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Employment and the collateral channel of monetary policy

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Abstract

This paper uses detailed firm-level data to show that monetary policy affects employment through housing collateral and corporate debt. Our research design exploits the fact that many small and medium-sized enterprises use their directors' homes as a key source of collateral for corporate loans, but directors typically live in a different region to their firm. This spatial separation of firms from their collateral allows us to distinguish the collateral channel from local demand effects. We find that younger and more levered firms with higher exposure to housing collateral fluctuations adjust employment the most following a change in monetary policy. The collateral channel explains a sizeable share of the aggregate employment response.

Key words: Firm heterogeneity, residential collateral, financial accelerator.

JEL classification: D22, E52, R30.

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1 Introduction

It is well-established that the housing market is a key driver of the business cycle and that monetary policy has a sizeable causal effect on house prices.[1] This has generated renewed interest in the role of housing in the transmission of monetary policy. For instance, the recent generation of heterogeneous agent models emphasise the importance of illiquid wealth, of which housing is a major component, and argue that illiquidity in the household sector interacts with monetary policy's effect on labour demand to amplify the response of aggregate consumption. However, little is known (i) about which groups of firms drive the labour demand response, and (ii) whether the heterogeneity in firm-level responses is due to monetary policy affecting firm employment and borrowing decisions directly through house price fluctuations.

In this context, our paper provides novel empirical evidence on the transmission of monetary policy to firm employment via house prices and the collateral channel. Our research design exploits three key features of the micro data. First, a large share of small and medium-sized enterprises (SMEs), particularly those that are younger and more-levered, secure their borrowing against their directors' homes and firm activity is sensitive to the home value (Bahaj, Foulis, and Pinter, 2018). Second, there is significant regional dispersion in the sensitivity of house prices (and of directors' home values) to monetary policy. Third, most firms are located in a different region from where their directors live.

The spatial separation of firms from their collateral is instrumental in identifying the collateral channel of monetary policy separately from local demand effects of monetary policy on firms. More specifically, we are able to compare the employment response, to a monetary policy shock, of two firms that are located in the same region, in the same industry and share similar characteristics, except for their exposure to the collateral channel: one firm's director lives in a region where house prices are more sensitive to monetary policy compared to the other firm.

We use firm-level data for the period 1997-2017 from the UK that contains income statement and balance sheet information on a large sample of firms, dominated by SMEs, combined with unique information on firm directors and their housing wealth. We merge this data with a high-frequency measure of monetary policy surprises, constructed by Gerko and Rey (2017), following Gurkaynak, Sack, and Swanson (2005) and Gertler and Karadi (2015).

Our main results can be summarised as follows. First, firms change employment heterogeneously after a monetary policy shock, with younger and more levered companies being the most sensitive group and driving the aggregate response. Second, two thirds of younger and more levered firms secure their corporate borrowing against their directors' homes; this is more

[1] See for instance Mian and Sufi (2011, 2014); Piazzesi and Schneider (2016); Berger, Guerrieri, Lorenzoni, and Vavra (2017); Beraja, Fuster, Hurst, and Vavra (2018) for the role of house prices in macroeconomics and Del Negro and Otrok (2007); Jarocinski and Smets (2008); Jorda, Schularick, and Taylor (2015) for the effects of monetary policy on house prices.

than double the same statistics for older and less levered companies.[2] Third, our key finding: within the younger and more levered group, firms with directors living in a region with higher house price sensitivity adjust their employment significantly more than firms with directors living in a lower house price sensitive region. This effect is concentrated only at firms where the directors' homes exceed 15% of the firms assets in value, therefore representing a meaningful source of collateral. Furthermore, the pattern of heterogeneity is matched in other firm-level variables: corporate debt, working capital (in particular prepaid expenses) and fixed assets all respond in a similar fashion to a monetary shock.

We interpret these result to be consistent with monetary policy propagating through financial frictions (Kiyotaki and Moore, 1997; Bernanke, Gertler, and Gilchrist, 1999). Two key components of the theory are: (i) firms face financing constraints that (ii) are eased by positive asset price movements, generating amplification. We seek to identify both components in the data: (i) to the extent that younger and more levered firms face more severe financing constraints than older and less levered firms, our firm-level variation proxies the first component of the theory; (ii) the regional variation in the price sensitivity of collateral to monetary policy shocks proxies the second component, the extent of the asset price movement. Indeed, we also find that among older and less levered companies, the employment response is muted and independent of their exposure to director housing, consistent with the theory. Collateral price movements should be less relevant for firms that are less financially constrained.

It is well known that asset values also affect demand and through that employment. Key for our results is disentangling fluctuations in collateral values from changes in local demand faced by the firm. Our strategy based on using director real estate (as directors can live in different regions from their firm), allows us to include region-time fixed effects, thereby controlling for the linear effect of local demand on firms' behaviour. However, firms may have heterogeneous sensitivity to local demand's response to monetary policy. This may also explain our findings. For example, directors who live close to their firm would have similar house price sensitivities to the region where their firm is located. This, in turn, could generate correlation between the firm's local demand sensitivity and the director's house price sensitivity. We address this in a number of ways. First, we alter our research design by considering only those firms whose directors live more than 30 miles away from the firm's headquarters, thereby attenuating geographical spillovers of local demand in any particular region. Second, we focus only on those firms that should be insensitive to demand conditions in the local region, i.e. those operating in the tradeable goods sector (Mian and Sufi, 2014). Our results are very similar to the baseline. Third, we detect homogeneous effects of monetary policy on firm sales, especially in the short-run, consistent with a more limited role for aggregate demand in explaining the heterogeneity

[2]While data access motivates our focus on the UK, the use of housing as corporate collateral is common to many industrialised economies (see Bahaj, Foulis, and Pinter, 2018).

in firm employment responses.

In addition, our findings survive tests designed to address multiple potential confounds. We observe the same patterns of heterogeneity after controlling for creditor bank-time fixed effects to account for a potential bank lending channel and after controlling for proxies for heterogeneity in hiring frictions. We further show that average wages respond homogeneously across firms, suggesting our results are not driven by heterogeneity in wage stickiness. Our results are also robust to controlling for director-level characteristics that may determine director location as well as proxies for the size of any direct cashflow effects arising through changes in mortgage rates. Directors who only have a managerial role have less incentive than owners to pledge personal assets to support their firm. Hence if the collateral channel lies behind the heterogeneous response of monetary policy shocks, we would expect to see an effect only based on the house price sensitivity of those directors who are also shareholders in their firm. We therefore alter our research design by exploiting this variation between shareholder and non-shareholder directors, and find that the sensitivity to director location is entirely driven by shareholder directors.

Taken together, our findings are consistent with the presence of financial constraints, according to which firms with worse credit access either pre-pay their wage bills or fund other factors complementary to labour using loans secured against their directors' homes. Following a contractionary monetary policy shock, the value of the assets used as collateral declines, forcing less credit worthy firms (as proxied by age and leverage) to reduce their borrowing; this in turn leads to a shortfall of finance to pay for production factors and ultimately destroys jobs.

Related Literature The findings in this paper connect to the empirical literature on firm dynamics which studies the sensitivity of various groups of firms to business cycle fluctuations (Davis, Haltiwanger, and Schuh, 1996; Moscarini and Postel-Vinay, 2012; Fort, Haltiwanger, Jarmin, and Miranda, 2013; Sedlacek and Sterk, 2017; Crouzet and Mehrotra, 2017; Decker, Haltiwanger, Jarmin, and Miranda, 2018). Compared to these papers, we study the sensitivity of firms conditional on a monetary policy shock and to propose a research design which can uncover how much of this sensitivity is driven by balance sheet constraints. Moreover, we draw on a recent body of work emphasising that shocks to real estate prices affect firm activity by relaxing their financial constraints (Gan, 2007; Chaney, Sraer, and Thesmar, 2012; Catherine, Chaney, Huang, Sraer, and Thesmar, 2018; Bahaj, Foulis, and Pinter, 2018; Davis and Haltiwanger, 2019). We use insights from this literature to identify the collateral channel of monetary policy in the present paper. Finally, our results speak to the recent work on firm finance over the business cycle and the response to credit market disruptions (Chodorow-Reich, 2014; Liam and Ma, 2018; Begenau and Salomao, 2018; Drechsel, 2018) by establishing a tight and direct link between firm finance and the transmission of monetary policy.

An influential strand of research has shown that a rise in regional house prices fosters local demand (Mian and Sufi, 2011, Mian and Sufi, 2014), that local demand shocks are transmitted through firm balance sheets (Giroud and Mueller, 2017), and alter firm pricing behaviour (Stroebel and Vavra, 2019). We complement these studies by showing that, over and above any local demand channel, monetary policy induced changes in house prices can have an additional effect on firms' employment and investment decisions through their impact on collateral values and corporate borrowing.

Our paper contributes to the empirical literature on the role played by financing constraints in the transmission of monetary policy to firms (Gertler and Gilchrist, 1994; Kudlyak and Sanchez, 2017; Ottonello and Winberry, 2018; Jeenas, 2018; Cloyne, Ferreira, Froemel, and Surico, 2018 among others). Our work differs from these papers in three important dimensions. First, we use a near-representative sample (covering both the listed and non-listed sectors across all industries), that is dominated by SMEs; firms that are most likely to be financially constrained. In contrast, most existing firm-level studies on monetary policy transmission use datasets on publicly listed firms (e.g. Compustat, Worldscope), thereby limiting their focus on a smaller segment of the size and age distribution of firms. Second, we focus primarily on the effects of monetary policy on *employment* (rather than on *investment* as done by the recent literature), as SMEs explain the majority of job creation and job destruction in the economy. Third, we explore multiple proxies for financial constraints (e.g. firm age, size, leverage, credit score, price sensitivity of firm collateral) and use multidimensional sorting along these measures to detect not only the presence of, but also possible shifts in, firms' financial constraints.

Our paper is also related to the theoretical literature on the interactions between the macroeconomy, asset prices and financial markets (Kiyotaki and Moore, 1997; Bernanke, Gertler, and Gilchrist, 1999). Recent quantitative models (Jermann and Quadrini, 2012; Liu, Wang, and Zha, 2013; Christiano, Motto, and Rostagno, 2014; Linde, Smets, and Wouters, 2016) have confirmed the importance of financial frictions in explaining business cycle fluctuations. Our firm-level evidence complements these findings and corroborates the notion that financial frictions amplify the effects of monetary policy.

2 Theoretical Motivation

In this section, we draw on the existing literature and informally lay out the theoretical framework for our empirical analysis. Appendix C provides a formal setting for our arguments by considering a firm that chooses how much labour to hire subject to the need to obtain external finance to prepay wages.[3]

[3]Our reasoning is not reliant on prepaid wages, although our empirical results suggest this mechanism is relevant. If the firm needs to obtain external finance to invest in physical capital and labour is a complement

An optimising firm will equate the marginal benefit of hiring a worker with the marginal cost of the funds needed to pay the worker (see Figure 1). Monetary policy will shift this optimal choice of employment in a number ways. It will shift the demand for the firm's goods as well as the price of factor inputs thereby altering the marginal benefit of hiring a worker. In general, at least in the short-run, the marginal benefit is decreasing in the level of the interest rate, due to lower aggregate demand for the firm's goods and services, because the interest rate may determine the cost of other factors that are complementary to labour in production (e.g. physical capital) and last, potentially due to a cost channel if wages are paid in advance of production (Christiano, Eichenbaum, and Evans, 2005). In Figure 1, this is illustrated by a rightward shift in the downward sloping red curve, "MB", in response to an expansionary monetary policy shock.[4]

A number of papers in the macroeconomics literature have focused on the role of firm-level financial constraints in governing the response to aggregate shocks including monetary policy surprises (Bernanke, Gertler, and Gilchrist, 1999; Ippolito, Ozdagli, and Perez-Orive, 2017; Ottonello and Winberry, 2018). Financial constraints in Figure 1 are represented by the convex, upward-sloping blue, "MC", curve. This captures the marginal cost of funds, beyond the risk free interest rate, required to hire additional workers, which would arise in many standard models of financial constraints. How monetary policy affects the equilibrium employment at the intersection of these two curves is ambiguous. There are two competing mechanisms.

First, *ceteribus paribus*, a firm facing financial constraints should be less sensitive to shocks to the demand for external finance (see Farre-Mensa and Ljungqvist, 2016 and Ottonello and Winberry, 2018). The intuition is that constrained firms face a steeper (or potentially vertical) supply curve for funding, and hence any given shift in demand results in a smaller change in quantities. This is illustrated by comparing a constrained firm who faces a steeper MC curve (shown by the light blue curve in Figure 1) to an unconstrained firm for whom the marginal cost curve is relatively flat (shown by the dark blue curve in Figure 1). The shift in the MB curve in response to an interest rate shock results in a smaller increase in employment for constrained firms.

Second, key macroeconomic theories have emphasised that monetary policy alters the degree to which firms are financially constrained. Expansionary monetary policy shocks could shift the MC curve rightward and flatten it. This is the heart of the financial accelerator

to capital in production then we would obtain similar predictions.

[4]The MB curve is downward sloping due to a production function with decreasing returns to scale in labour. How much the MB curve in Figure 1 shifts in response to a monetary policy shock, may also be heterogeneous across firms. Indeed Gorodnichenko and Weber (2016) show that equity values of firms within industries with sticky prices are particularly sensitive to monetary policy shocks. However, to the extent that firms within the same industry face similar demand and input prices, and are similarly sensitive to the aggregate price level, controlling for industry should be sufficient to net out the heterogeneity in the response to monetary policy shocks.

mechanism (Bernanke, Gertler, and Gilchrist, 1999). By raising assets prices, the net worth of firms increases thereby increasing their borrowing capacity. If the asset price response is sufficiently large, then financial conditions can improve sufficiently for constrained firms so that they experience a larger employment response than unconstrained firms. This is illustrated by the dashed blue lines in Figure 1b. On the other hand, for unconstrained firms, this asset price response is irrelevant.

A main contribution of this paper is not only to consider multiple firm-level characteristics as proxies of financial constraints in the data, but also —key for assessing the mechanism— to determine the extent to which those constraints are affected by monetary policy shocks. That is, we are able to proxy at the firm-level the initial *steepness* of the blue curve as well as how much it *shifts* in response to a monetary policy shock.

The analysis above allows us to sharpen our empirical predictions. If financial constraints are relevant for explaining the heterogeneous firm-level response to monetary policy, then we would expect to see the following: (i) across unconstrained firms, heterogeneity in the sensitivity of collateral values to monetary policy shocks will not generate heterogeneous employment responses; (ii) across constrained firms by contrast, heterogeneous collateral value sensitivity will translate into heterogeneous employment responses. The next Section describes the data used to test these predictions.[5]

3 Firm-Level Data

In this section we lay out the construction of our firm-level dataset for private and public firms in the United Kingdom. We also report descriptive statistics for our regression sample, both unconditionally, and when we group firms by age, leverage, and size, which are standard proxies for financial constraints. Finally, we detail our research design and present our source of variation in the sensitivity of firms' collateral values to monetary policy shocks.

3.1 Sample Construction

In the UK, under the Companies Acts of 1985 and 2006, all firms must file annual accounts with Companies House, a government agency. We access this data via Bureau van Dijk (BvD), a commercial data provider. This dataset covers around 1.5 million unique company accounts every year, and importantly, covers both public and private firms. Reporting requirements

[5]Note also that the theory predicts that an expansionary monetary policy shock reduces a constrained firm's cost of finance above and beyond the fall in the risk free interest rate. Our analysis is focused on quantities rather than prices but for evidence showing that borrowing costs fall for constrained firms following an expansionary monetary shocks see Anderson and Cesa-Bianchi (2018).

vary by firm characteristics such as size.[6] The dataset has a number of features that make it particularly well-suited for our analysis. First, it contains key variables of interest; *Number of Employees* and *Firm Age* (calculated using the date of incorporation). Second, while it also covers large listed firms, the dataset is dominated by small and medium-sized private firms; precisely the firms most likely to be affected by financial frictions (Dinlersoz, Kalemli-Ozcan, Hyatt, and Penciakova, 2018) and heavily dependent on asset-based borrowing (Liam and Ma, 2018). Third, firms from all sectors of the economy are covered, in particular, both manufacturing (Crouzet and Mehrotra, 2017) and non-manufacturing firms. Fourth, it contains detailed financial information on firms including their leverage, credit score, and outstanding secured banking relationships. Finally, it also contains detailed information on who runs the firm – *the directors* – including their name, date of birth, appointment and resignation dates, whether they're a shareholder, and, crucially, their usual residential address. This last piece of information allows us to measure the sensitivity of the director's home values to monetary policy shocks, which is a key source of variation in our empirical design discussed in Section 4.

Whilst the BvD dataset has these advantages, a significant limitation is that it is a live database, with many key variables of interest only available for the latest vintage, and not also historically. Most importantly for our purposes, there is no historical information on who company directors are and where they live. Moreover, whilst past accounting variables are available, there is much more missing data historically, in part because firms that die exit the database after five years. To overcome these limitations we use historical vintages of the database, which record company information when it was first published. Through combing 25 different vintages of the database we are able to improve data coverage substantially, observe the performance of firms who have since died, and track the identities of company directors and where they lived through time.[7] In effect, our dataset is annual due to the frequency at which firms file their accounts. However, a feature of the dataset is that firms file their accounts at different times during the year. Hence, a firm that files in January will have experienced a different sequence of shocks in their accounting window to one that files in July. As shown in Figure A3 of Appendix A, filing months are evenly distributed throughout the year, with two larger nodes at the end of the financial year and the calendar year. However, the sample size is sufficiently large that every month in a year will have many observations. As discussed in Appendix A, firms are unlikely to alter the filing months for strategic reasons.

[6] In Section 3.2 we discuss in detail the sample of firms used in our regressions.

[7] For a thorough description of the archival process followed in the construction of our dataset see Section C of the Online Appendix of Bahaj, Foulis, and Pinter (2018). See Kalemli-Ozcan, Sorensen, Villegas-Sanchez, Volosovych, and Yesiltas (2015) for a detailed discussion of the importance of using archival information when constructing a panel of firms using BvD data.

3.2 Firm Descriptive Statistics

Our sample comprises private limited and public quoted firms for whom the UK Companies Acts apply. We exclude firms that operate in the financial, public or non-profit sectors and we also exclude firms that have a parent with an ownership stake greater than 50% to correctly account for the firm's financial position and avoid double counting.[8] We further restrict to firms that report the lag of firm age, number of employees, and leverage; common proxies for firm-level financial frictions used in the recent literature (e.g. Dinlersoz, Kalemli-Ozcan, Hyatt, and Penciakova, 2018).[9] Our sample period covers firms that file accounts from May 1997 (when the Bank of England was granted operational independence and the Monetary Policy Committee was established) and extends until the end of 2017. Throughout in our employment regressions we consider firms who report employment growth over a five year horizon, from employment in the lagged accounts to four accounts hence. This means that our baseline estimates are conditional on firm survival. Since monetary policy can also shift exit rates, we will return to the issue of exiting firms separately below.[10]

In Table 1, we present summary statistics for the largest sample used in our firm-level regressions. Our sample contains 192,223 firm-level observations on 37,944 unique firms. The upper panel of Table 1 shows that the median firm in our sample has 48 employees, just below the UK small firm threshold of fewer than 50 employees. Furthermore, the lower quartile of firms have 8 or fewer employees, below the UK definition of a micro-entity. By this metric, it is clear that our sample is dominated by small firms. However, the right skew of the size distribution, illustrated by mean asset holdings of £83.8 million compared to £3.4 for the median firm, reflects an upper tail of large firms. In contrast, the age distribution is more evenly distributed: the median firm is 15 years old and the lower (upper) quartile of firms have been incorporated less than 7 (more than 29) years before the monetary policy shock hits. There is also an even dispersion of firm leverage (measured as the ratio of total liabilities to

[8]Specifically we exclude firms of the following types: "Economic European Interest Grouping", "Guarantee", "Industrial/Provident", "Limited Liability Partnership", "Not Companies Act", "Other", "Royal Charter", "Unlimited", "Public Investment Trust", thereby ensuring that our sample contains only limited liability firms to which the Companies Act applies. In addition, we exclude from the sample firms operating in utilities (2003-UK Standard Industrial Classification [SIC]: 4011-4100); finance and insurance (2003-SIC: 6511-6720); real estate (2003-SIC: 7011-7032); public administration (2003-SIC: 7511-7530); education, health, and charity (2003-SIC: 8010-8540); and clubs and organisations (2003-SIC: 9100-9199).

[9]Firm age is measured as years since incorporation; firm leverage is measured as the ratio of total liabilities to total assets.

[10]The focus on employment eliminates a large number of small entities that are either not required to report employment or have no employees. Nonetheless, our sample provides stable coverage of approximately 30% of aggregate employment in the industries in question, 40% of employment by *companies* in these industries, and tracks the business cycle dynamics of aggregate employment well (see Figures A1 and A2 in Appendix A.1). Furthermore, age and leverage are commonly used proxies for financial frictions and, as shown in Appendix Table A1, non-reporting firms tend to be even younger and more levered, suggesting the heterogeneity in monetary policy responses would be even stronger if these firms were included in our analysis. This suggests that selection is unlikely to be a major concern for our analysis.

total assets), with a median leverage ratio of 63% and an interquartile range running from 42% to 81%.

A number of earlier and concurrent contributions have proposed several proxies for financial constraints, including size (Gertler and Gilchrist, 1994; Haltiwanger, Jarmin, and Miranda, 2013; Crouzet and Mehrotra, 2017; Dinlersoz, Kalemli-Ozcan, Hyatt, and Penciakova, 2018), age (Cooley and Quadrini, 2001; Hadlock and Pierce, 2010; Cloyne, Ferreira, Froemel, and Surico, 2018)[11] and leverage (Ottonello and Winberry, 2018; Jeenas, 2018), with the latter directly mapping into firm net-worth – a key state variable governing access to external finance in models of financial frictions (Bernanke, Gertler, and Gilchrist, 1999; Kiyotaki and Moore, 1997). As shown by Figure 2, however, these proxies are correlated, with firms tending to reduce their leverage and increase their size as they age (conditional on survival). This highlights the importance of conditioning on firm age when assessing how firm size and leverage affect a firm's behaviour; a point made by Fort, Haltiwanger, Jarmin, and Miranda (2013) in relation to firm size and age.

