors. The dependent variable (wages) is in log levels.

B Value Functions of Young Firms

The value function for a new entrant (age 0) is given by:

$$\begin{aligned} V_{ent}(z,k_0) &= \pi_D\big(\pi(z,k_0)+(1-\delta)qk_0\big)+(1-\pi_D)\max_{k'}\Big\{\pi(z,k_0)+(1-\delta)qk_0 \\ &- \psi\left(\frac{k'-(1-\delta)qk_0}{k_0}\right)-qk'+\beta\sum_{z'}\big(\lambda V_1(z',k')+(1-\lambda)V(z',k',0)\big)H(z'|z)\Big\} \end{aligned} \tag{16}$$

The value function for an age 1 firm that has been unable to borrow is:

$$\begin{aligned} V_1(z,k_0) &= \pi_D\big(\pi(z,k_0)+(1-\delta)qk_0\big)+(1-\pi_D)\max_{k'}\Big\{\pi(z,k_0)+(1-\delta)qk_0 \\ &- \psi\left(\frac{k'-(1-\delta)k_0}{k_0}\right)-qk'+\beta\sum_{z'}\big(\lambda V_2(z',k')+(1-\lambda)V(z',k',0)\big)H(z'|z)\Big\} \end{aligned} \tag{17}$$

Finally, the value function for an age 2 firm that has been unable to borrow is:

$$\begin{aligned} V_2(z,k) &= \pi_D\big(\pi(z,k)+(1-\delta)qk\big)+(1-\pi_D)\max_{k'}\Big\{\pi(z,k)+(1-\delta)qk \\ &- \psi\left(\frac{k'-(1-\delta)k}{k}\right)-qk'+\beta\sum_{z'}V(z',k',0)H(z'|z)\Big\} \end{aligned} \tag{18}$$

The policy functions for capital in these cases are denoted, respectively, by $k'_{ent}(z,k_0)$, $k'_1(z,k)$, and $k'_2(z,k)$.

C Distribution of Firms and Dividends

Before turning to the equilibrium, we briefly discuss the evolution of the distribution of firms and the dividends paid to households.

The distribution of age 1 firms with a given $(\hat{k},\hat{z})$ today that cannot borrow is comprised of new entrants last period who survived, did not receive credit, and transitioned into $(\hat{k},\hat{z})$.

$$\mu^1(\hat{z},\hat{k})=\pi_D(1-\pi_D)\lambda\sum_{z}\mathbb{1}\left\{\hat{k}=k'_{ent}(z,k_0)\right\}h(\hat{z}|z)\mu^{ent}(z) \tag{19}$$

The distribution of age 2 firms with a given $(\hat{k}, \hat{z})$ today that cannot borrow is comprised of age 1 firms last period who survived, did not receive credit, and transitioned into $(\hat{k}, \hat{z})$.

$$\mu^2(\hat{z}, \hat{k}) = (1-\pi_D)\lambda \sum_{z,k} \mathbb{1}\left\{\hat{k} = k_1'(z,k)\right\} h(\hat{z}|z)\mu^1(z,k) \tag{20}$$

The distribution of mature firms at time t is made up of four groups: surviving mature firms, surviving age 2 firms last period, and surviving age 1 firms and startups last period who received credit:

$$\begin{aligned}
\mu_t(\hat{z}, \hat{k}, \hat{b}) = (1-\pi_D) &\sum_{z,k,b} \mathbb{1}\left\{\hat{k} = k'(z,k,b)\right\} \mathbb{1}\left\{\hat{b} = b'(z,k,b)\right\} h(\hat{z}|z)\mu_{t-1}(z,k,b) \\
&+ (1-\pi_D) \sum_{z,k} \mathbb{1}\left\{\hat{k} = k_2'(z,k)\right\} \mathbb{1}\left\{\hat{b} = 0\right\} h(\hat{z}|z)\mu^2(z,k) \\
&+ (1-\pi_D)(1-\lambda) \sum_{z,k} \mathbb{1}\left\{\hat{k} = k_1'(z,k)\right\} \mathbb{1}\left\{\hat{b} = 0\right\} h(\hat{z}|z)\mu^1(z,k) \\
&+ \pi_D(1-\pi_D)(1-\lambda) \sum_{z} \mathbb{1}\left\{\hat{k} = k_{ent}'(z,k_0)\right\} \mathbb{1}\left\{\hat{b} = 0\right\} h(\hat{z}|z)\mu^{ent}(z)
\end{aligned} \tag{21}$$

for all $(\hat{z}, \hat{k}, \hat{b})$.