In Section 6.1 we show that being younger and more levered is the best (combined) predictor of a larger employment response to monetary policy shocks. Although, as shown in Section 8, our results hold focusing on age alone which, conditional on entry, is an exogenous characteristic of the firm. We will also show in Section 8 that our results hold if we use other proxies for financial constraints such as credit scores or an estimated Whited and Wu (2006) constraint index.

4 Research Design: Exposure to Collateral Value Fluctuations

Our focus on traditional proxies for the presence of financial frictions is in keeping with the existing literature. Relative to earlier studies, however, we also exploit variation in the tightness of financial constraints, by measuring the sensitivity of firms' collateral values to monetary policy shocks. We do this by focusing on the value of real estate. This is for three main reasons. First, real estate is a major source of collateral, serving as security for more than 75% of loans to UK SMEs (Bahaj, Foulis, and Pinter, 2018). Below, we show that this is true in particular for the borrowing of younger and more levered firms.[12] Second, as is well known,

[11] Financially constraints are more likely to bind on younger firms as they: (i) (by definition) have less history, so less information is available to external creditors, (ii) often rely on a few key personnel, potentially exacerbating moral hazard problems, and (iii) tend to grow faster and are more likely to be reliant on external finance.

[12] Interestingly, using a sample of U.S. publicly listed firms, Liam and Ma (2018) show that while, on average, borrowing is mainly secured on cash flows, smaller firms rely disproportionally more on collateral-based borrowing. Collateral-based borrowing is also highly prevalent among SMEs, which dominate our sample.

monetary policy has a significant effect on real estate prices (Jarocinski and Smets, 2008; Jorda, Schularick, and Taylor, 2015). Third, exploiting the high-quality monthly regional house price indices available for the UK, we document that monetary policy has a heterogeneous impact on real estate prices across regions, providing a key source of variation in the sensitivity of collateral values.

4.1 The Role of Personal Guarantees

Our ideal empirical experiment would exploit variation in the value of the collateral a firm borrows against that is independent of the firm's business opportunities. It is established that a rise in local real estate prices increases the value of the firm's buildings, thereby boosting firm activity by relaxing collateral constraints (Gan, 2007; Chaney, Sraer, and Thesmar, 2012). However, local real estate prices are also likely to be correlated with local demand.

To circumvent this identification issue, we instead focus on the residential real estate of company directors, who frequently borrow against their own homes to finance their firms, typically by issuing a personal guarantee.[13] This *residential collateral* is a significant source of financing for firms, being worth around 80% of GDP, around four times more than the buildings owned by firms (i.e. corporate real estate). It also generates a source of transmission from real estate prices to firm employment: every £1.1m increase in the combined home values of a firm's directors causes the average firm to add one job in the first year (Bahaj, Foulis, and Pinter, 2018). Crucially, over 60% of the directors in our sample live in a different region to their firm, reducing the correlation between collateral values and local demand. Accordingly, we can compare the employment responses of two firms in the same location, with similar characteristics, one of which has its director living in a region where house prices have higher sensitivity to monetary policy and the other whose director lives in a lower sensitivity region.

We provide evidence on the prevalence of this type of borrowing in Table 2, sourced from the Bank of England's 2015 Survey of Bank Lending to SMEs and Mid-Corporates.[14] There are two key takeaways from the table. First, borrowing against personal guarantees is prevalent, being used as security by 50% of firms. Second, there is significant heterogeneity across firms. In Section 6.1, we show that the employment of younger and more levered firms is the most responsive to monetary policy shocks. So for brevity, we focus here (across rows) on four firm groups splitting based on the joint age-leverage distribution. In column (1) of Table 2, we show that almost two-thirds of borrowing by younger firms (less than 15 years old) with higher

[13] A personal guarantee is legal commitment given by the firm's director to back the firm's debt that typically involves a fixed charge on the director's home. Should the firm fail to repay the amount owed, the bank can seize the assets of any and all directors of the firm. For further details on personal guarantees, including their international prevalence, see Bahaj, Foulis, and Pinter (2018).

[14] The survey covers outstanding loans at the five major UK banks to firms borrowing at least £250,000 and whose annual revenue is less than half a billion pounds.

leverage (above the median) is secured by personal guarantees, being charged an average interest rate of 3.80%. These figures are significantly lower for the remaining groups, particularly for older and less levered firms. This latter group secures only one third of their loans by personal guarantees and for that are charged an interest rate which is about 60 basis points lower. More generally, the relationship between age/leverage and access to credit appears monotonic.[15]

Using our baseline regression sample we also highlight heterogeneity across these groups in the importance of director and firm real estate, relative to the size of the firm's balance sheet. As shown in Figure A7 in Appendix A.7, for younger, higher leverage firms, the median ratio of directors' personal real estate to the total assets of their firm is almost 60%, whilst the median ratio of the firm's own real estate to total assets is less than 1%. By contrast, for older, less levered firms, the importance of the two are more balanced, with the firm's buildings worth 15% of total assets, and the directors' houses worth 28%. It is worth noting however, that even for these older, less levered firms, the houses of their directors are a potentially meaningful source of collateral for the firm.

4.2 Regional House Price Variation

To measure the sensitivity of regional house prices to monetary policy we run a simple projection of local house prices on monetary policy shocks for each of 172 regions in England and Wales, using the Land Registry's monthly repeat sales house price index from 1995-2016.[16] This produces the average house price responsiveness to monetary policy shocks for each region which we refer to as the regional *house price beta*. We then rank regions by their cumulative house price responsiveness after two years.[17]

The regional variation in this measure is illustrated by a heat map in the left panel of Figure 3, confirming substantial spatial heterogeneity in the elasticity of house prices with respect to monetary policy shocks. At the firm-level, we average the estimated responses across the regions where each of the firm's current directors live to compute a *director* house price beta. In contrast, the *firm* house price beta refers to beta in the region where the firm

[15]Cutting the sample behind Table 2 by age only or by leverage only reveals that younger firms and more levered firms are also more reliant on personal guarantees and so are more exposed to variations in the value of their directors' homes. But the heterogeneity is further amplified by considering the two dimensions jointly, which motivates the focus in Table 2. Smaller firms are also more likely to use personal guarantees with 55% of loans to firms with less than 50 employees backed by them versus 33% for firms with more than 250 employees, although there is less heterogeneity in spreads splitting by size. Still, this shows even larger firms do make use of personal assets as collateral.

[16]Appendix A.4 describes the estimation procedure in detail. For further details on the Land Registry's repeat sales house price index see here. The house price sensitivities are not calculated for Scotland as the regional house price indices do not exist prior to 2004.

[17]Two years is the typical peak house price response to a change in a monetary policy shock although there is some regional heterogeneity. In Section 8 we show that our baseline results are robust to ranking regions by their house price responsiveness after three years.

is headquartered. From Sections 6.2 onwards, our regressions that exploit the house price sensitivity of the directors' regions further restrict the regression sample to firms where director house price beta is non-missing. This leaves us with 133,078 firm-year observations on 27,718 unique firms. These firms account for 84% of the employment to the sample in Section 3.2, and have very similar characteristics.[18]

As an alternative to these model-based estimates of house price sensitivities, we also use a regulation-based measure: the regional refusal rates of planning applications for residential projects, taken from Hilber and Vermeulen (2016).[19] The idea is that the increase in housing demand associated with an expansionary monetary policy shock will be translated into a greater increase in house prices in regions with a greater refusal rate, as the housing supply response will be weaker. In short, this a proxy for land supply elasticities similar to Saiz (2010). The right panel of Figure 3 demonstrates substantial regional variation in refusal rates. Appendix A.4 describes the data on refusal rates in greater detail and also discusses the relationship between the two measures: in particular, there is a 50% correlation between refusal rates and the regional housing betas.

Both measures of regional house price heterogeneity in Figure 3 record higher (absolute) values in the South. In a robustness check of Section 8, we will confirm that our results are not driven by the Greater London area.

Last, note that we can also value a director's house by matching their residential address to the Land Registry's Price Paid dataset, which records all property transactions in England and Wales since 1995; and the FCA's Product Sales Database (PSD), which records the universe of mortgage originations in the UK.[20] We use this for certain robustness checks below.

4.3 Firm and Director Characteristics and House Price Beta

Key to our research design is that, conditional on our control set, the director house price beta matters for how the firm reacts to a monetary shock only because it captures changes in the value of an important source of collateral to the firm. It should not matter because the director beta is correlated with other omitted characteristics at the firm or director level that govern the sensitivity of the firm to monetary policy.

[18]There are several reasons why director betas may be missing: (1) house price betas are not calculated for Scottish regions; (2) we only assign a region to a director's address when we are confident they lived there, based upon the dates they list the address and the transaction dates for the property (see Online Appendix E of Bahaj, Foulis, and Pinter 2018); (3) we do not assign a region to a director when they have matched addresses in multiple regions.

[19]Note that the refusal data is only available for England, and not for Wales.

[20]For a detailed discussion of this matching procedure see Online Appendix E of Bahaj, Foulis, and Pinter (2018). The Product Sales Data include regulated mortgage contracts only, and therefore exclude other regulated home finance products such as home purchase plans and home reversions, and unregulated products such as second charge lending and buy-to-let mortgages.

To explore whether the director house price beta is correlated with other firm-level characteristics, Table 3 presents summary statistics on firms and their directors by groups based on the beta. The Table presents medians unless otherwise stated (Appendix A.6 provides other moments). A few points stand out. The median director lives in a house worth £411,000, several times the average UK average house price over our sample period, reflecting that these are relatively wealthy individuals. The Table also highlights that there is geographical dispersion between directors and their firms with over 60% of directors living in a different region to their firm. The median director lives 9 miles away from their firm. This is in line with the average UK commuting distance for self-employed or full time workers.[21] However, there is a tail of approximately a fifth of directors who live more than 30 miles away from their firm, which provides more extreme spatial heterogeneity.

Directors in high versus low beta regions tend to live a similar distance from their firm and have a similar age and level of experience. However, directors located in high beta regions tend to own more valuable houses and run somewhat younger, smaller firms.[22] The issue with this comparison is that the director and firm betas are correlated, as directors tend to live near their firms. Our research design will essentially compare two firms operating in the same region, but which have directors living in regions with differing house price sensitivities. Therefore, ultimately, the source of variation that matters for our regressions is the director beta relative to firm's beta, not the director beta *per se*. The final three columns in Table 3 consider this. As can be seen, if one compares directors who live in a higher beta region than their firm, to those who live in a lower beta region, there is little difference in firm or director level characteristics.

As it is the relative betas between directors and firms that matter, in Figure A6 in Appendix A, we also report the correlation between the two, broken down by the average distance between the firm and its director's houses.[23] Across all firms, (first bar on the left) the correlation is 80%, but it falls substantially as the average distance increases. For firms whose directors live an average of at least 30 miles away this correlation is just over 40%. We exploit this low correlation in a robustness test below.

[21] From the UK National Transport Survey.

[22] The result on size flips if one compares means rather than medians: high beta directors run larger firms on average.

[23] We calculate this distance for each firm-director pair using the full postcode (an area of around 17 properties) of the firm's headquarters and the house of each director. The Office for National Statistics calculate the center of each postcode to the nearest meter; using data from the Ordinance Survey we then convert this to latitude and longitude coordinates and calculate the distance. We then average this distance at the firm-level across all of its directors. Note that if all directors lived in the same region as their firm this correlation would be 100%.

5 Empirical Framework

In this section we describe our strategy to identify monetary policy shocks, lay out the empirical model we use for firm-level estimation, and present the estimated average effect of monetary policy on employment over our full sample.

5.1 Identification of Monetary Policy Shocks

Our strategy for measuring exogenous fluctuations in UK monetary policy builds on the series of Gerko and Rey (2017). This series, making use of a high frequency identification strategy, essentially serves as an instrument for monetary policy in our empirical analysis that follows. It is constructed by measuring the reaction in the sterling rate futures market during the window from 10 minutes before to 20 minutes after the release of two UK monetary policy releases: (i) the publication of the minutes of the Bank of England's MPC meeting and (ii) the publication of the Bank of England's Inflation Report.[24] To convert the surprises to a monthly variable, they sum all the surprises within the same month. The monthly series is plotted in Figure A8 of Appendix B and covers the period January 2000 to January 2015.

Having obtained a source of exogenous variation in monetary policy, we use the series as an external instrument in a structural vector autoregression (proxy-SVAR) model covering UK aggregate data. The methodology for proxy-SVARs is now relatively standard and we refer readers to Stock and Watson (2012) and Mertens and Ravn (2013) for further information about implementation.

We use the identified monetary policy shock series from the VAR in our firm-level regressions. This is advantageous as we can use the patterns of correlation between the reduced form residuals and the instrument to extend the identified policy shock series back to periods before the Gerko and Rey (2017) series was available, hence extending our firm-level sample.[25]

Our VAR specification is almost identical to Gerko and Rey (2017): we specify a monthly VAR(12) covering the period January 1981 to March 2015. We include the following time series in the VAR: the UK index of manufacturing production (in logs), five year gilt yields (in percentage points), the UK retail price index (in logs) and the unemployment rate. We modify their specification in one dimension by additionally including aggregate employment (in logs). This is to obtain a comparable aggregate benchmark for the employment response to a monetary policy shock.

[24] See Appendix B of Gerko and Rey (2017) for further details on the construction of the series.

[25] This is a common approach in the proxy SVAR literature (Gertler and Karadi, 2015). Specifically, this methodology identifies the contemporaneous coefficients on the reduced form residuals that can be combined to produce the identified shock. Since our reduced form specification extends back beyond 2000, we can use the estimated residuals for the pre-2000 sample, along with the identified coefficients, to extend our shock series prior to 2000.

The F-statistic from the regression of the VAR residuals on the proxy is 16.3. This is, in effect, the first stage regression of our empirical model. This F-statistic represents the most conservative measure of instrument relevance as the firm-level regressions below cover a longer time period and, as one would expect, the extracted shock is more closely correlated with interest rate changes than the raw Gerko and Rey (2017) series.

Figure A10 in Appendix B presents the impulse response functions to the contractionary monetary policy shock that emerges from the VAR. To enable comparability with the firm-level results, the monetary policy shock is scaled so that the average increase of the 5-year yield over the first year is 25bps. The pattern of responses is in line with the monetary policy literature. The 5-year yield increases on impact and then decreases and returns to zero after around 2.5 years. Aggregate employment does not respond on impact, but thereafter decreases with a peak response after 3 years, before returning to zero at the end of the horizon. At its peak, the monetary policy shock results in around a 0.5% decrease in employment. These findings align with the results of Christiano, Eichenbaum, and Evans (1999) on the effects of monetary policy on employment.

5.2 A Panel LPIV model

Let $EMP_{i,t}$ be firm i's number of employees for accounting period t. Here it is necessary to introduce a brief remark on notation: as described, our firm-level data is effectively annual so t refers to the firm's accounting year and we use the index $m \in \{1, \ldots, 12\}$ to denote months within that year. To ensure no ambiguity, $m = 12$ is the month in which the firm files its accounts within that year, not December. We use the index s to denote months in the time domain, which is common to all firms.

Our baseline linear specification is specified as a local projection (Jorda, 2005) and is an extension of the model discussed in Ramey (2016) into a panel instrumental variable setting:

$$ln(EMP_{t+h,i}) - ln(EMP_{t-1,i}) = \sum_{g=1}^{G} \alpha_g^h \times Dg_{i,t-1} + \sum_{g=1}^{G} \beta_g^h \times Dg_{i,t-1} \times \Delta r_t + v_{i,t}^h, \quad (1)$$

where $h \in \{0, \ldots, 4\}$ indexes a set of regressions at different horizons, running from 0 to 4 years. The term Δr_t is the change in the average 5-year interest rate over the firm's accounting year.[26] We instrument the interest rate changes with the series $\sum_{m=1}^{12} e_{m,t}$, where the term $e_{m,t}$ denotes the monetary policy shock for month m of accounting year t as extracted from the VAR described in Section 5.1.[27]

[26]Precisely, $\Delta r_t = 1/12(\sum_m (r_{m,t} - r_{m,t-1}))$, where $r_{m,t}$ is the average of daily observations of the 5 year gilt yield in month m of firm accounting period t.

[27]We can also estimate an over-identified model using the 12 shocks that occur over the firm's accounting year

To allow for heterogeneous responses, the term $Dg_{i,t-1}$ is a dummy variable that takes a value of 1 when firm i is part of a particular group of firms (e.g. firms less than 15 years old) in period $t-1$, and 0 otherwise. The impulse response to an interest rate change for a particular group is then given by the vector of coefficient estimates$\left\{\beta_g^h\right\}_{h=0}^4$. We re-scale all impulse responses so they can be interpreted as a shock that raises the interest rate by 25bp on average over the firm's accounting year (i.e. $\Delta r_t = 25bp$).

By including time fixed effects, we can also compute relative impulse responses:

$$ln(EMP_{t+h,i}) - ln(EMP_{t-1,i}) = \delta_{j,s}^h + \gamma_{l,s}^h + \sum_{g=1}^{G} \tilde{\alpha}_g^h \times Dg_{i,t-1} + \sum_{g=1}^{G-1} \tilde{\beta}_g^h \times Dg_{i,t-1} \times \Delta r_t + v_{i,t}^h. \quad (2)$$

In this context, $\delta_{j,s}^h$ is a dummy that takes a value of 1 for firms operating in (SIC-1) industry j that file their accounts in month s, and 0 otherwise. This means we are comparing firms within industry and thus eliminating the role of industry-specific sensitivities to monetary policy. Similarly, $\gamma_{l,s}^h$ is a dummy that takes a value of 1 for firms that operate in (NUTS-1) region l and file their accounts in month s, and 0 otherwise. Hence, we are comparing two firms in the same region subject to the same local economic conditions.

We refer to the impulse responses arising from the two specifications in Equations (1) and (2) as the level and relative effect respectively. They have different advantages. In terms of the former, the fact $e_{m,t}$ is an identified structural shock with ample time series variation, means that omitting time fixed effects does not bias the estimates of how monetary policy in total affects a firm in a particular group g. There is no missing intercept problem that typically arises from a fixed effect absorbing general equilibrium feedback loops. Hence, we can conduct aggregation exercises and consider which types of firms explain most of the aggregate employment response to monetary policy.

However, the specification in Equation (2) is better placed to disentangle the mechanisms that explain the heterogeneity. In particular, as described, the fixed effect allows us to compare two firms in the same region and industry and ask what patterns of heterogeneity remain. Furthermore, this specification is better suited for conducting inference over differences between groups because estimation uncertainty over the average effect of the shock is absorbed. In particular, the term $\tilde{\beta}_g^h$ captures the response of group g relative to the Gth group. The statistical significance of the difference in responses between groups g_1 and g_2 can be assessed by a formal hypothesis test that $\tilde{\beta}_{g_1}^h = \tilde{\beta}_{g_2}^h$.

Last, further details are in order on the setup of our baseline specification. When constructing cumulative growth rates, $log(EMP_{i,t+h}) - log(EMP_{i,t-1})$, we (i) omit observations in

as a separate instrument. However, this is computationally intensive and the results, available upon request, for our main specification are near identical.

the 99th and 1st percentiles of observations in order to prevent outliers distorting the results, (ii) omit observations where any accounting period in the window between $t-1$ and $t+h$ is not one year, (iii) rectangularise the sample such that for any observation to be included $ln(EMP_{t+4,i}) - ln(EMP_{t-1,i})$ must be reported, and (iv) when using alternative left hand side variables from employment, recast all nominal variables in real terms by dividing through by the seasonally adjusted UK consumer price index for the month when the account was filed. We compute standard errors using the methodology of Driscoll and Kraay (1998). This accounts for the serial correlation at the firm-level that is standard in local projections as well as arbitrary cross-sectional dependence between firms both contemporaneously and through time.

5.3 Average Firm-Level Effect of Monetary Policy

Figure 4 shows the average firm-level employment response to a contractionary monetary policy shock that raises the interest rate by 25bp on average over the firm's accounting year, together with 90% confidence intervals.[28] Our results suggest that the contractionary shock brings about a 0.3% decline in firm-level employment on impact[29], although this effect is not statistically different from 0. The fall in employment continues with the mean response reaching a trough of about -1% after 2 years, followed by the recovery.

Appendix D shows that this employment response is robust to a number of alternative specifications of the baseline regression. We obtain similar findings using Davis-Haltiwanger growth rates (Figure A13).[30] Using a non-rectangularised sample and only restricting to firms reporting employment at horizon h (rather than 4) yields similar results (Figure A14). This suggests that the selection effect from different reporting across horizons is small. The orthogonality of $e_{m,t}$ means that it is unnecessary to control for additional firm-level or aggregate variables for the purposes of reducing omitted variable bias. Adding controls neither affects the coefficient estimate nor the error bands (Figure A15). For the same reason it is not necessary to include firm fixed effects. Adding a firm fixed effect is equivalent to estimating a firm specific trend in employment growth. However, the time dimension of any given firm in the panel is relatively small, between five to ten years on average. Hence, adding firm fixed effects is demanding of the data, particularly at long horizons where there may only be a couple of observations per firm. We do report results including firm fixed effects in Figure A16, which shows a similar, if slightly larger, employment impact, though the effect of monetary policy on firm-level employment is more persistent.

Importantly, we can compare these firm-level employment responses to the VAR responses

[28]This regression, showing the average affect across all firms, is equivalent to $G = 1$ in Equation 1.

[29]To reiterate, as the firm-level data is annual, this impact response is the annual employment response to monetary policy shocks over the firm's accounting year.

[30]Specifically, we change the dependent variable to: $\frac{EMP_{t+h} - EMP_{t-1}}{0.5(EMP_{t+h} + EMP_{t-1})}$.

in Figure A10 in Appendix B. The aggregate response displays a very similar hump shaped pattern but the effect is diminished: peaking at 0.5% in the aggregate data versus 1.0% for the average firm. This discrepancy does not reflect that our firm-level regressions are not size weighted. To illustrate the effect of size weighting, we use administrative employment data to calculate the contribution of firms in fine employment size bins to aggregate employment.[31] Using this data we can re-weight the regression, to ensure that the weight placed on firms in each size bin matches their contribution to aggregate employment (see Appendix A.2). The results are presented in Figure A17 of Appendix D.5. As can be seen, the weighted and unweighted regressions are not dissimilar. Instead, the discrepancy likely emerges because the VAR in Gerko and Rey (2017) covers a different sample period and is not specified in the equivalent manner to the firm-level regression. In Figure A18 in Appendix D.6, we instead present an equivalent local projection to that in Figure 4 but replace the left hand side with aggregate employment growth over the same sample period. This delivers a peak employment contraction similar to our baseline firm-level response.

Having established that the average effect of a monetary policy shock on a firm is sensical and can be reconciled with the aggregate employment response, we now turn to the heterogeneity in firm-level responses.

6 The Heterogeneous Effects of Monetary Policy

In this section we explore heterogeneity in the responses of firm-level employment to monetary policy shocks along our three proxies for financial constraints – age, leverage, and size – showing that employment responses are particularly large for younger, more levered firms. We then exploit geographical variation in house price sensitivity to monetary policy shocks to show that the employment response of the younger, more levered firms is materially larger when their directors live in more house price sensitive regions. Last, we show that these results extend to other aspects of firm behaviour beyond employment.

6.1 Employment Responses by Firm Characteristics

Figure 5 shows the two year employment response cut by alternative firm age, leverage, and size groups (for the full dynamic responses see Figures A19, A20, and A21 in Appendix E). Starting with age on the top row, we find that firms established less than five years prior to the monetary policy shock clearly respond the most, with a peak employment contraction of over 2%, whereas the oldest firms (more than 30 years old) respond the least, with a peak employment contraction

[31] Specifically, we use the following employment size bins: 1-9,...,90-99,100-149,...,950-999,1000-1999,...,19000-20000,20000+

of less than 0.4%. In between these two extremes, the effect of monetary policy on employment decreases near monotonically in firm age.

Turning to leverage, Figure 5 shows that the upper three quintiles of firms by leverage (approximately those with a ratio of total liabilities to total assets greater than 50%) respond in a relatively homogeneous fashion but the difference relative to the lower two quintiles is sharp, with only the latter characterised by far smaller and, for the lowest quintile, insignificant effects.

The estimates based on a size split in the last row, in contrast, are non-monotonic and thus less clear cut. For instance, the largest response is recorded for firms with between 500 and 2000 employees, whereas the two smallest adjustments are associated with the groups at either tail of the size distribution, namely firms with the smallest (below 50) and the largest (above 10,000) number of employees. This implies that using the sample cut in Crouzet and Mehrotra (2017) one would find that smaller firms react more to monetary policy shocks;[32] using instead 500 employees as the threshold above which firms are classified as large, the differences across groups would become far less stark; using 250 employees, the European Union upper limit for the definition SMEs, larger firms would now adjust their employment more than smaller firms. Indeed, the recent academic literature is mixed on whether smaller or larger firms are more responsive over the business cycle.[33] Moreover, Figure 5 shows that among SMEs the employment response is fairly homogeneous across firms of different sizes. Indeed, our key results that follow are based on our SME-dominated sample, where there is less heterogeneity in firm-level employment responses by size.

In summary, the employment of younger or more levered firms appears more sensitive to monetary policy shocks than the employment of older or less levered firms, in a way that is not dependent on the specific threshold used. While younger and more levered firms also tend to be smaller (see Table 1), not all small firms are young and highly levered. Accordingly, the heterogeneity in the employment responses by size appears less marked and often insignificant.

In an effort to identify sharply the dimensions most closely related to the unobserved characteristics driving a greater firm-level response, we build on the estimates in Figure 5 to further decompose the distribution of firms into more levered (above the median in a given year) and less levered (below the median in a given year) firms. In a balancing act between exploring

[32] Crouzet and Mehrotra (2017) do not categorise firms by employment, but by assets, with small firms the bottom 99.5% and large firms the top 0.5% by assets. In our sample, cutting at these thresholds, a large firm is one with over £2bn in assets. Such large firms have a median of 32,000 employees in our sample.

[33] Kudlyak and Sanchez (2017) find that, following the financial crisis of 2008, the sales and short-term debt of large firms contracted much more than for small firms. Updating the dataset of Gertler and Gilchrist (1994), Chari, Christiano, and Kehoe (2013) find that the response of small and large firms are similar following recessions. Moscarini and Postel-Vinay (2012) find that large firms contract employment by more when unemployment is high. Whilst Crouzet and Mehrotra (2017) do find that the sales of small firms respond more following a fall in GDP or tight periods of monetary policy, the effect does not materially affect the aggregate and cannot be attributed to financial frictions.

the full extent of heterogeneity in the employment responses across firms and maximizing the number of observations per group-time cell, we focus on two age categories: less than 15 years (younger), and above 15 years (older) since incorporation, which cuts almost exactly around the median firm age in our sample.[34]

The result of the double cut by age and leverage is reported in the four panels of Figure 6a. The top (bottom) row refers to the younger (older) group whereas the left-hand (right) column represents more levered (less levered) firms. A comparison of the IRFs across columns highlights the marginal contribution of leverage for any given age level. A comparison across rows reveals the marginal contribution of age within a given leverage group. In Figure 6b, we report the relative effect version of the specification behind Figure 6a, in which we have also added (industry by time, region by time) fixed effects and chosen the older, less levered firms as the baseline group.

Figure 6 delivers three main takeaways. First, being younger makes a significant contribution to the heterogeneity in employment responses, over and above having higher leverage. This is visible in the first columns of Figures 6a and 6b, which compare younger and older, more levered firms. Second, being highly leveraged makes a significant contribution over and above being a younger firm, as can be seen from the first row of Figures 6a and 6b. Third, the most sensitive group, with a peak employment contraction of almost 2%, is younger, more levered firms: exactly the firms more likely to be financially constrained. This is consistent with the results in Table 2 showing that younger, more levered firms face higher interest rates and are more likely to have their loans secured on the personal assets of the company directors.

Contribution to the Aggregate Response. The heterogeneity documented in this section can be used to compute the contribution of younger and more levered firms to the response of aggregate employment to monetary policy shocks. More specifically, based on the employment shares of each of the four groups, we calculate the individual contributions to the average response of firm-level employment. Younger and more levered firms account for over a quarter of total employment in our sample. Combined with their materially larger employment response in Figure 6a, this group is then responsible for about half of the peak average employment response to monetary policy shocks. By contrast, whilst the older and less levered firms represent over 30% of employment, they account for less than 10% of the peak employment response.

This calculation may overstate the contribution of young, high leverage firms to the aggregate employment response following a monetary policy shock, if their share of aggregate employment is significantly lower than their share of employment in our sample. To assess this,

[34] This choice of firm age is not crucial: in Section 8 we show that our baseline results (utilising heterogeneity across firm age, leverage, and director house price sensitivity) are robust to splitting firms at 5 years old rather than 15 years old.

we again use administrative employment data to reweigh the regression, to ensure that the weight placed on firms in each size bin matches their contribution to aggregate employment. Figure A22 in Appendix E shows that, even with this re-weighting, young high leverage firms still respond significantly more than the other groups of firms.[35] Moreover, using these size weights, young high leverage firms are estimated to make up a similar proportion of aggregate employment as they do in our sample (Appendix A.2 provides details of the calculation). The implication of these two results is that young, high leverage firms also contribute around half of the *aggregate* employment response to monetary policy shocks.

6.2 Employment Responses by Regional House Price Sensitivity

As described in Section 2, if financially constrained firms respond *more* to monetary shocks this implies a key role for collateral constraints and asset price fluctuations. In this section, we exploit regional heterogeneity in the sensitivity of real estate values to monetary policy shocks and ask: is the employment response of younger/more levered firms more pronounced when their company directors live in regions with a higher sensitivity of house prices to monetary policy?

For ease of exposition, in Figure 7a, we focus on the groups on the main diagonal of Figures 6a-6b, namely younger firms with higher leverage (Figure 7a: top row) and older firms with lower leverage (Figure 7a: bottom row), as these two groups are distinguished by the two key characteristics that drive the heterogeneity in the employment responses. In Figure 7a, we further split these two groups depending on whether the firm directors live in a region with high (top tertile, left column) or low (bottom tertile, right column) house price sensitivity to monetary policy shocks.[36] In Figure 7b, we report estimates from the relative effects specification with time fixed effects (Equation 2), using the older, lower levered firms with directors living in low house price sensitive regions as the baseline group.

Three main findings emerge from Figure 7. First, our key result: among younger, more levered firms (the top row in Figures 7a–7b), the employment of firms with directors living in high sensitivity regions (left column) contracts more than the employment of similar firms whose directors are located in low sensitivity regions (right column). This is consistent with the notion that while younger, more-levered firms are more likely to be financially constrained, the constraints tighten more in regions where real estate collateral values are more sensitive to monetary policy. This effect is economically and statistically significant. Firms with directors

[35] Implicitly, this assumes that the firms that do not report employment behave similarly to those that do. Table A1 in Appendix A.1 shows that non-reporting firms tend to be even younger and more highly levered than reporting ones, suggesting they may be more responsive than the firms in our sample, and that this may be a conservative assumption.

[36] The use of the director beta implies that we have a different sample from the previous Section. However, we confirm in Figure A23 of Appendix E that our results on age and leverage apply to this sample also.

in more sensitive regions experience an employment response approximately 1-1.5 percentage points greater than firms with directors in less house price sensitive regions. Formal hypothesis tests that the coefficients in the top row of Figure 7b are the same yield p-values of less than 1% at 2- and 3-year horizons, and less than 2% at the 4-year horizon (to save on repetition: all deviations from this baseline presented below for robustness also yield statistically significant differences). This finding is consistent with the prediction that monetary policy transmission partly works through altering the collateral value of financially constrained firms.

Second, among the group of older less-levered firms, house price sensitivity is irrelevant: the bottom left and bottom right panels in Figure 7a exhibit very similar dynamics (the bottom left chart in Figure 7b formally shows no statistical difference). This is consistent with heterogeneity in collateral value changes, induced by a monetary policy shock, having no impact on unconstrained firms.

Third, even within the group of firms whose directors live in higher house price sensitivity regions (left column), the employment response of younger, more levered firms is large and very significant whereas the response of older, less-levered firms is small and insignificant, consistent with the notion that older, less levered firms are less likely to be financially constrained.

These results pose an immediate question given that director house values do not scale with firm size: is the director beta relevant only for firms where housing is a meaningful source of collateral?[37] Bahaj, Foulis, and Pinter (2018) show that the relevant metric to assess this is the ratio of director house values to the firm's total assets: they demonstrate that once this ratio falls below 15%, the sensitivity of firm behaviour to the director house value goes to zero. This is typically the case for very large firms. We proceed in a similar vein in Figure 8 and split the sample into firms above and below the 15% house value to asset ratio at the time the shock hits. For brevity we show relative effects, with the results in levels shown in Appendix F, Figure A24. Inspecting this figure, it is clear that the director beta is irrelevant for determining the sensitivities of firms below the 15% threshold to a monetary policy shock. Whereas for firms above the 15% threshold the differences by director beta are even more pronounced. Moreover, when it comes to aggregation, firms above the 15% threshold still have a material impact on macroeconomy: Table A3 in Appendix A.8 shows that they account for about half of employment.

Planning Application Refusal Rate. The baseline estimates of the heterogeneous firm-level employment responses of this section rely on a sample split based on the ranking of the estimated house price sensitivities to monetary policy shocks across the regions where the firm's

[37] A second related question is whether the relative magnitudes in the impulse responses are plausible? In Appendix A.5 we provide a back-of-the-envelope calculation, showing that the magnitudes are consistent with the findings of Bahaj, Foulis, and Pinter (2018) on the unconditional response of firm employment to a shock to the house values of its directors.

directors live. As an alternative sample split, we exploit here the average refusal rate of planning applications for residential projects to group director regions into high and low sensitivity, based on a cutoff of 25% for the average refusal rate. Using this measure and threshold, we find results that are very similar to our baseline case (Figures A25 and A26 in Appendix E.7). Specifically, the formal hypothesis testing of Figure A26 reveals that the employment response of younger and more levered firms is statistically and economically larger when their directors live in a high rather than a low refusal rate region. This corroborates the heterogeneity uncovered in Figure 7 based on the estimated regional house price sensitivity sample split.

6.3 Debt, Working Capital and Investment

In this subsection, we consider heterogeneity in other aspects of firm behaviour, beyond employment, in response to a monetary policy shock to further inform our understanding of the mechanism.

Debt As laid out in Section 2, the heart of the collateral channel runs through external borrowing. Therefore the heterogeneity in the employment responses to monetary policy shocks observed in the previous section should be mirrored in the response of a firm's debt stocks. Moreover, for unconstrained firms we would not expect collateral values to play a role in governing the dynamics of their debt position. In Figure 9, we show the equivalent to Figure 7a after replacing employment as a left-hand-size variable with logarithmic growth of the firm's total debt stock, measured from its balance sheet. As can be seen, the patterns of heterogeneity are similar when using debt compared to when using employment. If anything, the difference between the impulses shown in the top row of Figure 9 is larger than in our baseline: debt falls by 5 percentage points more for younger and more levered firms whose directors live in high sensitivity regions compared to similar firms whose directors live in low sensitivity regions. Figure A27 in the Appendix shows the same model with the time fixed effects.

Prepaid Expenses In many theoretical models, the firm's cost of borrowing interacts with employment decisions via a working capital channel. The firm must pay workers in advance of production and therefore requires external financing to employ workers (Christiano, Eichenbaum, and Evans, 2005; Mendoza, 2010). The prepayment of wages and other inputs can be approximated as *Current Assets* less *Bank Deposits* less *Trade Debtors*. If our results partially reflect a collateral driven working capital constraint (as we assume in our theoretical framework in Appendix C), we would expect that firms whose employment is particularly responsive to monetary policy shocks should have particularly responsive prepaid expenses. In Figure 10, we explore this by altering our left-hand-size variable, replacing employment growth with growth in prepaid expenses (with the relative effects shown in Figure A28 in the Appendix). The results again confirm that the prepaid expenses of younger more levered firms, whose directors live in high house price sensitivity regions, respond the most (this is particularly clear for the relative effects).

Fixed Assets The employment response may be explained not just by a working capital channel. As many recent papers (Ippolito, Ozdagli, and Perez-Orive, 2017; Ottonello and Winberry, 2018; Jeenas, 2018) show, financial constraints are also relevant to how firm investment responds to monetary policy shocks. To the extent that capital and labour are complements in production, a reduction in investment may also reduce firms' employment. In this paper, we focus on employment, because we have a sample dominated by SMEs, and these firms are particularly important for driving aggregate employment dynamics. However, we can assess the heterogeneity in the impact of monetary policy shocks on investment as well. To proxy investment, or more precisely the firm's capital stock, in Figure 11 we use the cumulative growth of fixed assets as a left-hand-side variable (with the relative effects shown in Figure A29 in the Appendix). Again, we find that the patterns of heterogeneity in the investment response maps that of our baseline employment response.

6.4 Summary

In this section, we have documented that younger and more levered firms are characterised by a significantly larger response and account for about half of the movement in aggregate employment following a monetary policy shock. The estimated heterogeneity is even more pronounced when we focus on younger and more levered firms whose directors own a home that is valuable relative to the firm's assets and live in a region with a higher house price sensitivity to monetary policy or with a higher planning application refusal rate. We have also shown that the change in borrowing following a monetary policy shock is large and significant only for younger and more levered firms whose directors live in more house price sensitive regions. This is also the group of firms whose fixed assets and whose prepaid expenses respond the most to interest rate changes.

7 Alternative Mechanisms

In this section, we consider alternative mechanisms beyond a collateral channel that could explain the patterns of heterogeneity that we observe in the data.

7.1 Local Demand

A key challenge for identification is to disentangle fluctuations in collateral values from changes in local demand faced by the firm. The latter is also potentially related to how sensitive real estates prices are to monetary policy shocks in the region where the firm is located.

As a first pass to argue against demand effects, we use turnover as a proxy for demand at the firm-level and use it as an alternative left-hand-size variable in our regression. Figures A30-A31 in Appendix F.1.1 shows that monetary policy shocks have a material effect on turnover across all firm groups, consistent with a decline in aggregate demand. Yet, there is no meaningful heterogeneity in the responses of turnover across these firm groups, suggesting that our baseline responses are not a result of these firms experiencing heterogeneous demand following monetary policy shocks.

However, turnover may not be fully capturing demand or there may be other local economic factors that are driving the firm's response. Our strategy based on using director real estate (as directors can live in different regions from their firm) allows us – in the relative effect specification – to control for region-time fixed effects. By doing so, we are comparing two firms operating in the same region that file accounts in the same month, thereby being exposed to the same local economic conditions at that point in time. This strategy controls for the linear effect of local economic conditions on firms' behaviour.

In our baseline regressions, the definition of the region is at the NUTS-1 level, which is relatively coarse. In Figure A32 of the Appendix, we add region-time fixed effects, where regions correspond to the same smaller geographical areas that we use to compute spatial house price sensitivities. Unfortunately, at such disaggregated regional levels, we lack a sufficient number of observations to include monthly fixed effects, so instead we use annual fixed effects, thereby comparing two firms in the same region that file accounts in the same calendar year. These results are very similar.

To further address this concern, we can exploit the fact that some directors live far away from their firms. In Figures A33–A34 of Appendix F.1.3, we re-run the specifications corresponding to Figure 7 but only for firms whose directors live, on average, more than 30 miles away from the firm's headquarters. In Figure A6, we plot the average correlation between the house price sensitivity in the firm region and in the firm director region, based on the average distance between the director home address and the firm location. When directors live at least 30 miles away on average, the correlation is just over 40%. Using this cut-off, we find that younger and more levered firms still have a greater employment response to monetary policy shocks when their directors live in more house price sensitive regions.[38]

[38] Due to a smaller number of observations for this subsample, and the shareholder subsamples below, for these specifications we include region-year and industry-year fixed effects for the relative responses (as opposed to region-month and industry-month).

Even accounting for directors that live relatively far away from their firm and their shareholder status, there may be some residual correlation between local demand in the firm's region and house price sensitivities in the directors' regions if the relative locations of the director and the firm reflect local patterns of commuting.[39] To further ensure that local demand spillovers are not driving our results, in Figures A35–A36 of Appendix F.1.4, we focus on firms that should be insensitive to demand conditions in the local region, namely those operating in the tradeable goods sector (Mian and Sufi, 2014).[40] Our results are very similar to the baseline. At this point, it is worth re-emphasising that industry-specific sensitivities to monetary policy shocks are also not driving our results as they are absorbed by industry-time fixed effects.

7.2 Director Characteristics and Cashflows

Our results so far suggest that the heterogeneity in firm-level responses is driven by the house price sensitivity of the director's location. However, the director's location may proxy for omitted firm-level heterogeneity: as described above, directors living in high-beta regions may be inherently different and run different types of firms. One immediate concern is that directors' choice of where to live could be endogenous either to monetary policy shocks or house price growth more generally. For example, directors whose firm becomes successful could move to regions where house prices are growing rapidly. To address this concern, we adopt a strategy analogous to Chaney, Sraer, and Thesmar (2012), and fix who directors were and where they lived at the start of our sample, in 1997, and calculate their house price beta, holding this fixed for the firm throughout the rest of the sample. This means that we omit endogenous director location switches in response to shocks that occur in sample. Using this alternative measure of directors' betas, we obtain similar results, as shown in Figures A37 and A38 of Appendix F.2, suggesting that this potential source of endogeneity is not biasing our results.

A further concern is that directors that are located in London are, or run firms that are, systematically different from those in other parts of the UK. For example, London based directors may have better access to financial or political networks. The estimates in Figures A39 and A40 show that excluding directors living in London has no effect on our results. More generally, directors living in high-beta regions may differ along a number of additional dimensions. For example, directors in high-beta regions may be more experienced, and this may affect how they manage their firm in response to monetary policy shocks (although Table 3 suggests this is not the case). To address this concern we saturate the regression with a large number of director characteristics, capturing their age, experience, and directorship history.[41] We average

[39] We thank Erik Hurst for raising this point.

[40] We proxy this with firms in the manufacturing sector. Specifically, in this specification, we restrict to firms with 2003 UK SIC Codes between 1511 and 3720.

[41] Specifically we include the following director characteristics: (i) the director's age; (ii) the number of

these director characteristics at the firm-level, and then place firms into three buckets for each characteristic, before including these additional controls in the regression both linearly, and interacted with the monetary policy shock. Figures A41–A42 show that, even controlling for these director characteristics, we obtain similar results, with a significantly greater response for young, high leverage firms when their directors live in high house price responsive regions.

To further corroborate the interpretation that the heterogeneity in the employment responses stems from the collateral channel on the director house and the variation induced by heterogeneity in the regional house price sensitivity, we exploit the fact that directors who are only *managers,* and not also *owners,* have much less incentive to pledge personal assets to support the firm. Hence if the collateral channel lies behind the heterogeneous response of employment to monetary policy, we would expect to see an effect only based on the house price sensitivity of those directors who are also shareholders in their firm. To avoid the house price sensitivity of non-shareholder director regions being correlated with the house price sensitivity of the firm region, for this sub-sample analysis we limit to firms where directors live 30 miles from the firm on average. In Figures A43–A44 (for shareholder directors) and Figures A45–A46 of Appendix F.2 (for non-shareholder directors) we show that the differential responses induced by the house price sensitivity of director regions is entirely due to shareholders. For non-shareholders, there is no statistically significant difference in the responses of younger and more levered firms based on the house price sensitivity of the directors' region.[42]

Last, we consider the fact that monetary policy shocks in the UK have a direct impact on the cash flows of individuals due to the prevalence of variable rate mortgage contracts. A shift in director cash flows could also affect the employment decisions of their firms and it is possible that the size of the cash flow effect is correlated with the director house price beta.[43] However, the size of these cash flow shocks on company directors is likely to be small compared to the effects coming through the changing value of their house. Using administrative mortgage data Cumming (2018) estimates that, for the average UK neighbourhood, the 400bp fall in Bank Rate during the Great Recession increased individual annual cash flows by £1,970. This implies that a 25bp fall in interest rates increases an individual's annual cash flow by just under £125. By contrast, in 2014, the estimated average house value across all company directors in the UK was £570,000 (Bahaj, Foulis, and Pinter 2018). Typical estimates suggest that a 25bp

directorships held; (iii) the number of firms the director has worked for; (iv) the number of industries she has been a director in; (v) her cumulative years of experience, across all directorships held; (vi) the number of directorships resigned; (vii) the number of firms where the director was present from the birth of the firm; and (viii) the number of directorships at firms that since died. See Online Appendix D of Bahaj, Foulis, and Pinter (2018) for further details.