Each period, firm dividends depend on whether the firm can or cannot borrow. In addition, each firm may or may not receive the death shock, which affects their payments to households. In the case of a death shock, all firms pay their output less non-depreciated capital and debt payments. We denote this quantity as $D_x(z,k,b) = \pi(z,k) + (1-\delta)k - R^f b$. If the death shock does not occur, we must determine dividends for non-borrowers and borrowers separately. Starting with the non-borrowers, dividend payments are

$$D_0(z,k_0) = D_x(z,k_0,0) - \psi\left(\frac{k_{ent}'(z,k_0) - (1-\delta)k_0}{k_0}\right) - k_{ent}'(z,k_0)$$

for entrants, and

$$D_i(z,k) = D_x(z,k,0) - \psi\left(\frac{k_i'(z,k) - (1-\delta)k}{k}\right) - k_i'(z,k)$$

for young firms age $i = 1, 2$ with no credit. For firms that can borrow, dividend payments are

$$D(z,k,b) = D_x(z,k,b) - \psi\left(\frac{k'(z,k,b) - (1-\delta)k}{k}\right) - k'(z,k,b) + b'(z,k,b)$$

Aggregate dividends are therefore given by the following expression:

$$\begin{aligned}\overline{D}_t = \sum_{z,k,b}(1-\pi_D)D(z,k,b)\mu_t(z,k,b) + (1-\pi_D)\big[D_0(z,k_0)\pi_D\mu^{ent}(z) + D_1(z,k)\mu^1(z,k) \\ + D_2(z,k)\mu^2(z,k)\big] + \pi_D D_x(z,k,b)\big[\mu_t(z,k,b) + \mu^2(z,k) + \mu^1(z,k) + \pi_D\mu^{ent}(z)\big] \quad (22)\end{aligned}$$

D Equilibrium

An equilibrium consists of value functions $\pi(z,k)$, $V_i(z,k_0)$, $i = 0,1,2$, and $V(z,k,b)$, policy functions $\ell^D(z,k)$, $k'(z,k,b)$, $b'(z,k,b)$, $k'_i(z,k_0)$, $i = 0,1,2$, and $\ell^S(C,w)$, aggregate consumption C_t, a wage $w*$, a price of capital q_t, and a distribution of firms $\mu(z,k,b)$ such that (i) firms optimize, (ii) the household optimizes, (iii) the distribution of firms is consistent with decision rules and stationary, (iii) wages clear the labor market, and (iv) the price of capital clear the corresponding market.

(i) Firms optimize: $\pi(z,k)$ solves (12) with associated policy function $\ell^D(z,k)$. $V_0(z,k_0)$ solves (16) with associated policy function $k'_{ent}(z,k_0)$. $V_1(z,k)$ solves (17) and $V_2(z,k)$ solves (18) with associated policy functions $k'_1(z,k)$ and $k'_2(z,k)$, respectively. $V(z,k,b)$ solves (14) with associated policy functions $k'(z,k,b)$ and $b'(z,k,b)$.

(ii) The distribution of mature firms $\mu(z,k,b)$ is stationary, satisfies (21), and

$$\sum_{z,k,b}\mu(z,k,b) + \mu^2(z,k) + \mu^1(z,k) + \pi_D\mu^{ent}(z) = 1$$

(iii) Wages are given by the labor market clearing condition

$$\sum_{z,k,b} \ell^D(z,k)\big(\mu(z,k,b) + \mu^2(z,k) + \mu^1(z,k) + \pi_D \mu^{ent}(z)\big) = \ell^S(w,C)$$

where $\ell^S(w,C) = \left(\frac{w}{\phi C}\right)^{1/\theta}$.

(iv) Aggregate consumption is given by

$$C = w_t \ell^S(w,C) + \overline{D} + (R^f - 1)B$$

where aggregate dividends are given by (22) and aggregate debt is $B = \sum_{z,k,b} b\mu(k,z,b)$.