[42]To run these specifications we separately calculate at the firm-level the average house price sensitivity across directors that are shareholders and across directors that are not shareholders.

[43]This would be the case, for instance, if regions where variable rate mortgage contracts are more concentrated experience a greater change in local demand and house prices in response to a monetary policy shock.

expansionary monetary policy shock raises house prices by 2% after 2 years (see, for example Williams (2015)). This would raise the average director's house value by £11,400 – almost 90 times more than the average cash flow shock from monetary policy. Moreover, we can also proxy for the size of director cash flow shocks due to monetary policy. In Appendix F.3, we merge director information with administrative mortgage data from the UK and show that controlling for the overall size of a director's mortgage or its size relative to the director's salary does not alter our main result.

7.3 Bank Lending Channel

Monetary policy can also affect banks, and our results could be confounded if bank lending to different types of firms is heterogeneous with respect to monetary policy shocks. A specific concern is that banks may be sensitive to house prices in a given region through their mortgage book. For example, if firms borrow from (regionally specialised) banks in the region where the director lives, the sensitivity of bank credit supply to monetary policy could be correlated with the house price sensitivity of the directors' region.[44]

For firms that have secured debt, we also observe the name of the bank that holds the loan (although not its quantity). This allows us to match firms to their creditor banks and include bank-year fixed effects[45] in the regression to control for any effects that may be due to bank credit supply.[46] The results, shown in Figure A53 of Appendix F.4, are similar to the baseline estimates. However, bank-time fixed effects only control for bank behaviour on average. A given tightening in bank lending may affect the weakest firms the most (Holmstrom and Tirole 1997). To explore this, we interact the bank-combination x year fixed effects with a dummy for whether the firm is young (less than 15 years old) or old (above 15 years old).[47] Figure A54 shows that, even allowing for young firms to be differentially affected by the lending conditions of individual banks in a given year, the responsiveness of young, high leverage firms to monetary policy shocks is significantly greater when their directors' live in a region with high house price sensitivity.

[44] This concern may be less relevant for the UK, which has a concentrated banking sector, with a small number of large banks accounting for the majority of bank lending, and lending throughout the country (Beck, Demirguc-Kunt, and Levine, 2006; Flogel and Gartner, 2018). Specifically, the four largest banks accounted for 90% of business lending in 2013 (Flogel and Gartner 2018).

[45] Bank combination fixed effects create groups for all the combinations of banks borrowed from. For example, there will be a separate group for firms that borrow from both banks A and B.

[46] See Anderson, Bahaj, Chavaz, Foulis, and Pinter (2018) for further details on the construction of the bank-combination x year fixed effects.

[47] We thank Yueran Ma for this suggestion.

7.4 Hiring Frictions and Wage Rigidity

An alternative explanation for the relative cyclicality of different groups of firms' employment is hiring frictions in labour markets.[48] As documented by Moscarini and Postel-Vinay (2012), smaller firms are net job creators when the labour market is slack and larger firms are net job creators when the labour market is tight. Since large firms tend to pay higher wages, they can poach workers from smaller enterprises, hence they are able to expand when workers are in short supply, whereas smaller firms need unemployed workers to grow. This argument is based around the level of unemployment rather than in response to a particular shock (a point Moscarini and Postel-Vinay (2012) emphasise clearly). Nonetheless to the extent that monetary policy influences the degree of slack in the labour market, this may be an alternative explanation of our findings.

Our approach to account for any heterogeneity in hiring frictions is to control for the average wage paid by the firm before the monetary policy shocks hit. Specifically, we use dummy variables to divide firms into three tertiles based on the average wage paid, defined as the ratio of *Remuneration* to *Number of Employees*. We then interact this new dummy variable with the dummies for leverage and age we used in our main specification and the monetary policy shock. This specification controls for any heterogeneity in the ability of firms to attract workers in response to a monetary policy shock due to wages paid and allows the importance of wages to vary with the firm's age and leverage. As can be seen in see Figures A55–A56 of Appendix F.5, including this control does not make a difference to our baseline result.

Alternatively, firms may also be heterogeneous in their degree of wage rigidity. Firms that have to reduce their wage bill following a reduction in the availability of external finance can adjust either their employment or wages. If firms face differing degrees of wage rigidity, this could result in heterogeneous employment decisions in response to a common decrease in external financing. To explore this, we instead alter the dependent variable to the average wage paid by the firm rather than using it as a control. As shown in Figure A57 of Appendix F.5, across all groups there is little response of wages over the first two years, and the response is still insignificantly different from zero after 3 years, consistent with firms having to reduce their total wage bill through shrinking their workforce. Moreover, among the younger, higher leverage firms, there is no significant difference in the response of average wages across firms with directors living in high vs low beta regions, suggesting that our employment results are not being driven by heterogeneous wage rigidities that are correlated with director betas (Figure A58 shows more generally that there are no significant differences in the average wage responses across the firm groups).

[48]We thank Guiseppe Moscarini for suggesting this point.

7.5 Exit Rates

Our analysis so far has focused on the employment behaviour of continuing firms who do not exit. As described above, and further shown in Section 8, it makes little difference whether we rectangularise the sample (as in the baseline) or consider the response of any firms who just survive until horizon h. So on impact, and at short horizons, the effect of monetary policy on employment of firms who subsequently exit seems similar to those who survive for several more years.

Nonetheless, the shock may have an impact on exit rates themselves. We discuss this issue, alongside the data and the specification in Appendix F.6. For the sake of brevity, here we just summarise the results. A contractionary monetary policy shock generates an immediate spike in exit rates among firms in year 0 but has no effect on exit rates at longer horizons. On impact, exit rates of young, high leverage firms are more sensitive to monetary policy than old low leverage firms although there is no persistent effect for either group. Nor is there any heterogeneity in exit rate responses associated with director beta. This latter result is perhaps unsurprising given the relative dynamics of exit and house prices in response to a monetary policy shock. Exit rates exhibit a short lived spike. House prices typically have a delayed hump shaped response and so collateral values are unlikely to adjust sufficiently to generate heterogeneity in year 0 exit rates.

7.6 Summary

In this section, using a number of alternative strategies, we have shown that the heterogeneity we observe in the data cannot be accounted for by controlling for local demand effects, hiring and wage frictions, the bank lending channel or director characteristics. Of course, these findings do not imply that these other channels have no effect on the transmission of monetary policy shocks to firms; rather that our identification strategy allows us to control for these channels and separately identify the collateral channel of monetary policy.

8 Sensitivity Analysis

In Appendix G, we subject our main result from Section 6.2 to an extensive range of robustness tests. To preview the results, no alternative cut of the data overturns our findings.

The results are robust to splitting by director house price betas, when classifying regions by their house-price responsiveness after 36, rather than 24 months: see Figures A62–A63. As with the linear model, adding firm controls has little effect on either the point estimates or the error bands (Figures A64–A65). Nor does using Davis-Haltiwanger growth rates of employment (Figures A66– A67), considering a non-rectangularised sample (Figures A68–A69), size weighting (Figures A70–A71) or adding a firm fixed effect (Figures A72–A73).

Firms also borrow using their own commercial real estate as collateral (Chaney, Sraer, and Thesmar, 2012), hence we can consider heterogeneity in firms' house price betas as an alternative. This is less well-identified and we cannot use region-time fixed effects. However, cutting the data in this dimension (rather than our baseline specification using the directors' region), and restricting to firms in the tradeables sector to mitigate local demand concerns (Mian and Sufi, 2014), gives similar results (Figures A74–A75).

As an alternative to using the director house price beta, we can also calculate a *value* based measure of how exposed the firm is to the collateral channel. This interacts the house price sensitivity of a director's region with the *value of their house*, before summing across all directors at a firm. This adds an additional source of variation: within a region, a director with a more expensive house will experience a greater change in the value of their house, for a given monetary policy shock. However, the value of the director's house is likely endogenous to firm characteristics to a greater extent than director location so this specification is less well identified. Nonetheless, as shown by Figures A76–A77, the results are similar to the baseline. If anything the heterogeneity is sharper, further corroborating that it is the sensitivity of the house prices of individual directors to monetary policy shocks that matters.

One may be also concerned with what is being captured by our monetary policy shock. Our sample intersects with a period when interest rates were stuck against the zero lower bound. In Figures A78–A79, we therefore end our sample in 2008 and still find a very similar heterogeneity relative to the one estimated over the full sample in Section 6.2. A second potential concern is that high frequency market reactions to monetary policy announcements used in the Gerko and Rey (2017) series could reflect the revelation of private information of the central bank rather than random fluctuations in interest rates (Miranda-Agrippino, 2016). This could bias our estimates upwards if central bank tightening reflects good news about future economic prospects. To control for changes in the central bank's information set we use the change in the sum of 4-quarter ahead forecasts over the firm's accounting year for both inflation and output, taken from Cloyne and Hurtgen (2016), and interact these series with the age x leverage x director beta buckets as additional controls. As shown in Figures A80–A81, the results are very similar to the baseline when controlling for these forecast changes.

Our results are also robust to alternative proxies for financial constraints. Using our firm-level data we estimate a financial constraints index in the spirit of Whited and Wu 2006 (see Online Appendix G of Bahaj, Foulis, and Pinter (2018) for further details). We place firms into four buckets of the constraint index per year, and interact this with the director betas. As shown in Figures A82–A83, the sensitivity of house prices in the director's region to monetary policy shocks makes a difference to the employment response for the firms with the highest value of the constraint index, but not the firms with the lowest value of the index. As a further check we replace leverage with credit score as an alternative measure of balance sheet strength.[49] Figures A84–A85 confirm that the pattern of heterogeneity along the dimension of collateral price sensitivity continues to resemble our baseline when using credit score in place of leverage. Further, as shown in Figures A86–A87, we see a similar pattern of heterogeneity when sorting firms only by their age and the house price sensitivity of their directors' regions. Moreover, we show that our results are not specific to our particular choice of age. Other studies have defined young firms at a lower age, e.g. age of 5 (Fort, Haltiwanger, Jarmin, and Miranda, 2013). We cut at 15 trading off maximising heterogeneity whilst maintaining a reasonable number of firms in each each group. Nevertheless, we explore changing our age threshold, and the results are similar to our baseline when we instead chose 5 years of age as the threshold, as shown by A88–A89.

Finally, we check whether the patterns of heterogeneity along the dimensions of age, leverage and house price sensitivity are masking heterogeneity in size. We do this in two ways. First we focus on smaller firms with less than 250 employees and find similar results to our full sample, as shown by Figures A90 and A91 in Appendix G.15. Second, as an additional control, we add to the baseline regression four buckets for firm size (measured by annual quartiles of lagged employment) interacted with director betas, included linearly, and interacted with the monetary policy shock. As shown by Figures A92 and A93, the baseline results are robust to the inclusion of this additional control.

9 Conclusion

This paper finds that the employment adjustment to monetary policy is large and significant for younger and more levered firms but is small and statistically negligible for older and less levered firms. This heterogeneity becomes even more pronounced when we look at regions with a higher sensitivity of local house prices to monetary policy shocks (or a higher housing supply elasticity). This finding is mirrored by the response of corporate debt to monetary policy shocks.

Our results are consistent with monetary policy transmitting via asset prices through collateral constraints on firms. To arrive at this conclusion, our research design employed various strategies to ensure that we are not simply picking up monetary policy effects via demand chan-

[49]We measure the Credit Score of a given firm in a given year using the "QuiScore", which is reported in the FAME dataset. The QuiScore is produced by CRIF Decision Solutions Limited and is designed to reflect the likelihood that the company will fail in the following 12 months. Each firm is assigned a value between 0 and 100, with a larger value indicating a lower probability of failure. We split firms into two categories: *lower credit score,* for firms with a QuiScore below 60 (a rating below "Stable"); and *higher credit score,* for firms with a QuiScore of 60 or above (those who are "Stable" or "Secure".)

nels. Furthermore, this interaction between collateral values, monetary policy and firm-level characteristics is of quantitative importance. It is large enough to explain a significant share of both the observed firm-level heterogeneity in response to monetary shocks and the aggregate employment response to monetary policy.

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Tables

Table 1: Regression Sample Summary Statistics

Full Sample Summary Statistics				
Variable	**Mean**	**Median**	**25%tile**	**75%tile**
Number of Employees	496	48	8	115
Total Assets (£'000s)	83,754	3,418	713	8,240
2-year Employment Growth (%)	6.3	0	-3.9	16
2-year Real Asset Growth (%)	8.9	6.1	-8.9	25
Age (years)	22	15	6.8	29
Leverage (% assets)	66	63	42	81
Average Wage (£'000s)	25	22	14	31
192,223 Firm-Year Observations on 37,944 Firms				

Median/Mean values by Age, Leverage, Size						
	Age		**Leverage**		**Size (Employees)**	
	0-15	**15+**	**Below**	**Above**	**1-250**	**250+**
Variable			**Median**	**Median**		
Number of Employees[a]	25	66	53	43	37	528
Total Assets (£'000s)[a]	2,166	4,439	3,854	2,976	2,858	33,435
2-year Employment Growth (%)[b]	9.2	3.5	5.3	7.4	6.6	4.4
2-year Real Asset Growth (%)[b]	12	6.3	8.8	9	9.1	7.6
Age (years)[a]	6.8	29	20	11	15	20
Leverage (% assets)[a]	71	55	41	81	63	61
Average Wage (£'000s)[a]	21	22	22	21	22	21

a = median, b = mean

Notes: The Table presents summary statistics for the baseline regression sample (see Section 3.1). Age is defined as the number of years elapsed from the date of incorporation. Leverage is measured as the ratio of the balance sheet items "Total Liabilities" to "Total Assets". Size is measured as the "Number of Employees". Average wage is defined as the ratio of "Remuneration" to "Number of Employees". All of these variables are measured at the beginning of the firm's accounting period. Employment and Asset growth are measured as the log difference from the beginning of the firm's accounting period to the end of the subsequent accounting period, a period of two years. Asset growth is deflated using the change in the consumer price index over the same period. These growth rates are trimmed at the 1/99 percentiles. For presentation in this table, leverage and the average wage are winsorised at the 1/99% levels. The upper panel shows the statistics based on the regression sample. The lower panel splits the statistics into two groups for each of age, leverage and size.

Table 2: Personal Guarantees and Interest Rate by Firm Age and Leverage

	Lending Secured by Personal Guarantee (1)	Interest Rate (2)
Younger, Higher Leverage	63%	3.80%
Younger, Lower Leverage	51%	3.06%
Older, Higher Leverage	49%	3.27%
Older, Lower Leverage	33%	3.24%
All Firms	50%	3.41%

Notes: The Table presents the results of the Bank of England's 2015 survey of UK SME and Mid-Corporate Lending by the five major UK banks. We merge this with BvD data on firms to measure firm leverage. The survey covered lending from the five major UK banks to businesses borrowing at least £250k, and whose annual revenue was no more than £500million. To facilitate comparison with our regression results, we exclude lending to businesses in Human Health, Education, Financial and Insurance Activities, and Commercial Real Estate. We further exclude businesses with 0-1 employees and limit to limited liability firms firms that not subsidiaries in Scotland, England, and Wales. Column (1) shows the fraction of business lending (weighted by number) that was secured by a personal guarantee, broken down by the leverage of business being lent to (with higher/lower leverage being above/below median firm leverage in the baseline regression sample and younger/older being firm age below/above 15 years old). Column (2) shows the interest rate on the bank's largest exposure to the business, averaged within each firm leverage group and weighted by number.

Table 3: Summary Statistics Split by Director Beta

Summary Statistics by House Price Beta						
				Director Beta		
	Unconditional	**Director Beta**		**vs Firm Beta**		
Variable	**Median**	**Low**	**High**	**Same**	**Lower**	**Higher**
Firm-level Summary Statistics: *133,078 Firm-Year Observations on 27,718 Firms*						
Number of Employees	56	70	43	41	59	65
Total Assets (£'000s)	3,900	4,320	3,414	2,764	4,273	4,674
Age (years)	15	18	14	15	15	15
Leverage (% assets)	63	62	63	62	63	63
Director-level Summary Statistics: *270,350 Director-Year Observations on 61,612 Directors*						
Director House Value (£'000s)	411	307	473	354	460	446
Director Outside Firm Region (%)*	62	57	66	0	100	100
Director Distance From Firm (Miles)	8.7	7.8	8.1	3	16	15
Director Age (Years)	49	48	49	48	49	48
Experience (Years)	9.7	8.8	9.8	8.2	11	10

Notes: (I) Firm-level statistics: further restricts the baseline regression sample to firms where the average director beta is non-missing. Age is defined as the number of years elapsed from the date of incorporation. Leverage is measured as the ratio of the balance sheet items "Total Liabilities" to "Total Assets". Medians are presented. The second and third column breaks the statistics down by whether the average director beta of the director's firm (averaged across all directors at the firm) is in the top tertile (*High Beta*) or bottom tertile (*Low Beta*) in a given year. The fourth, fifth and sixth column panel breaks the statistics down by whether the average director's region has the same house price beta as the firm (*Same*), a lower house price beta, or a higher house price beta.
(II) Director-level summary statistics: statistics cover the directors of the firms in the first part of the table and are shown only for the directors whose regional housing beta can be calculated. Director House Value is the value of the director's house in £000s. Director Outside Firm Region is a dummy variable which takes value 1 when the director lives in a different region to their firm, and 0 otherwise. Director Distance From Firm is the distance between the director's house and the firm, in miles. Director Age is the director's age, in years. Experience is the cumulative years of experience the individual has in years, across all directorships held. The columns are broken down by betas in the same manner as the firm-level statistics.

Figures

Figure 1: Theoretical Employment Responses to an Expansionary Monetary Policy Shock

(a) No Easing of Financial Constraints (b) With Easing of Financial Constraints

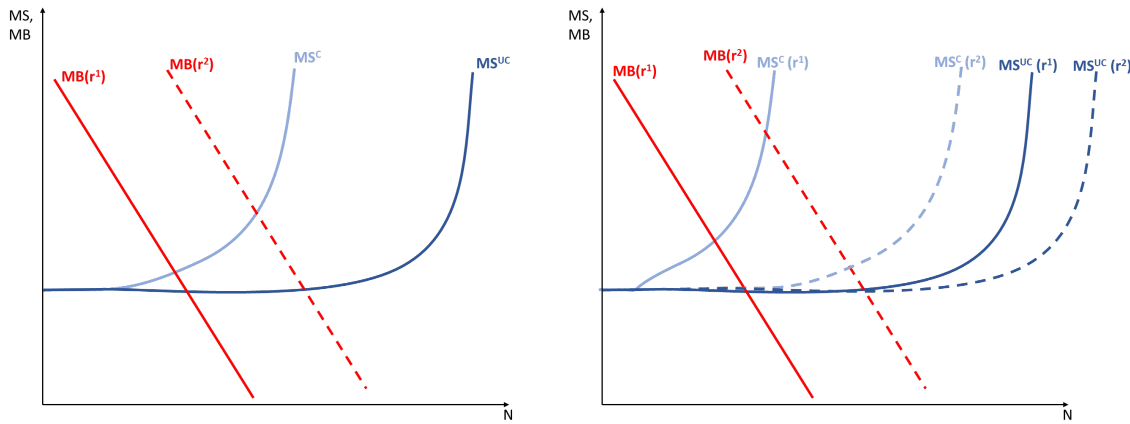
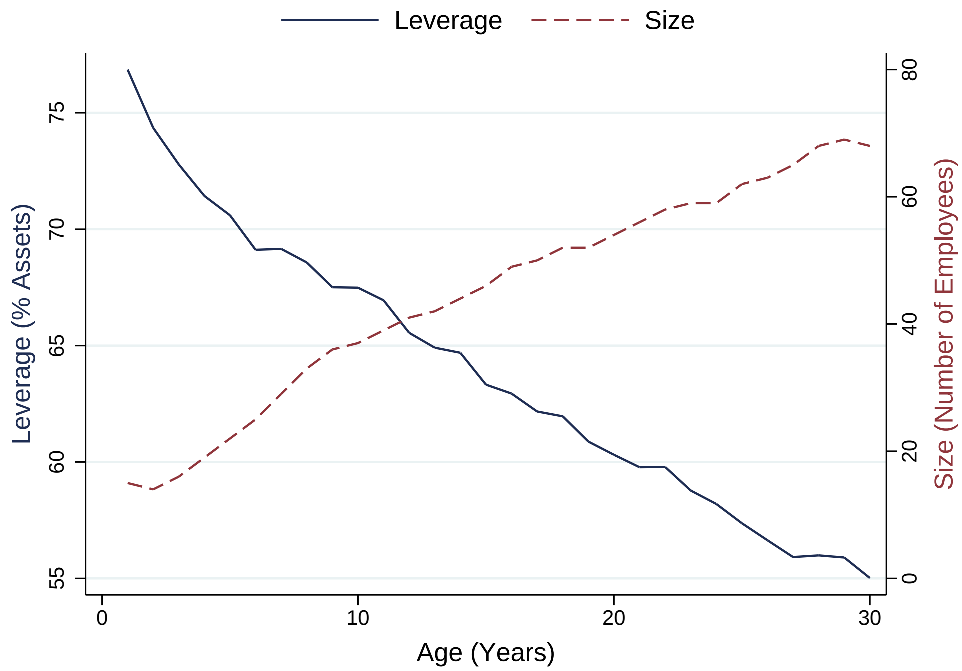
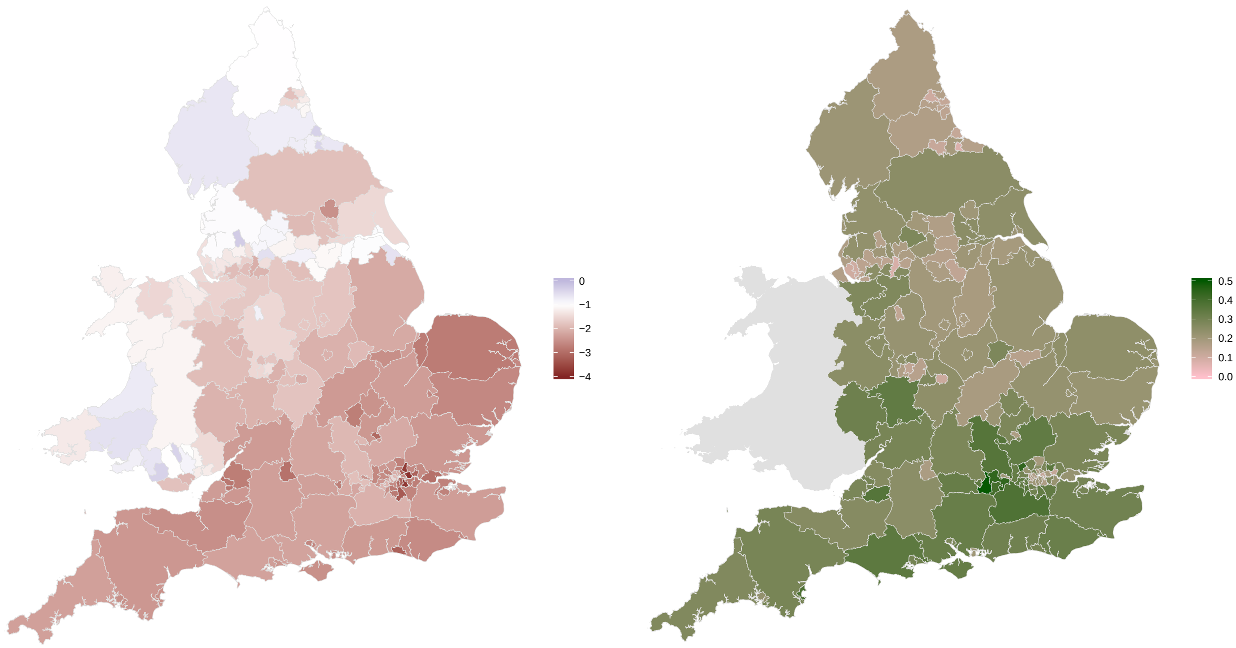


Figure 2: Firm Leverage and Size Over the Life-Cycle



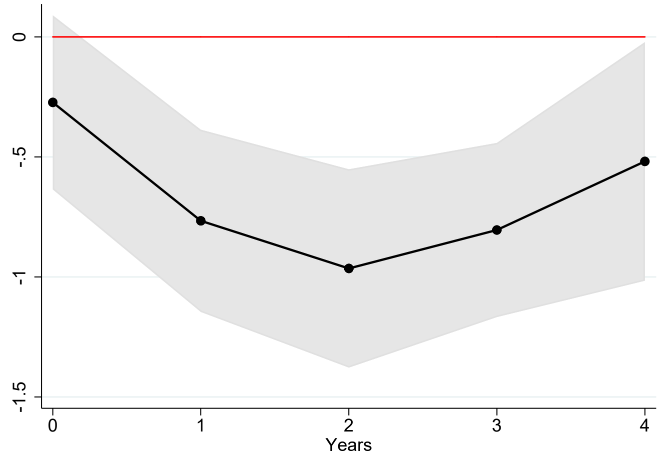
Notes: the Figure shows the median leverage (measured as the ratio of total liabilities to total assets) and the median firm size (measured as number of employees) for firms of each age group from 1 to 30. Age is measured as number of years since incorporation.

Figure 3: Regional Variation in House Price Beta and Residential Planning Application Refusal Rates



Notes: the chart on the left displays a heat map of regional variation in house price sensitivity to monetary policy shocks, as summarised by the average year-on-year house price growth, computed over the two-year horizon after a shock that increases the annualised interest rate by 25bp. The chart on the right displays a heat map of regional variation in refusal rates of residential planning applications, averaged over the sample 1979-2008. The measure, constructed by Hilber and Vermeulen (2016), shows the average fraction of planning applications on residential projects consisting of 10 or more dwellings that were refused by the local authority. This data is not available for Wales.

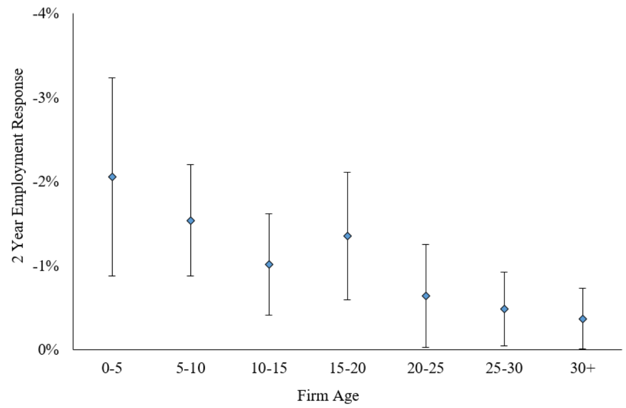
Figure 4: The Linear Effect of Monetary Policy on Firms



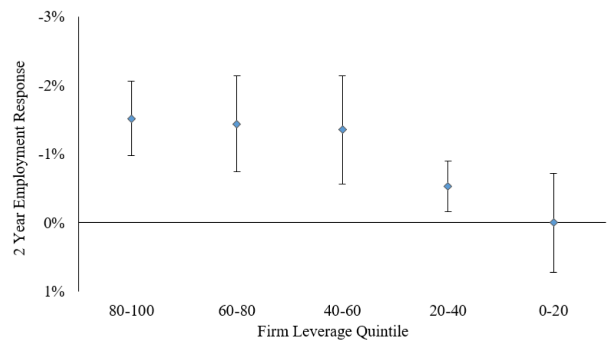
Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis.

Figure 5: Employment Responses to a Contractionary Monetary Shock by Age, Leverage, Size Groups - 2 year horizon

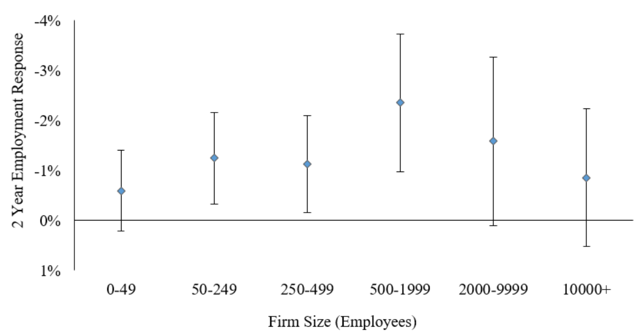
(a) Age



(b) Leverage



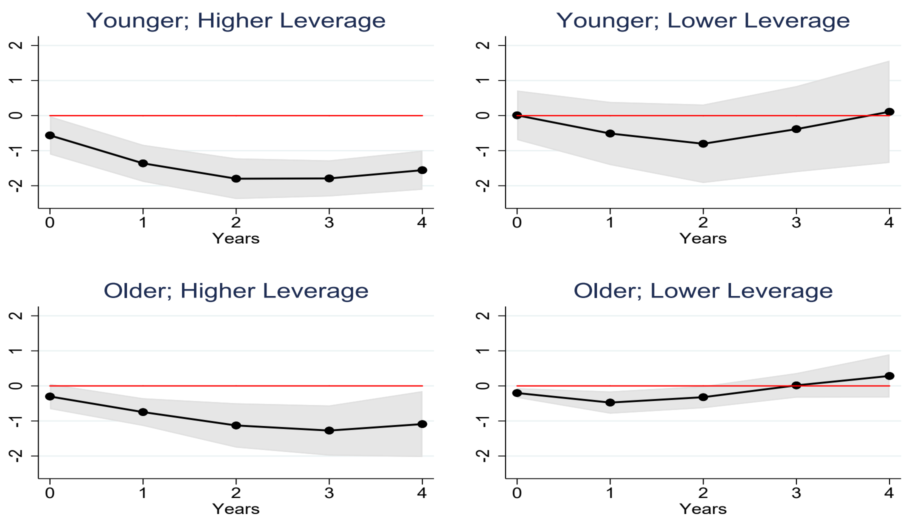
(c) Size



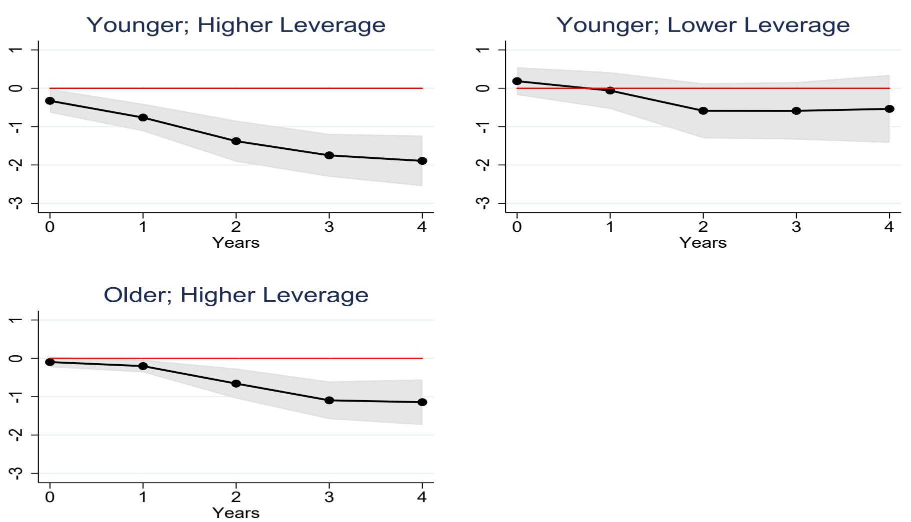
Notes: The candle chart summarises the point estimates (together with the 90% confidence interval) corresponding to the effect of a 25bp contractionary monetary policy shock for different groups of firms, sorted by age (top panel), leverage (middle panel) and size (bottom panel), as estimated by Equation 1.

Figure 6: The Effects of Monetary Policy on Employment by Age and Leverage, Double Sorted

(a) Level Effects



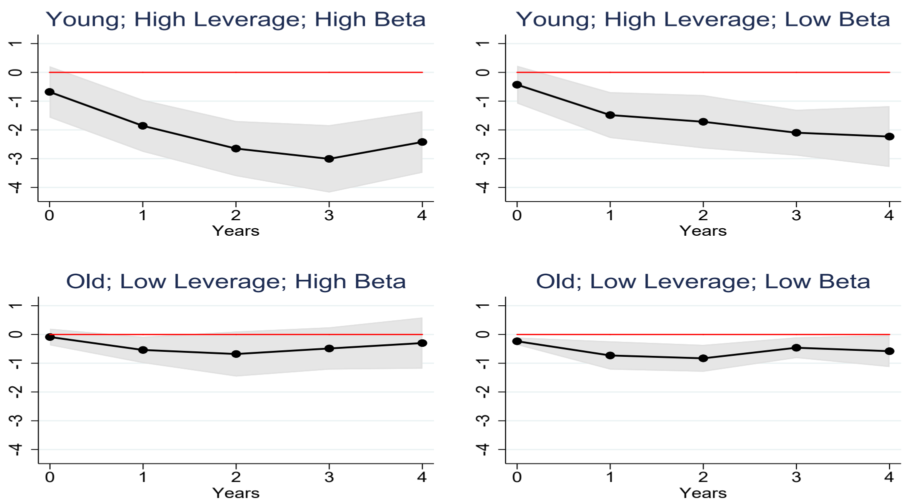
(b) Relative Effects



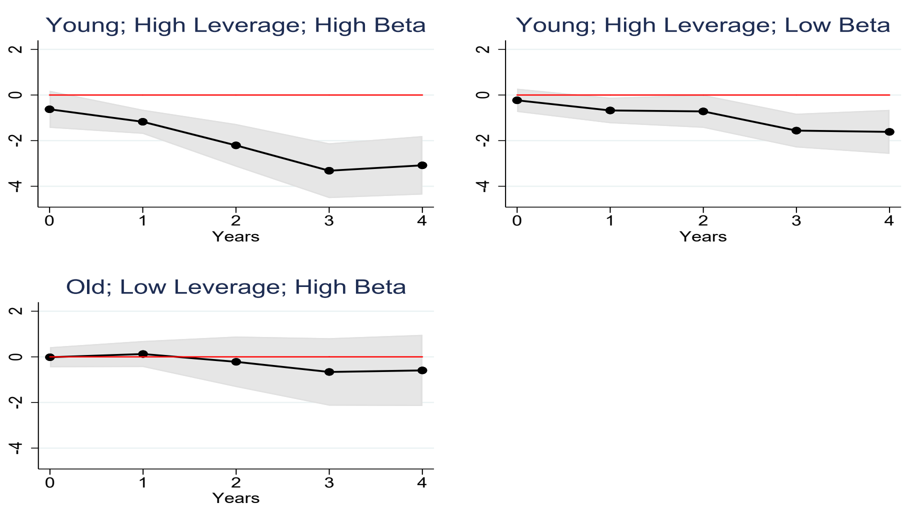
Notes: The figure shows firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. Panel a and b shows the results for specification 1 and 2, respectively. All the responses in Panel b are relative to the group of older and more levered firms (omitted given the inclusion of industry-month and NUTS1-month fixed effects). Younger is defined as less than 15 years old, and higher leverage is defined as above the median leverage by year.

Figure 7: The Effects of Monetary Policy on Employment by Age, Leverage and Director Beta

(a) Level Effects



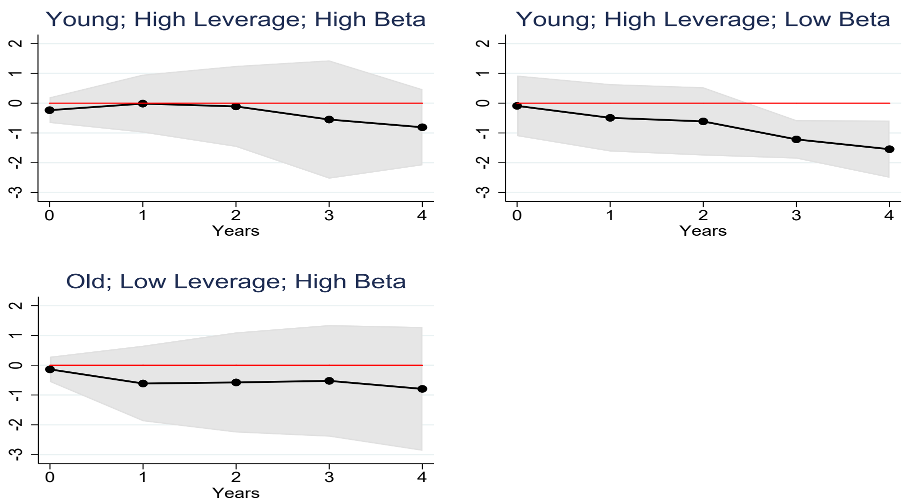
(b) Relative Effects



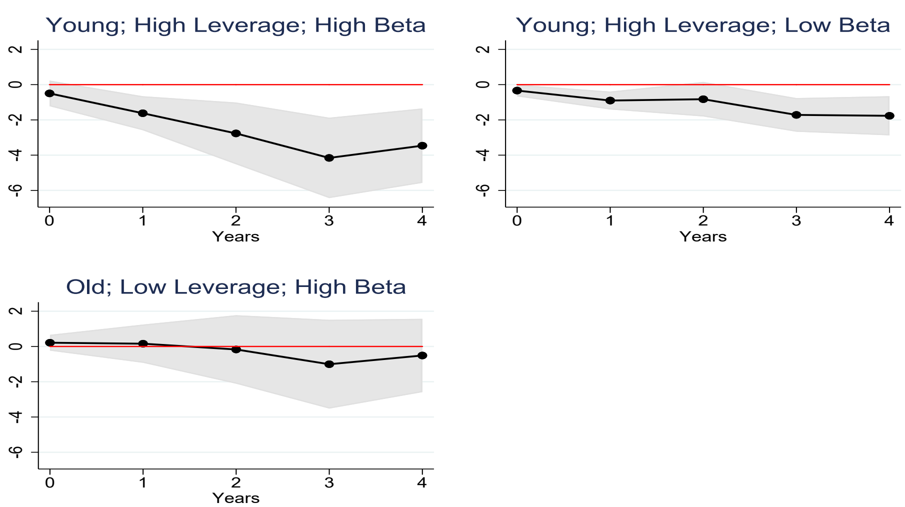
Notes: The figure shows firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. Panel a and b shows the results for specification 1 and 2, respectively. All the responses in Panel b are relative to the group of older and more levered firms in low-β regions (omitted given the inclusion of industry-month and NUTS1-month fixed effects). Younger is defined as less than 15 years old, and higher leverage is defined as above the median leverage by year.

Figure 8: The Effects of Monetary Policy on Employment by Age, Leverage and Director Beta

(a) Director Real Estate <15% Total Assets

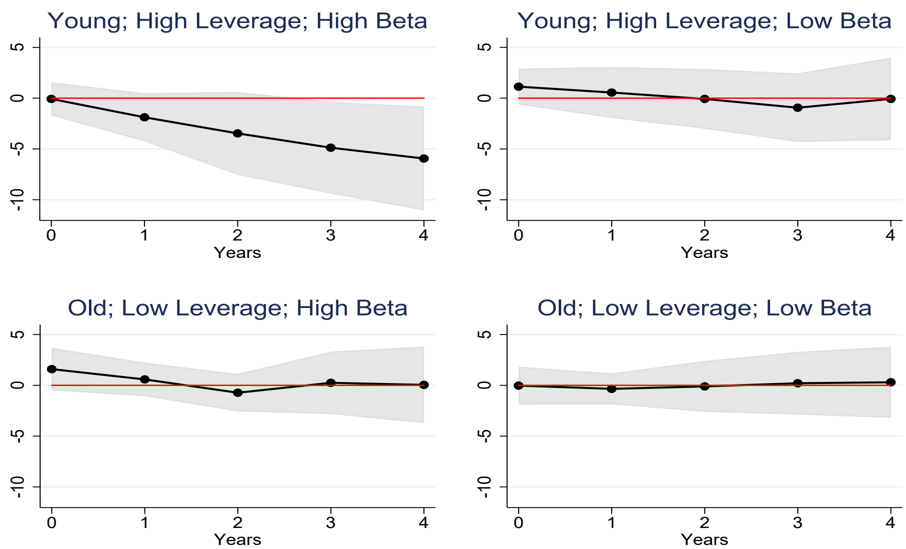


(b) Director Real Estate $\geq$ 15% Total Assets



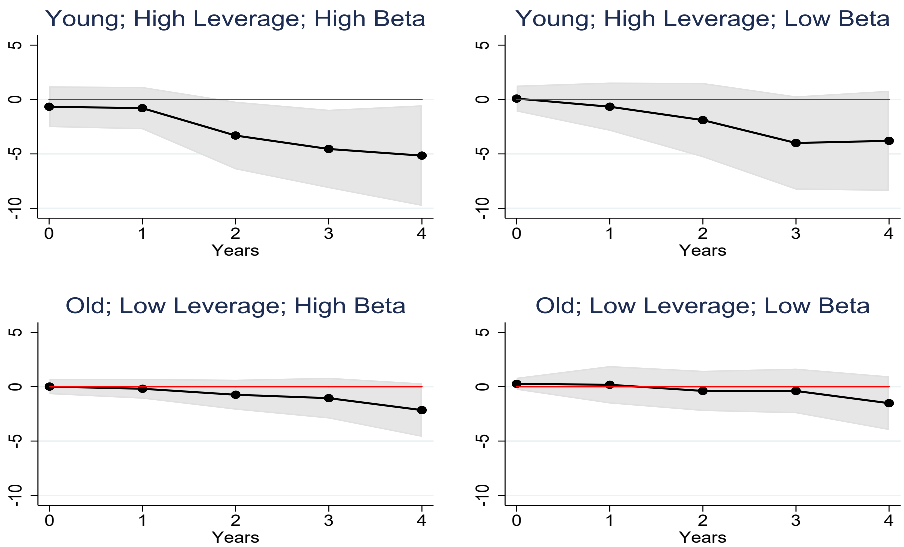
Notes: The figure shows firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. Panels a and b both show the results for specification 2, and in both cases the responses are relative to the group of older and more levered firms in low-β regions (omitted given the inclusion of industry-month and NUTS1-month fixed effects). Younger is defined as less than 15 years old, and higher leverage is defined as above the median leverage by year. Panel a restricts to the subsample of firms where the total value of director real estate is worth less than 15% of the firms' balance sheet; Panel b restricts to the sample of firms where director real estate is above this threshold.

Figure 9: Level Effects on Total Debt by Age, Leverage and Director Beta, Triple Sorted



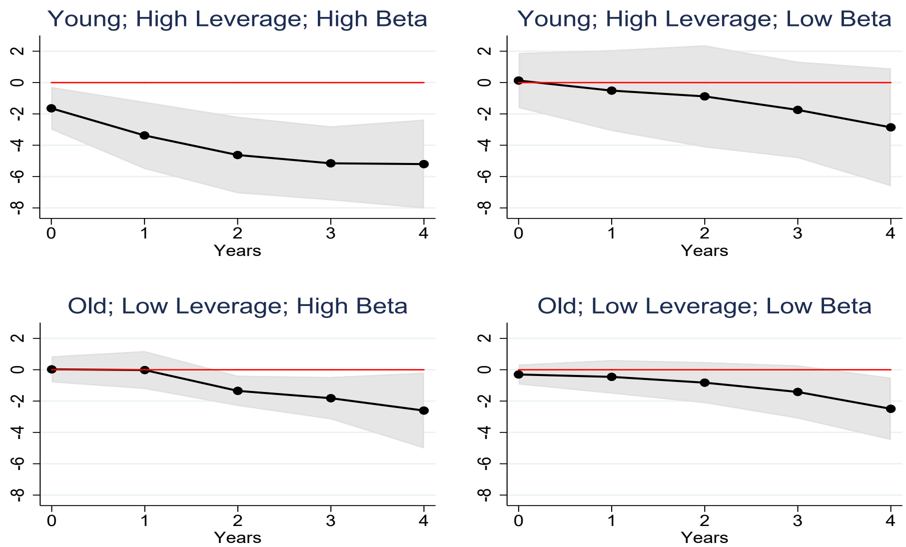
Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Total Debt from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis – see specification 1. All the responses are %-deviations.

Figure 10: Level Effects on Prepaid Expenses by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Prepaid Expenses (*Current Assets* less *Bank Deposits* less *Trade Debtors*) from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis – see specification 1. All the responses are %-deviations.

Figure 11: Level Effect on Fixed Assets by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Fixed Assets from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis – see specification 1. All the responses are %-deviations.

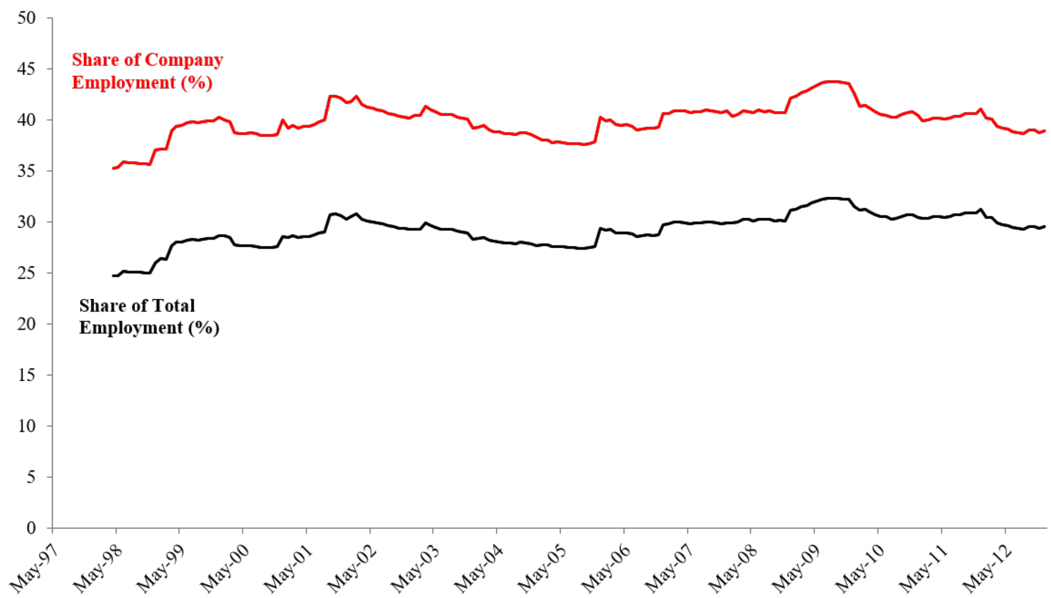
Appendix (For Online Publication)

A Data Construction and Sample Selection

A.1 Sample Selection

This section provides further details on the firms in our regression sample. Figure A1 shows the fraction of aggregate employment accounted for by the firms in our baseline regression sample. The black line shows that these firms account for around 30% of aggregate employment in the same industries, with fairly stable coverage over time. As our analysis is limited to *companies,* the red line further shows the share of aggregate company employment in these industries accounted for by the firms in our regression sample, excluding employment by partnerships and sole proprietors from the aggregate. The coverage of aggregate company employment hovers around 40%.

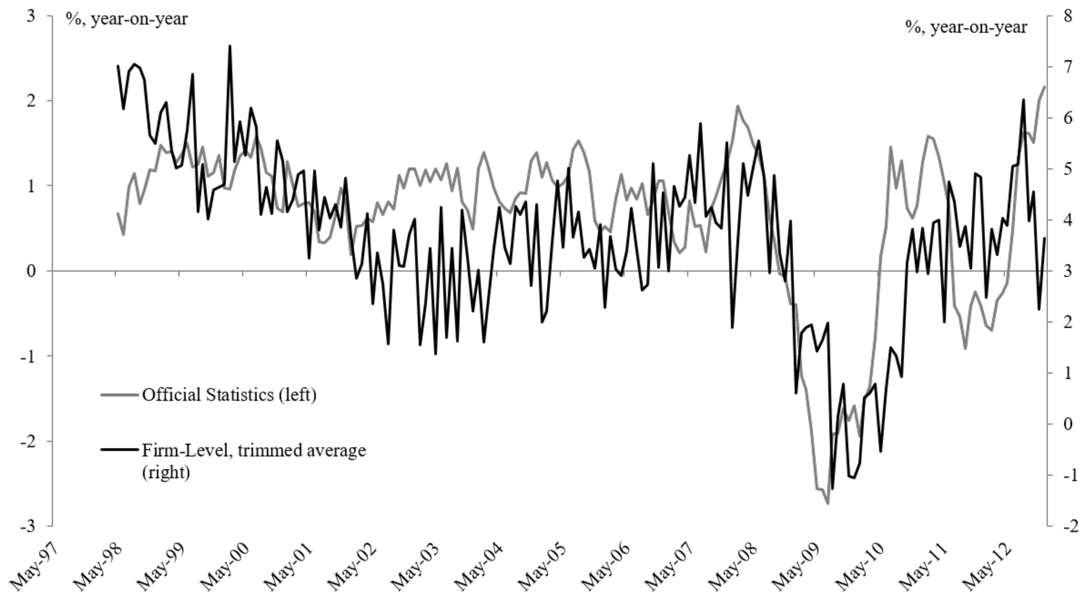
Figure A1: Sample Coverage of Aggregate Employment



Notes: The Figure presents the share of aggregate employment (black line) and the share of aggregate company employment (red line) of the firms in our regression sample. Aggregate employment, from the *Office for National Statistics,* covers the same industries as the baseline regression sample (see Section 3.2). *Share of Total Employment* is the ratio of the rolling sum of employment for the firms in our regression sample who filed accounts in the past 12 months, to aggregate employment in the month. *Share of Company Employment* replaces the denominator with the aggregate employment of *companies*, estimated by the annual shares of company employment to total employment, taken from the *Office for National Statistics.* This excludes employment by sole proprietors and partnerships.

Moving beyond the share of employment coverage, Figure A2 compares annual employment growth for the aggregate, and the firms in our sample. The average firm-level employment growth is more volatile, though the two series track each other well through time.

Figure A2: Employment Growth at the Firm and Aggregate Level



Notes: The Figure presents annual employment growth for the firms in our regression sample (black line, right axis) and the aggregate (grey line, left axis). Aggregate employment, from the *Office for National Statistics,* covers the same industries as the baseline regression sample (see Section 3.2). Aggregate employment growth is year-on-year. Firm-Level employment growth is the unweighted annual employment growth of the firms in our regression sample, that file in same month. This growth rate is unweighted and trimmed at the 1/99% level.

Our baseline regression sample imposes the restriction that firms report their age, leverage, and number of employees. Age and leverage are better reported than number of employees in our dataset. Table A1 presents summary statistics on these variables for the firms in our regression sample, and the same firms without the employment reporting restriction (we maintain the same industry and company type restrictions). The firms that don't report employment are clearly younger, with a median age of 4 rather than 15, and more highly levered, with median leverage of 75% rather than 63%, than the firms that do.

Table A1: Summary Statistics of Firms That Do and Do Not Report Employment

	Summary Statistics			
	Age (Years)		Leverage (% Assets)	
	Mean	**Median**	**Mean**	**Median**
All Firms	7	4	87	75
Regression Sample	22	15	66	63

Notes: The Table presents summary statistics on firm age and leverage for all firms in our dataset, and the firms in our baseline regression sample. Age is defined as the number of years elapsed from the date of incorporation. Leverage is measured as the ratio of the balance sheet items "Total Liabilities" to "Total Assets". The first row presents summary statistics for all firms that satisfy the company type and industry codes described in Section 3.2. This sample does not limit to firms that report employment. In this sample the leverage ratio is trimmed at the 1/99% levels. The second row presents summary statistics for the firms in our baseline regression sample, from Table 1. This includes the additional restriction that firms report employment growth over a four year horizon.

A.2 Aggregate Employment Contribution by Age and Leverage

To estimate the aggregate contribution of young, high leverage firms we use constructed weights for the share of employment accounted for by firms of different sizes. Administrative micro-data is taken from the *Business Structure Database* from the *Office For National Statistics* (ONS), covering total employment by companies in the same industries as the baseline regression.[50] The share of total employment for these companies accounted for by different firm size groups is calculated for the following employment bins: 1-9,...,90-99,100-149,...,950-999,1000-1999,...,19000-20000,20000+. The share of observations in our baseline regression sample accounted for by each firm size bin is also calculated. Weights are then constructed for each size bin using these two sets of numbers, to ensure that the weight placed on each group in our regression matches their contribution to aggregate employment. Figure A22 in Appendix E shows the employment response to monetary policy shocks broken down by age and leverage groups, using these weights.

We then calculate, within the same firm size groupings, the share of employment in our regression sample accounted for by young, high leverage firms; and each of the remaining categories of firms. We then estimate the aggregate employment share of young, high leverage firms, assuming that the employment share of young high leverage firms within our given fine size buckets is the same in our sample as in the aggregate. Using this procedure we find a similar estimated employment share in the aggregate as in our sample.

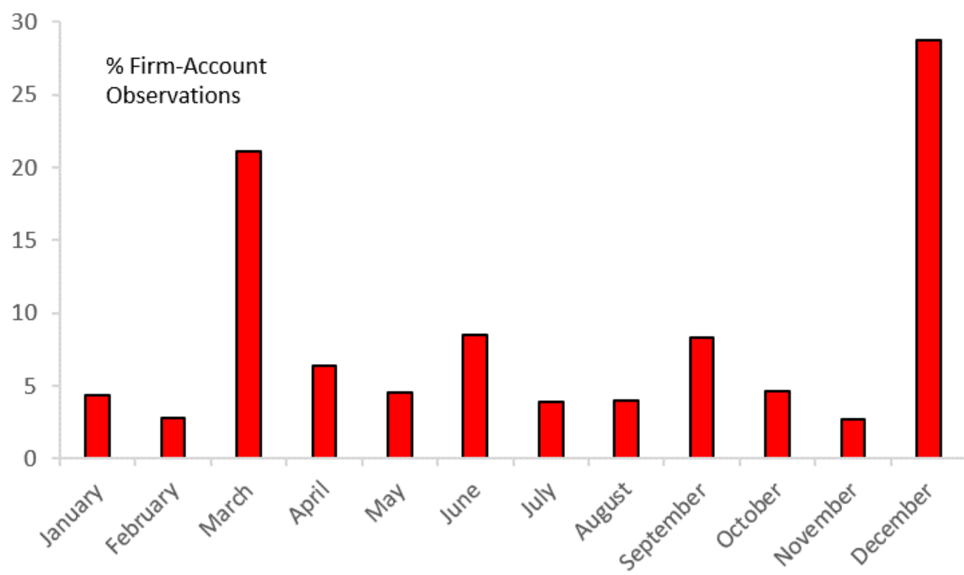
A.3 Filing Months

Figure A3 displays the distribution of the months in which firms in our regression sample file their accounts. Firms can choose to alter their filing date and file outside an annual cycle (this happens for approximately 4% of firm-account observations). All our regressions focus on time windows where the firm is filing regularly; that is to say, when computing firm growth rates, at any horizon, we exclude any observations when there is an irregular filing period (not, 11, 12, or 13 months between accounts). One concern is that firms may strategically alter their filing dates in response to monetary policy shocks, thereby introducing a selection effect. There are a number of reasons to assume that this sort of behaviour is not distorting our results. First, 91% of firm-account observations are filed in the same month as the first set of the firms' accounts in our sample, and 83% of firms never have an irregular filing window. Second, while firms can always choose to shorten the intervals between account filings, they can only lengthen their accounting period once every 5 years and only to a maximum of 18 months, which limits firms'

[50] This work was produced using statistical data from ONS. The use of the ONS statistical data in this work does not imply the endorsement of the ONS in relation to the interpretation or analysis of the statistical data. This work uses research datasets which may not exactly reproduce National Statistics aggregates.

ability to file strategically. Third, empirically, monetary policy shocks explain a tiny fraction of the time series variation of an individual firm's activity, suggesting the incentive to strategically alter filing dates in response to monetary policy shocks is small.

Figure A3: Distribution of Filing Dates by Month



Notes: The Figure presents the distribution across calendar months in which the firms in our baseline regression sample (see Section 3.2) file their accounts.

A.4 Regional Variation in House Price Sensitivities

To estimate spatial variation in the sensitivity of real estate prices to monetary policy shocks, we proceed as follows. First, we apply local projection methods and estimate region-by-region the following house price regression:

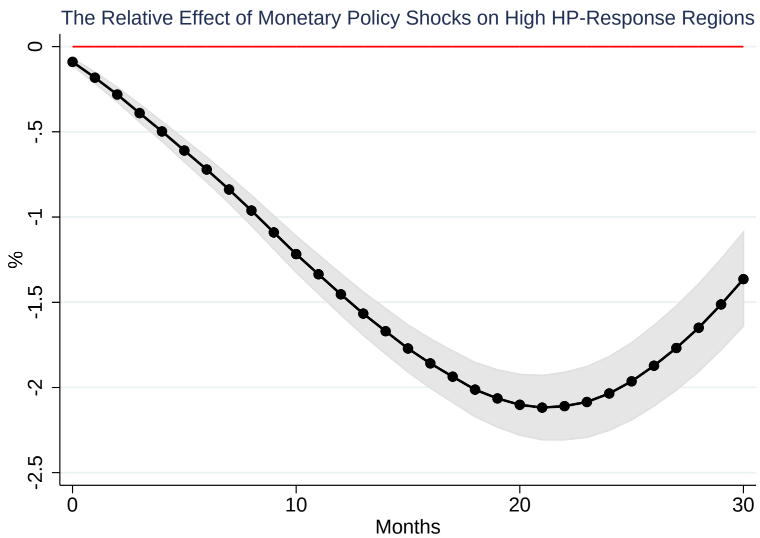
$$\log\left(P_{j,t+h}\right) - \log\left(P_{j,t-1}\right) = \alpha_j + \beta_j^h \times e_{m,t} + controls_{j,t} + \varepsilon_{j,t}^h, \tag{A1}$$

where h is the horizon (in months) over which the local projection model is estimated, and $P_{j,t}$ is a monthly repeat sales real estate price index, obtained from the Land Registry's Price Paid dataset, covering 172 regions in England and Wales.[51] As controls, we include a linear and a quadratic time trend. For each region j, we estimate A1 and sum the estimated β's to obtain a region-specific measure of house price sensitivity:

$$B_j = \sum_{i=1}^{h} \beta^i. \tag{A2}$$

[51]The one area omitted in England and Wales is the *Square Mile* financial district in London, in which there is very little residential property and no house price index is calculated. For this region we take the average responsiveness of the other London regions.

Figure A4: The Relative Response of House Prices to Monetary Policy in High-Sensitivity Regions



Notes: Regional house prices responses to a contractionary monetary policy shock that raises the five-year interest rate by 25bps on average over a year. Black lines are point estimates. The graph shows the effect on the top tertile of house price responsive regions, relative to the bottom tertile. The grey shaded area is a 90% confidence interval. The dependent variable is the cumulative growth rate in log points of house prices from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is months.

To illustrate how much more sensitive house prices in the high-sensitivity regions are to monetary policy shocks, we estimate the following monthly regression:

$$\log\left(P_{j,t+h}\right) - \log\left(P_{j,t-1}\right) = \alpha_j + \mu_t + \sum_{g=2}^{3} \delta_g^h \times D_{g,j}^{HP} \times \Delta r_t + \varepsilon_t^h, \tag{A3}$$

where the subscript j denotes the region ($j = 1, 2, \ldots, 172$), μ_t is a time fixed effect, $D_{g,j}^{HP}$ is a dummy variable taking value 1 if the given region has a gth tertile of B_j (as given by Equation A2), and Δr_t is the annual change in the interest rate, instrumented by the sum of monetary policy shocks over the previous year. Figure A4 shows that a contractionary monetary policy shock that raises the interest rate by 25bps on average over the course of the year has an average 2.1pp larger peak effect in regions whose house price sensitivity is in the top tertile, compared to the bottom tertile (i.e it is a plot of δ_3^h). This confirms the quantitatively large regional heterogeneity in the sensitivity of real estate prices to monetary policy shocks, which is a major source of variation allowing us to test the collateral channel.

As an alternative measure of regional house price sensitivities, we use the refusal rate of planning applications on residential projects consisting of 10 or more dwellings, as constructed in Hilber and Vermeulen (2016). This proxies the tightness of land supply. The primary source is the Department of Communities and Local Government, and the measure aims to capture the regulatory restrictiveness of local governments on housing supply. Although the measure is based on new construction projects, it also proxies the regulatory stance on improvements of the existing housing stock. Given the endogenous and cyclical nature of refusal rates (i.e. number applications is high/low during economic booms/busts), we use for each region the *average* refusal rates between 1979 and 2008.

Figure A5 shows the relationship between our estimated housing betas and planning refusal rates across regions. As can be seen, the two are positively related with a correlation of 49.6%, and Spearman rank correlation of 50.5%.

Figure A5: Housing Betas and Refusal Rates

Notes: The Figure shows a scatter plot of regional house price responsiveness to monetary policy shocks (*House Price Beta)* against the average planning refusal rate (*Refusal Rate*), for 151 English Regions. See Section A.4 for variable definitions; both variables are shown relative to their means.

A.5 Magnitude of Differential Employment Response by Director Beta

Our baseline result is that the employment response of younger, more levered firms is 1-1.5 percentage points higher when their directors live in regions where house prices are more responsive to monetary policy. How does this compare to the unconditional estimates of the effects of an increase in director real estate values on firm employment? Bahaj, Foulis, and Pinter (2018) provide an estimate of the contemporaneous unconditional effect. If we use the same specification but extend it to a three year horizon, we find that an increase of £147k in the combined value of the homes of a firm's directors is required for a net addition of one worker after three years. Now, the median total value of director homes for younger, more levered firms in our sample is £1.3m (across all directors at the firm). Following a 25bps increase in interest rates, house prices increase by 2.1pp more in high beta than low beta regions (Figure

A4 in Appendix A.4) or a net additional increase in housing wealth of £27.3k high beta versus low beta regions. Extrapolating from the unconditional estimate, this should result in a net hiring of 0.19 workers. The median younger, more levered firm with directors in high beta region in our sample has 23 employees, so this amounts to an extra employment differential of around 0.8pp between high and low beta regions. This is of a similar order of magnitude to the difference in the baseline estimate in Figure 7a.

A.6 Additional Summary Statistics

Table A2: Summary Statistics when Director Beta Present

(a) ***Firm Summary Statistics***

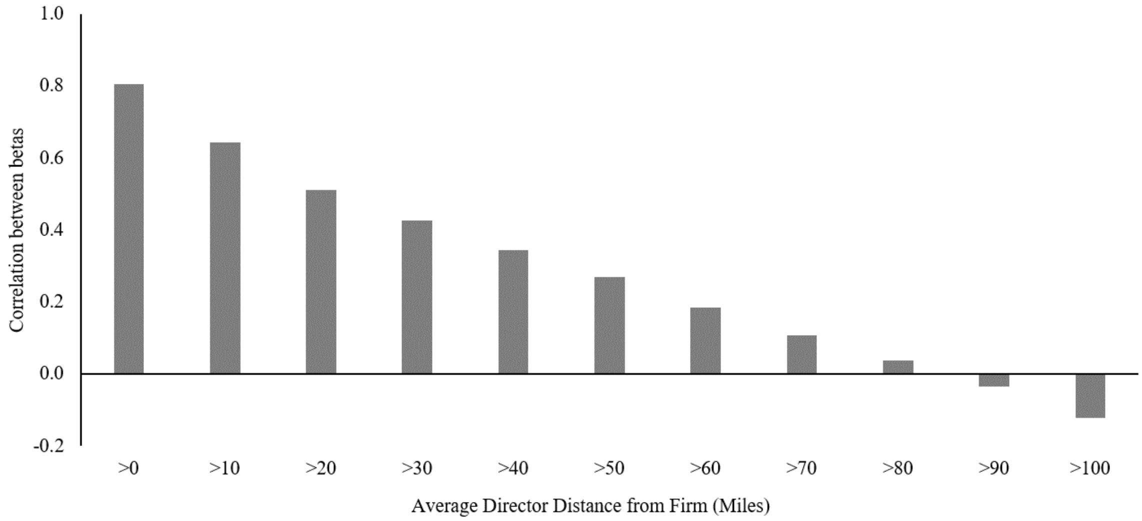
Variable	**Mean**	**Median**	**25%tile**	**75%tile**
Number of Employees	602	56	12	129
Total Assets (£'000s)	103,160	3,900	1,290	9,502
2-year Employment Growth (%)	6.7	1.4	-4.4	17
2-year Real Asset Growth (%)	8.8	6	-8.9	25
Age (years)	22	15	6.8	30
Leverage (% assets)	65	63	42	81
Average Wage (£'000s)	27	23	16	33
133,078 Firm-Year Observations on 27,718 Firms				

(b) ***Director Summary Statistics***

Variable	**Mean**	**Median**	**25%tile**	**75%tile**
Director House Value (£'000s)	682	411	237	754
Director Outside Firm Region (%)	62	100	0	100
Director Distance From Firm (Miles)	27	8.7	3.4	24
Director Age (Years)	49	48	41	56
Experience (Years)	22	9.7	4.1	23
270,350 Director-Year Observations on 61,612 Directors				

Notes to Table A: This table further restricts the baseline regression sample to firms where the average director beta is non-missing. Age is defined as the number of years elapsed from the date of incorporation. Leverage is measured as the ratio of the balance sheet items "Total Liabilities" to "Total Assets". Size is measured as the "Number of Employees". Average wage is defined as the ratio of "Remuneration" to "Number of Employees". Employment and Asset growth are measured as the log difference from the beginning of the firm's accounting period to the end of the subsequent accounting period, a period of two years. Asset growth is deflated using the change in the consumer price index over the same period. These growth rates are trimmed at the 1/99 percentiles. For presentation in this table, leverage and the average wage are winsorised at the 1/99% levels. Notes to Table B: Summary statistics on the directors of the firms in the Table A (see Section 3.1). The statistics are at the director level and are shown for the directors whose regional housing beta can be calculated. Director House Value is the value of the director's house in £000s. Director Outside Firm Region is a dummy variable which takes value 1 when the director lives in a different region to their firm, and 0 otherwise. Director Distance From Firm is the distance between the director's house and the firm, in miles. Director Age is the director's age, in years. Experience is the cumulative years of experience the individual has in years, across all directorships held.

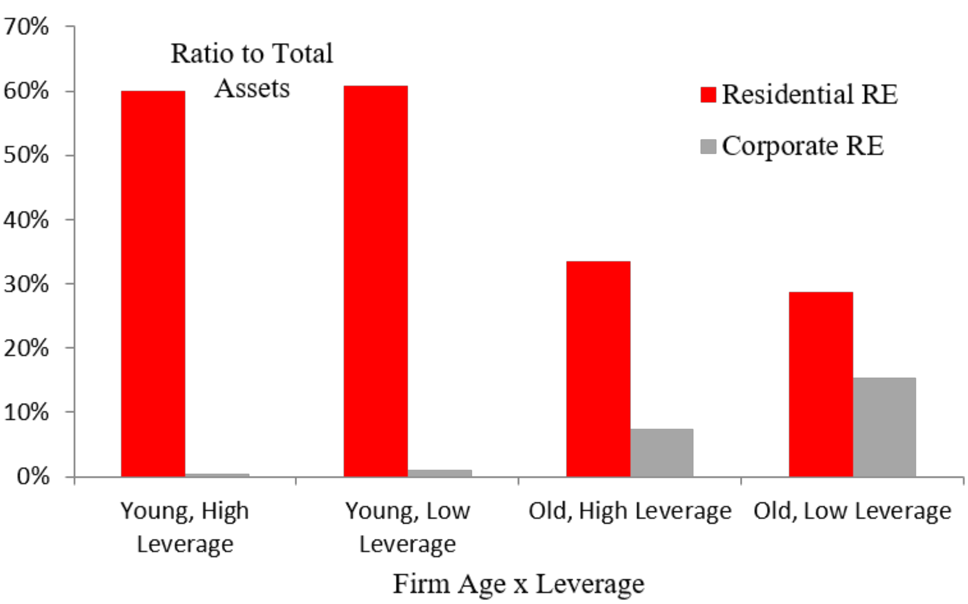
Figure A6: Correlation Between Firm and Director Betas



Notes: the Figure shows the correlation between the house price sensitivity of the firm's region to monetary policy shocks, and the house price sensitivity of the directors' regions, averaged across all directors at the firm, and broken down by the average distance between the directors' house and the firm.

A.7 Real Estate Holdings By Firm Age and Leverage

Figure A7: Median Real Estate Holdings by Firm Age and Leverage



Notes: The Figure shows how the median ratios of the directors' residential real estate and the firm's corporate real estate to total assets vary by the firm's age and leverage. The Figure is calculated using the regression sample in Section 6.2. As with the regression analysis, a *Young* firm is defined as one under 15 years old, and a *High Leverage* firm is defined as one that has above the median leverage in a given year.

A.8 Employment Shares by Director Real Estate to Total Assets

Table A3 shows the calculations used to estimate the share of aggregate employment accounted for by firms whose combined director real estate is worth at least 15% of the firm's Total Assets. The second column of Table A3 shows the aggregate employment shares (for private firms in the industries of our regression sample) accounted for by firms with different numbers of employees. The third and fourth columns of Table A3 calculate, within the same firm size groupings, the share of employment in our regression sample accounted for by firms with above/below 15% director real estate to Total Assets. As is intuitive, among firms with less than 10 employees, around 96% of employment is accounted for by firms with director real estate above this threshold. This share steadily falls with firm size. However, it is notable that, even among firms with 250-499 employees, this share is just under 50%. For firms with at least 500 employees, the share falls to around 3%. The last two columns of Table A3 combine these proportions with the numbers from Column 2 to estimate the aggregate employment shares for high and low director real estate firms, assuming that, within firm size buckets, the proportions that hold in the regression sample also hold in the aggregate. The relatively large share of smaller firms in aggregate employment, combined with the high values of director real estate for smaller firms, result in an estimated aggregate employment share of 49% for firms whose director real estate is worth at least 15% of the firm's Total Assets.

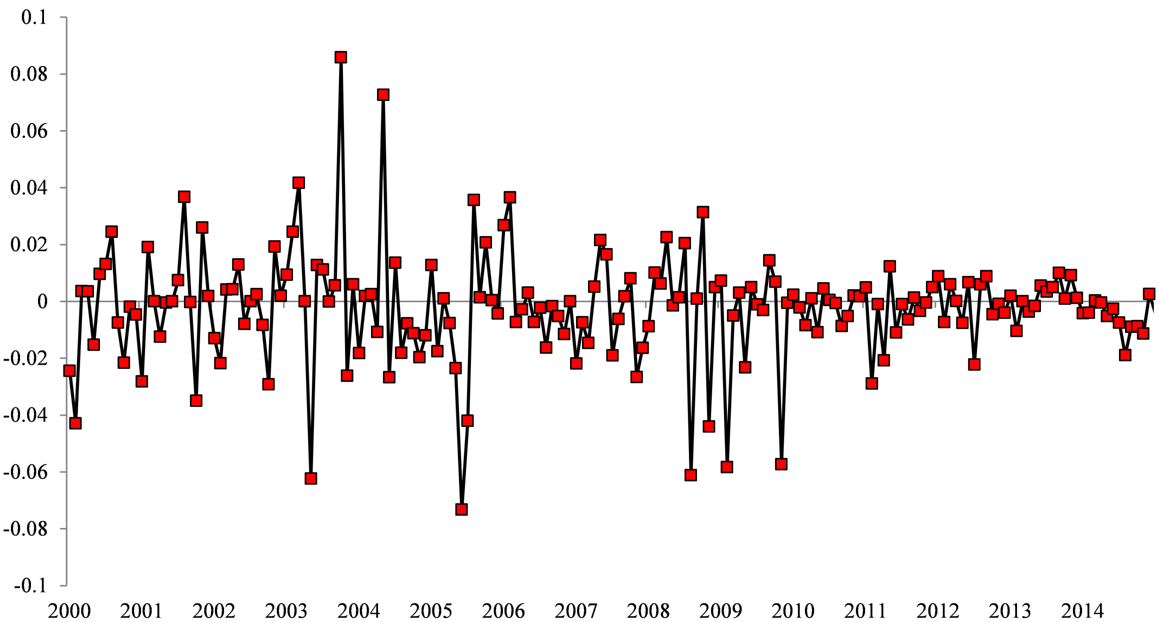
Table A3: Employment Share by Director Real Estate to Total Assets Ratio

		Emp. Share in Sample Dir. RE/Total Assets		Est. Aggregate Share Dir. RE/Total Assets	
Employees	Aggregate Employment Share	$\geq$ 15%	$<$ 15%	$\geq$ 15%	$<$ 15%
1-9	20.4%	95.8%	4.2%	19.6%	0.9%
10-49	16.8%	87.2%	12.8%	14.7%	2.2%
50-249	14.5%	71.9%	28.1%	10.4%	4.1%
250-499	5.8%	46.2%	53.8%	2.7%	3.1%
500+	42.5%	3.2%	96.8%	1.4%	41.1%
All	100.0%	–	–	48.7%	51.3%

Notes: The Table shows the calculations used to estimate the share of aggregate employment undertaken by firms whose director real estate is worth at least 15% of the firm's total assets. The second column shows the share of aggregate private sector employment (in the industries of our regression sample-see Section 3.2) accounted for by different employment size groups. The third column shows, within the same firm size groups, the share of employment accounted for by firms in our regression sample whose combined director real estate is worth at least 15% of the firm's Total Assets (see Section 4). The fourth column shows the share accounted for by firms for whom this ratio is below 15%. The last two columns use these numbers to estimate the aggregate employment shares of each group of firms. Aggregate data on employment shares is for 2012 and comes from The *Business Population Estimates For The UK and Regions.*

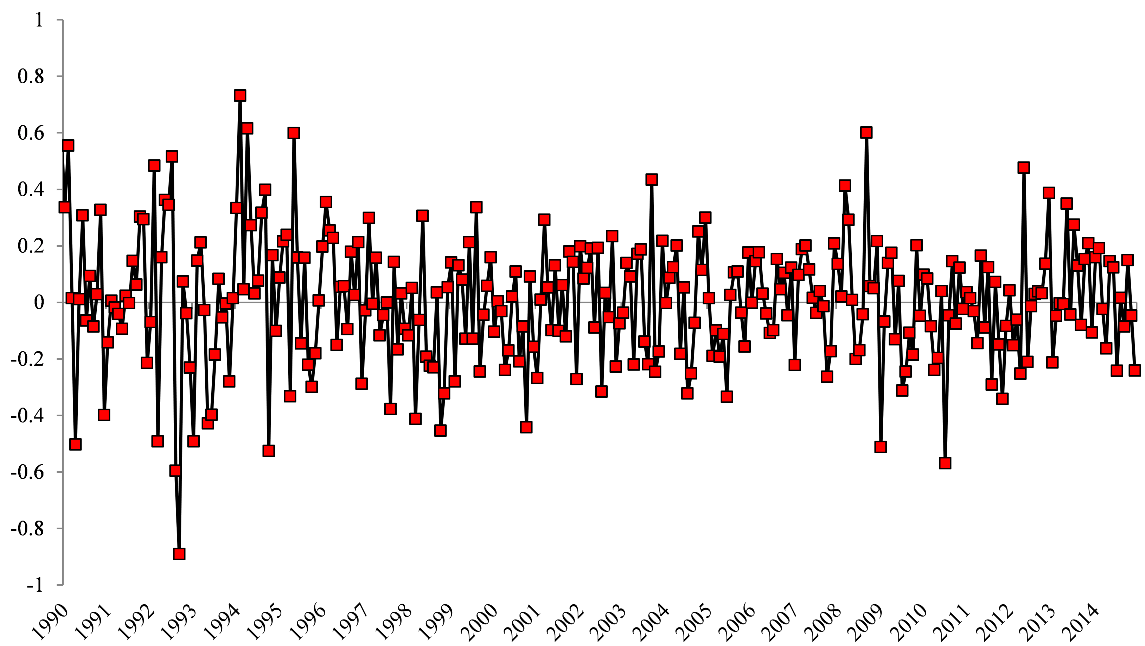
B Monetary Policy Surprises and VAR Macro Evidence

Figure A8: The Gerko-Rey instrument for UK monetary policy shocks



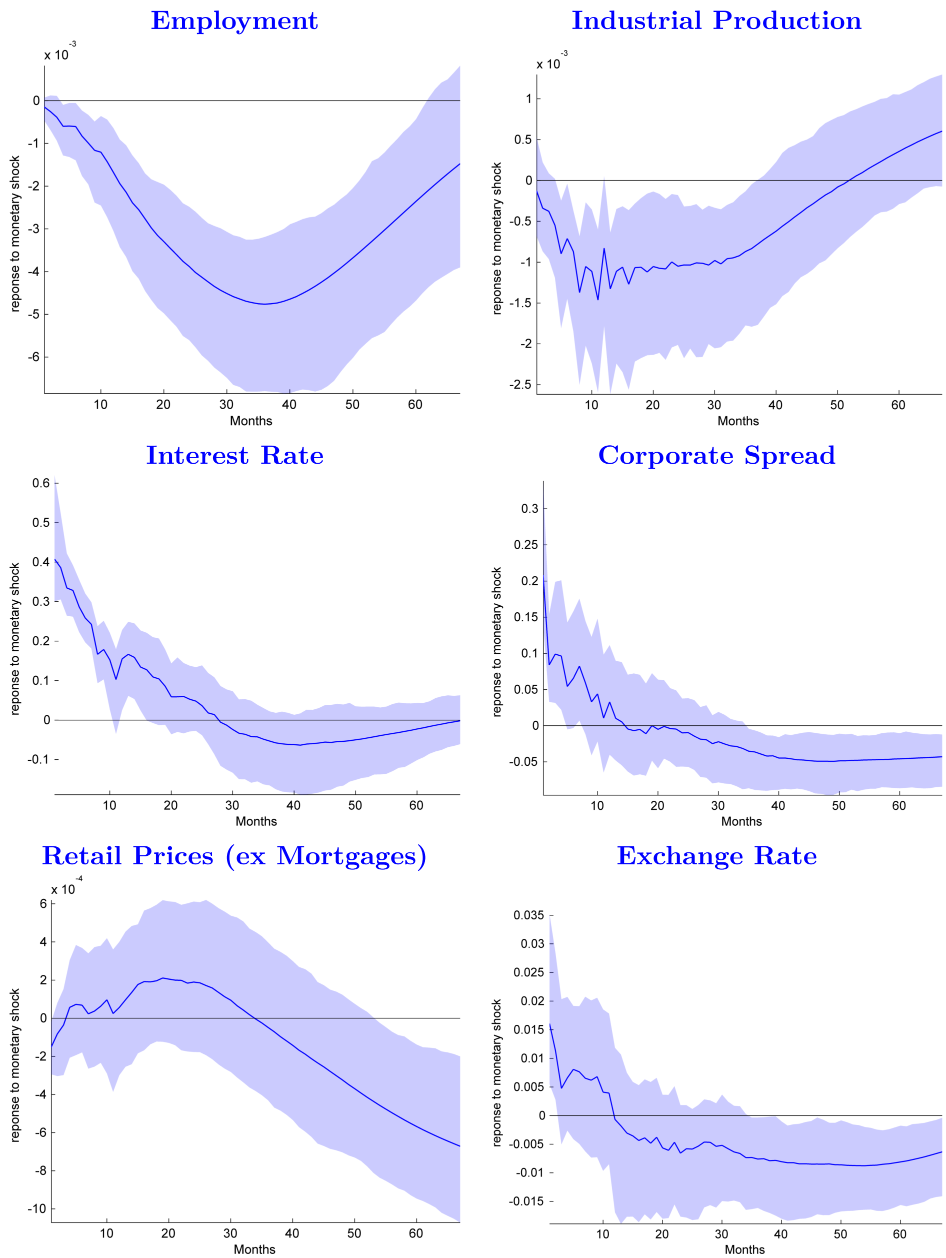
Notes: Instrument for monetary policy shocks from Gerko-Rey (January 2001 to March 2015). The time series is the raw market surprises to monetary policy announcements. The y-axis can be interpreted as changes in an interest rate.

Figure A9: Monetary Policy Shock Series Extracted From the VAR



Notes: Monetary monetary policy shock series extracted from the VAR. The y-axis is in stand a can be interpreted as changes in an interest rate.

Figure A10: Aggregate Impulse Responses to a Monetary Policy Shock



Notes: Estimates are from a proxy SVAR estimated on UK monthly data over the period 1982-2016. Monetary policy shocks are identified using the Gerko-Rey series. The blue solid lines are the point estimates, and the shaded areas are the 90% confidence intervals constructed from a wild recursive bootstrap.

C Theoretical Framework

Our results above suggest that proxies for financial constraints govern the strength of a firm's response to monetary policy shocks. However, such a finding is not necessarily in line with the theory on how firms behave under financial frictions. There are two competing mechanisms. First, *ceteribus paribus*, a firm facing financial constraints should be less sensitive to shocks to the demand for external finance (see Farre-Mensa and Ljungqvist (2016) and Ottonello and Winberry (2018)). The intuition being that constrained firms face a steeper (or potentially vertical) supply curve for funding, and hence any given shift in demand results in a smaller change in quantities. Second, and alternatively, key macroeconomic theories emphasise how financial frictions *accelerate* the response of activity to monetary policy shocks (Bernanke, Gertler, and Gilchrist (1999)). Expansionary monetary policy raises assets prices. Tis increases the net worth, or the value of collateral, available to financially constrained firms, alleviating the constraint and allowing a larger expansion.

The goal of this section is to provide a very simple theoretical framework to illustrate this intuition, to fix ideas and to allow us to discipline the analysis of the data so as to disentangle mechanisms. We proceed in a partial equilibrium setting but a fully microfounded general equilibrium model containing similar ideas can be found in Ottonello and Winberry (2018).

Imagine a firm i that produces a good using a labour input with production function $Y_t^i = A_t^i (N_t^i)^\alpha$ ($\alpha \leq 1$), where A_t^i is an exogenous, idiosyncratic, stochastic productivity level that realises at the end of the period. We assume that $\mathbb{E}_t(A_t^i) = 1$.

The firm faces a working capital constraint: its product can be sold at price p_t at the end of the period but employees must be hired at the start of the period and paid a real wage w_t (see Christiano, Eichenbaum, and Evans (2005)). Following Catherine, Chaney, Huang, Sraer, and Thesmar (2018), to operate the firm owns a factory which requires a fixed quantity of land L^i that has a liquidation value $q_t L^i$. This will serve as a meaningful source of collateral for the firm. The firm enters the period with initial real resources on hand, which we refer to as cash, worth W_t^i. The firm must therefore borrow $b_t^i = max\{w_t N_t^i - W_t^i, 0\}$ in order to pay its workers. The risk free real interest rate is r_t, the firm's shareholders discount future dividends at the same rate and the firm can reinvest its cash at the risk free rate. Hence, without loss of generality we can assume all cashflows are retained in the firm. The firm cannot raise new funding in the form of equity. In addition to the the risk free rate, if the firm is a net borrower ($w_t N_t^i - W_t^i > 0$), creditors demand an additional spread $\lambda(b_t^i, q_t L^i) = \lambda_t^i \geq 0$.

The aggregate state vector is given by $S_t = \{p_t, r_t, w_t, q_t\}$.The firm behaves as if it has perfect foresight over the aggregate state but the central back can make a marginal change to the real interest rate, r_t, which has knock on effects on the other aggregate prices in S_t (this is similar to the set up Auclert (2018) which considers households).

The firm's expected cash carried forward to the next period is given by:

$$W_{t+1}^i = p_t A_t^i (N_t^i)^\alpha - (1 + r_t)\left(w_t N_t^i - W_t^i\right) - \lambda_t^i max\{w_t N_t^i - W_t^i, 0\}. \tag{A4}$$

Assume that the firm can commit not to default,[52] the firm's problem is to choose:

[52]In addition, assume that the function λ is bounded above by $\bar{\lambda}$ and that, for any potential aggregate state

$$max_{N_t^i} V(W_t^i; S_t) = \frac{1}{1+r_t}\mathbb{E}_t\left[V\left(p_t A_t^i (N_t^i)^\alpha - (1+r_t)\left(w_t N_t^i - W_t^i\right) - \lambda_t^i max\{w_t N_t^i - W_t^i, 0\}; S_{t+1}\right)\right] + q_t L_t^i.$$

The corresponding transversality condition is given by $lim_{s\to\infty}\Pi_{j=0}^s (1+r_{t+j})^{-1} W_{t+s}^i \geq 0$. Taking first order conditions yields

$$\mathbb{E}_t\left[V'(W_{i.t+1}; S_{t+1})\right]\left(\alpha p_t (N_t^i)^{\alpha-1} - (1 + r_t + \mathbf{1}\left[w_t N_t^i - W_t^i > 0\right](\lambda_t^i + \frac{\partial \lambda_t^i}{\partial b_t^i} w_t N_t^i)) w_t\right) = 0.$$

For convenience, drop t subscripts and let subscripts denote derivatives. We assume that $\lambda_1^i \geq 0$ and $\lambda_{11}^i \geq 0$ such that the spread is weakly convex and increasing in the amount borrowed. We also assume that $\lambda_2^i \leq 0$ and $\lambda_{12}^i \leq 0$ such that increasing the value of the firm's buildings both weakly lowers the spread and flattens the spread function. This reduced form way of modelling a financial constraint is similar to Kaplan and Zingales (1997).

In terms of microfoundations, the λ function in the model above is compatible either with models of costly default (e.g. Townsend (1979)) or models of limited commitment/moral hazard (e.g. Kiyotaki and Moore (1997)). The difference with the latter is that the financial friction manifests as a constraint on the quantity of credit available rather than its price (credit rationing), in which case the marginal spread term in the firm's first order condition should be interpreted as the shadow value of a leverage constraint rather than a genuine credit spread.

The first order condition simplifies to:

$$\alpha p (N^i)^{\alpha-1} = \left(1 + r + \mathbf{1}\left[wN^i - W^i > 0\right](\lambda^i + \lambda_1^i w N^i)\right) w. \tag{A5}$$

Focusing on the case where $wN^i > W^i$, taking logarithms yields:

$$\underbrace{log(MPL^i) - log(w) - r}_{\text{unconstrained firm's foc}} = \underbrace{\lambda^i + \lambda_1^i w N^i}_{\text{wedge due to constraint}}, \tag{A6}$$

where $MPL^i = \alpha p (N^i)^{\alpha-1}$. So $log(MPL^i) = \alpha + log(p) + (\alpha-1)log(N^i)$. Define the term $MB^i = log(MPL^i) - log(w) - r$, such that the efficient level of employment is the level that sets $MB^i = 0$, and define $MS^i = \lambda^i + \lambda_1^i w N^i$ as the marginal credit spread. Applying the implicit function theorem to A6, we get:

$$\frac{dN^i}{dr} = -\frac{\frac{\partial MB^i}{\partial r} - \frac{\partial MS^i}{\partial r}}{\frac{(\alpha-1)}{N^i} - 2wcs_1^i - cs_{11}^i}. \tag{A7}$$

vector, there exists an $\bar{N}_t^i$ such that $p_t(\bar{N}_t^i)^\alpha - (1 + r_t + \bar{\lambda})\left(w_t \bar{N}_t^i\right) > r_t q_t L^i$. A penniless firm always generates sufficient cashflows in expectation to make liquidating the building suboptimal. Coupled with the commitment not to default, this means that the firm will always choose to operate.

By construction, $\frac{\partial MB^i}{\partial r}$ can be treated as homogeneous among firms and we can drop the i superscript. We assume also that $\frac{\partial MB}{\partial r} = \frac{\partial log(p)}{\partial r} - \frac{\partial log(w)}{\partial r} - 1 < 0$, which implies that a contractionary monetary policy shock is contractionary for an unconstrained firm. Note that all derivatives with respect to r refer to contractionary shocks:

$$\frac{dN^i}{dr} = -\frac{\frac{\partial MB}{\partial r} - \frac{\partial \lambda^i}{\partial r} - wN^i \frac{\partial \lambda_1^i}{\partial r} - \frac{\partial w}{\partial r} N^i \lambda_1^i}{\frac{(\alpha-1)}{N^i} - 2w\lambda_1^i - \lambda_{11}^i}. \tag{A8}$$

Define $\mathit{\Lambda}^i = -\left(\frac{(\alpha-1)}{N^i} - 2w\lambda_1^i - \lambda_{11}^i\right)^{-1}$ and note the following regarding the denominator of A8: (i) it is strictly negative, as we are at an interior maximum, so the sign of $\frac{dN^i}{dr}$ is pinned down by the numerator; (ii) consider two firms who both need to borrow but with different volumes of buildings $L^i > L^j$ but are otherwise identical. Firm i will hire more workers and will be on a less convex part of the credit spread curve hence the denominator will be smaller for the less constrained firm (this comes from the convexity of the spread). Now consider the numerator. We can write the following:

$$\frac{\partial MB}{\partial r} - L^i \frac{\partial q}{\partial r}\left(\lambda_2^i + \lambda_{12}^i\right) - N^i \frac{\partial w}{\partial r}\left((1+w)\lambda_1^i + \lambda_{11}^i\right). \tag{A9}$$

The standard assumption in the literature is that wages respond acyclically to monetary policy (see Christiano, Eichenbaum, and Trabandt (2018)) hence we will assume $\frac{\partial w}{\partial r} \approx 0$. A change in the interest rate then has two effects: (i) The first term in A9 captures that it shifts labour demand through its effect on MB. Holding prices and wages fixed, a higher interest rate works through the cost channel of monetary policy. Even an unconstrained firm needs to pay cash in advance, the higher the interest rate the more expensive that is and the lower the demand for labour. (ii) The second term in A9 captures the effect through the value of the firm's buildings which serve as collateral. As discussed $\frac{\partial q}{\partial r} < 0$, and since $\lambda_2 \leq 0$ and $\lambda_{12} \leq 0$, a higher interest rate increases and steepens the credit spread function. This reduces labour demand for constrained firms.

C.1 Constrained versus Unconstrained Firms

Let c and uc superscripts denote constrained firms and unconstrained firms respectively. An unconstrained firm, which may or may not be a net borrower, has the following characteristics: (i) $\mathit{\Lambda}^{uc} = \frac{N^{uc}}{(1-\alpha)}$; (ii) $MS^{uc} = 0$; and (iii) $\frac{\partial MS^{uc}}{\partial r} = 0$. A constrained firm is a net borrower and has $\lambda^c > 0$, $\lambda_1^i > 0$, $\lambda_2^c < 0$ (other restrictions on the derivatives of λ^c apply only weakly). Now we can write:

$$\frac{dN^c}{dr} - \frac{dN^{uc}}{dr} = \left(\mathit{\Lambda}^c - \mathit{\Lambda}^{uc}\right)\frac{\partial MB}{\partial r} - L^c \mathit{\Lambda}^c \frac{\partial q}{\partial r}\left(\lambda_2^c + \lambda_{12}^c\right). \tag{A10}$$

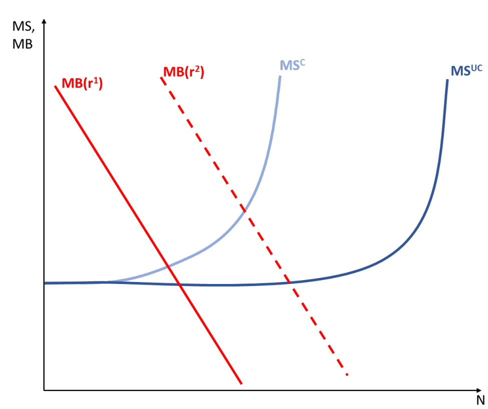
The above is a relative impulse response and hence is an analogue of our empirical analysis in Section 6.1. If the sources of firm-level heterogeneity we are relying upon are proxying financial constraints our empirical evidence suggests that $\frac{dN}{dr}^c - \frac{dN}{dr}^{uc} < 0$. However, note that $(\Lambda^c - \Lambda^{uc}) < 0$ so the first term on the right-hand side of equation A10 implies that a shock has a smaller effect on constrained firms due to the fact they are on the upward sloping region of the spread curve. This is the first mechanism highlighted in the first paragraph of this appendix: constrained firms are less responsive.

The second term on the right-hand side of equation A10 comes from the fact that for the constrained firm, tighter monetary policy reduces the value of its real estate and therefore tightens the financial constraint. This is the financial accelerator. This makes the constrained firm more sensitive to monetary policy shocks. For constrained firms to respond more, this effect needs to dominate. The relative sensitivity of constrained firms is increasing in $\frac{\partial q}{\partial r}$, i.e. the sensitivity of asset prices to interest rates. In order for constrained firms to respond more, we need the term $\frac{\partial q}{\partial r}$ to be sufficiently large.

We can also say that if $\frac{dN^c}{dr} < \frac{dN}{dr}^{uc}$ as $\alpha \to 1$, then $\frac{dMS^c}{dr} > 0$. That is to say that a contractionary monetary policy shock must tighten credit spreads for constrained firms in equilibrium. Since unconstrained firms face no credit spreads, the average spread across firms must also tighten. Inspecting Figure A10 in the Appendix, this is exactly what emerges from the aggregate data using our VAR in Section 5.1.

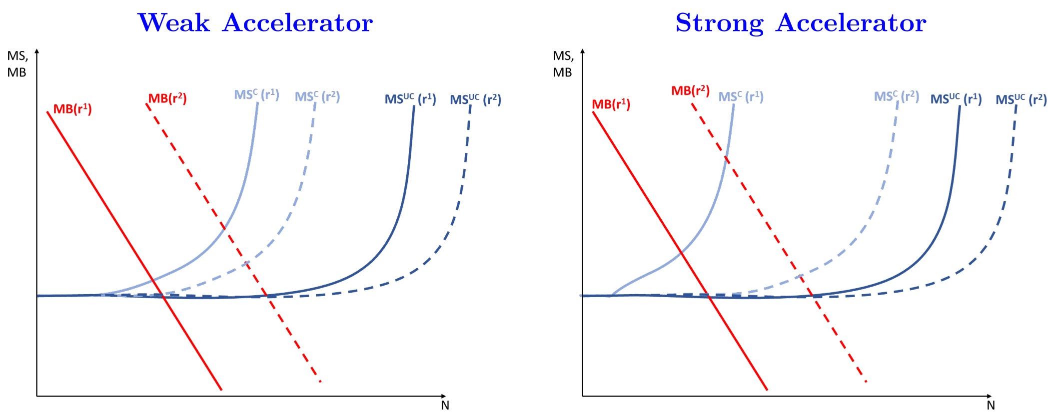
Curve Shifting Let us illustrate these effects graphically. Consider two interest rates r^1 and r^2 with $r^2 < r^1$. Assume that the two firms face two different marginal spread curves: $MS^{uc} \leq MS^c$ (e.g. because $W^c < W^{uc}$). In Figure A11 we assume that $\frac{\partial q}{\partial r} = 0$. This switches off the financial accelerator. The constrained firm increases employment by less due to the convexity of the MS curve (which is what $\Lambda^c - \Lambda^{uc}$ captures in the expression A10 above).

Figure A11: Employment responses: no financial accelerator



In Figure A12 we relax the assumption that $\frac{\partial q}{\partial r} = 0$. In the left panel we assume that $\frac{\partial q}{\partial r}$ is relatively small. The response of the constrained firm increases but it is still smaller than that of the unconstrained firm. The financial accelerator is weak. Note also that the expansionary monetary policy shock increases the marginal credit spread for the constrained firm. The right panel has a large $\frac{\partial q}{\partial r}$ and thereby a strong financial accelerator. In these circumstances, MC^c can shift sufficiently far outward following a fall in interest rates so that the constrained firm would respond more.

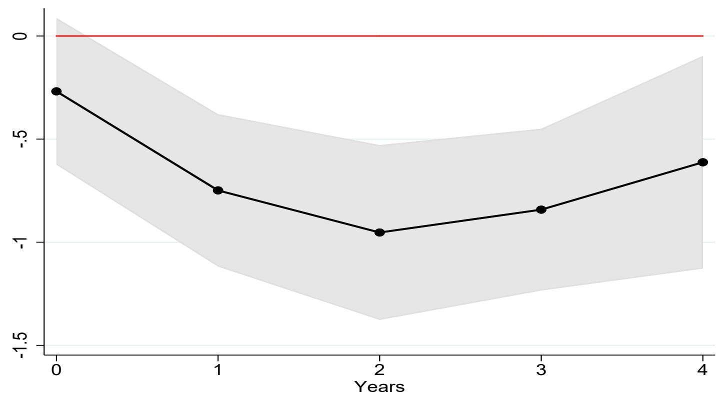
Figure A12: Employment responses: with financial accelerator



D Average Firm-Level Response: Robustness

D.1 Davis-Haltiwanger Employment Growth

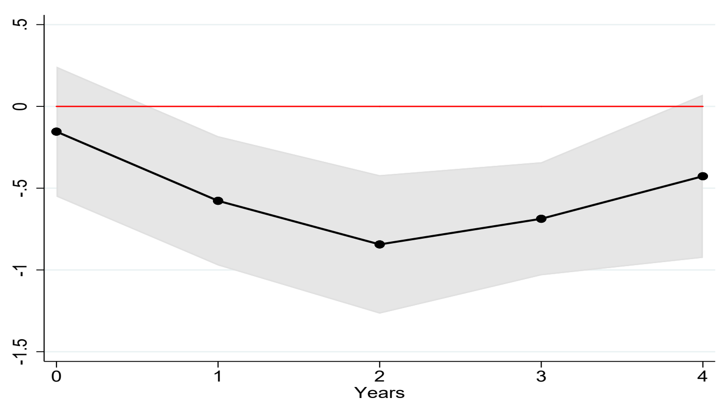
Figure A13: Linear Effect of Monetary Policy on Firms: Davis-Haltiwanger Employment Growth



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative Davis-Haltiwanger growth rate of employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis, i.e. $\frac{emp_{t+h}-emp_{t-1}}{0.5(emp_{t+h}+emp_{t-1})}$.

D.2 Non-Rectangularised Sample

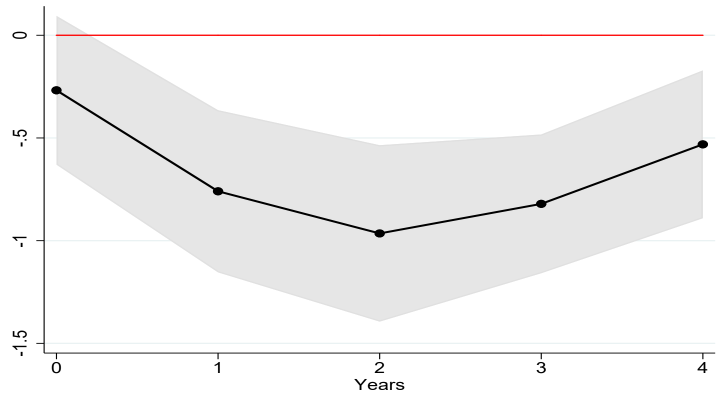
Figure A14: Linear Effect of Monetary Policy on Firms: Non-Rectangularised



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. This specification doesn't restrict the sample to employment growth from t-1 to t+4 being non-missing.

D.3 Adding Firm Controls

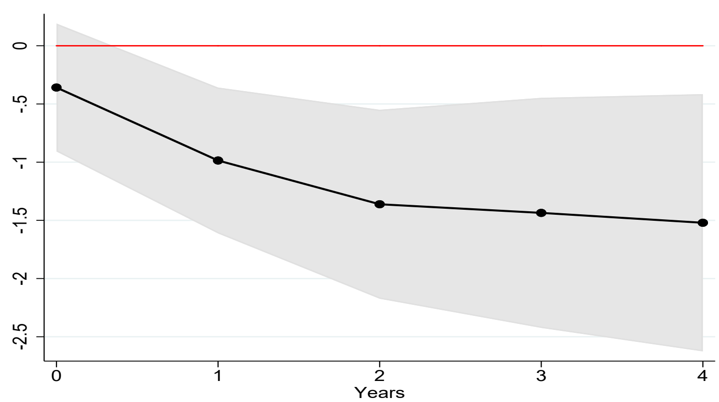
Figure A15: Linear Effect of Monetary Policy on Firms: Adding Firm Controls



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. This regression adds a lag of leverage, a lag of log total assets and the lagged ratio of current to total assets to the baseline regression as controls.

D.4 Adding Firm Fixed Effects

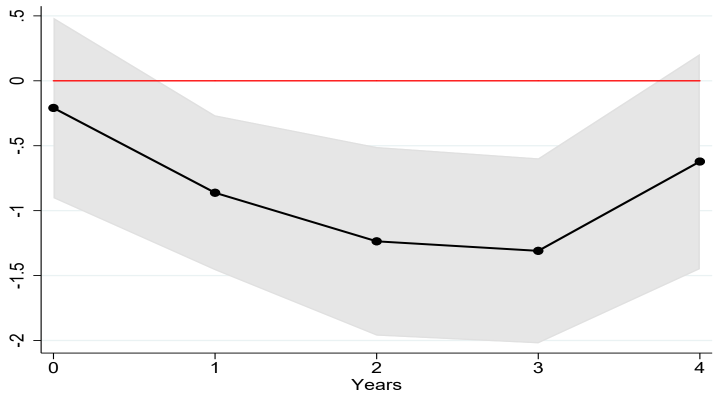
Figure A16: Linear Effect of Monetary Policy on Firms: Firm Fixed Effect



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. This regression adds firm fixed effects.

D.5 Weighting by Employment

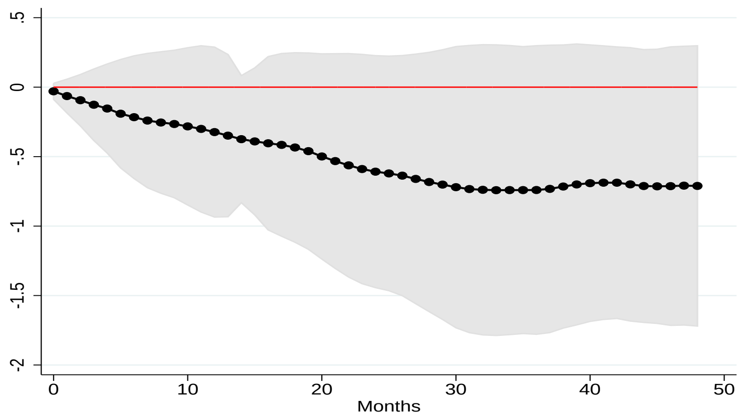
Figure A17: Linear Effect of Monetary Policy on Firms: Employment Weighted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. This regression weights the firm observations by lagged employment, to align their weight in the sample with their contribution to aggregate employment. Administrative microdata is taken from the *Business Structure Database* from the *Office For National Statistics* (ONS), covering total employment by companies in the same industries as the baseline regression. The share of total employment for these companies accounted for by different firm size groups is calculated for the following employment bins: 1-9,...,90-99,100-149,...,950-999,1000-1999,...,19000-20000,20000+. The share of observations in our baseline regression sample accounted for by each firm size bin is also calculated. Weights are then constructed for each size bin using these two set of numbers, to ensure that the weight placed on each group in our regression matches their contribution to aggregate employment. This work was produced using statistical data from ONS. The use of the ONS statistical data in this work does not imply the endorsement of the ONS in relation to the interpretation or analysis of the statistical data. This work uses research datasets which may not exactly reproduce National Statistics aggregates.

D.6 Local Projection on Aggregate Data

Figure A18: The Effect of Monetary Policy on Aggregate Employment

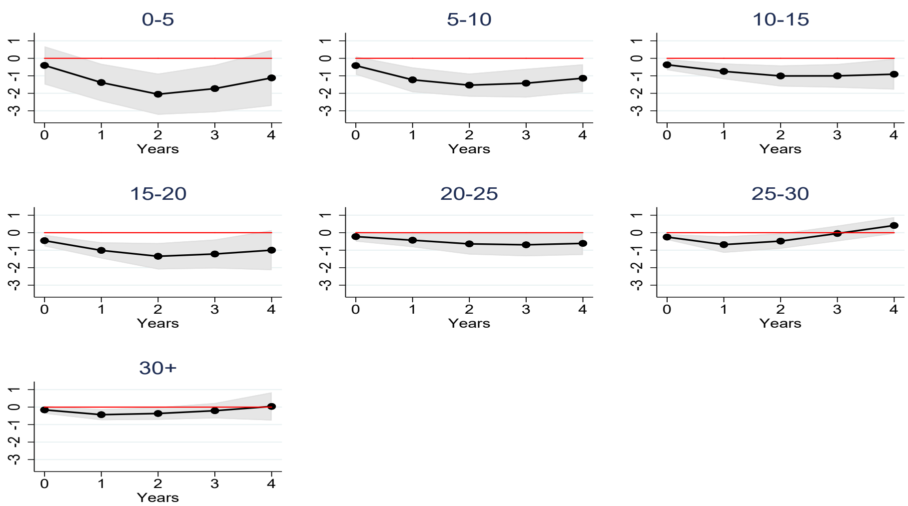


Notes: Aggregate employment response to a 25bp contractionary monetary policy shock. Grey shaded area is 90% confidence interval based on robust standard errors, and the black line is point estimates, β^h, from the regression $\log(E_{t+h}) - \log(E_{t-1}) = \alpha^h + \beta^h \times \Delta r_t + controls + \varepsilon_t^h$. The dependent variable is the cumulative growth rate in log points of employment (E) from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis measured in months. The definition of employment is the same as in the VAR (Section 5.1). Δr_t is the annual change in the interest rate, instrumented by the sum of monetary policy shocks over the previous year; and *controls* includes a linear and quadratic trend. The sample covers 1997m1-2016m9.

E Further Results on Firm-Level Heterogeneity

E.1 Alternative Firm Age Cuts

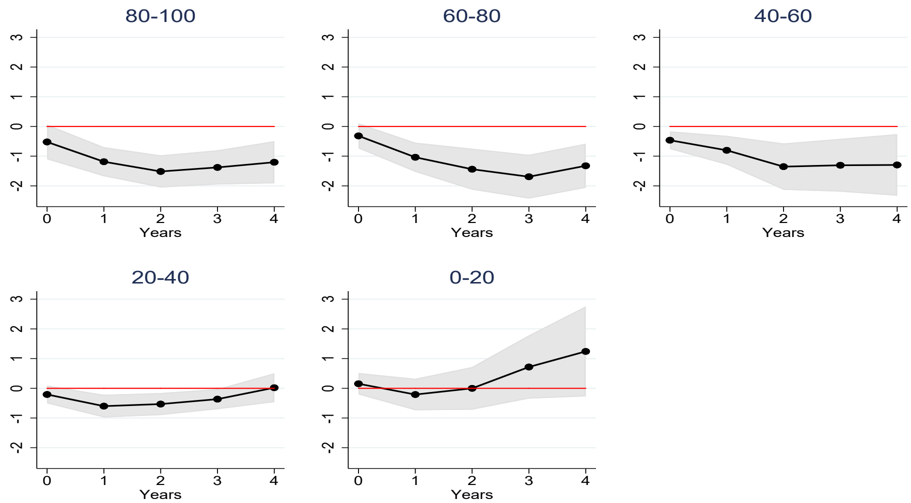
Figure A19: Level Effects on Employment by Firm Age Groups



Notes: Firm-level responses to a 25bp contractionary monetary policy shock for different firm age groups. Firm Age is measured in years. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis – see specification 1.

E.2 Alternative Firm Leverage Cuts

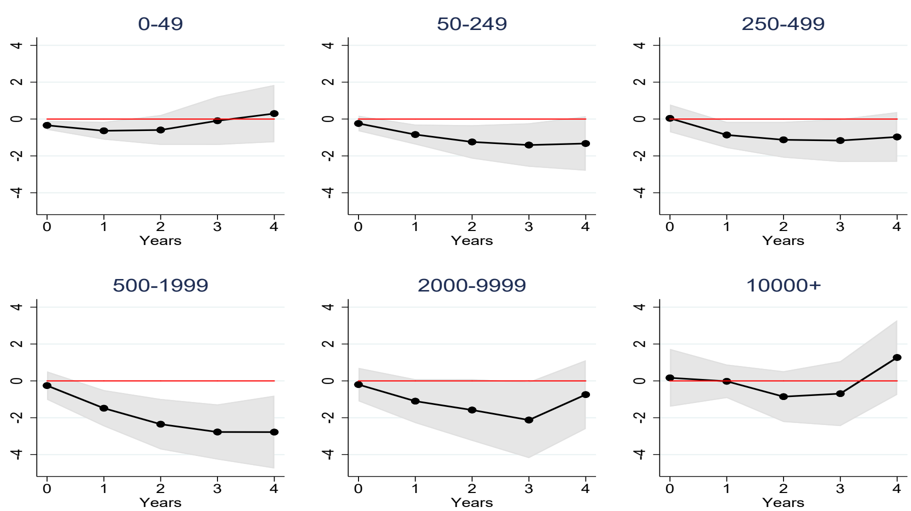
Figure A20: Level Effects on Leverage by Firm Leverage Groups



Notes: Firm-level responses to a 25bp contractionary monetary policy shock for different firm leverage groups. Firm leverage is measured as the ratio of the balance sheet items “Total Liabilities” to “Total Assets”. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis – see specification 1.

E.3 Alternative Firm Size Cuts

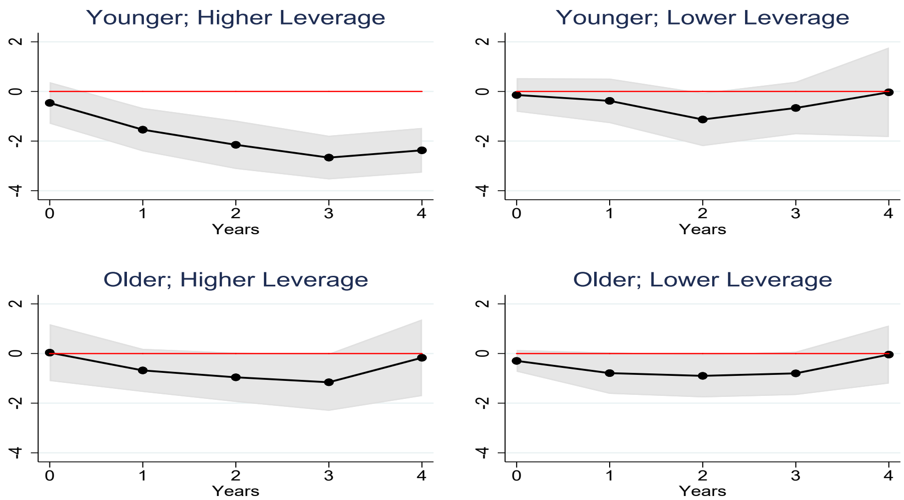
Figure A21: Level Effects on Employment by Firm Size Groups



Notes: Firm-level responses to a 25bp contractionary monetary policy shock for different firm size groups. Firm size is measured as the “Number of Employees”. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis – see specification 1.

E.4 Age x Leverage: Weighted by Employment

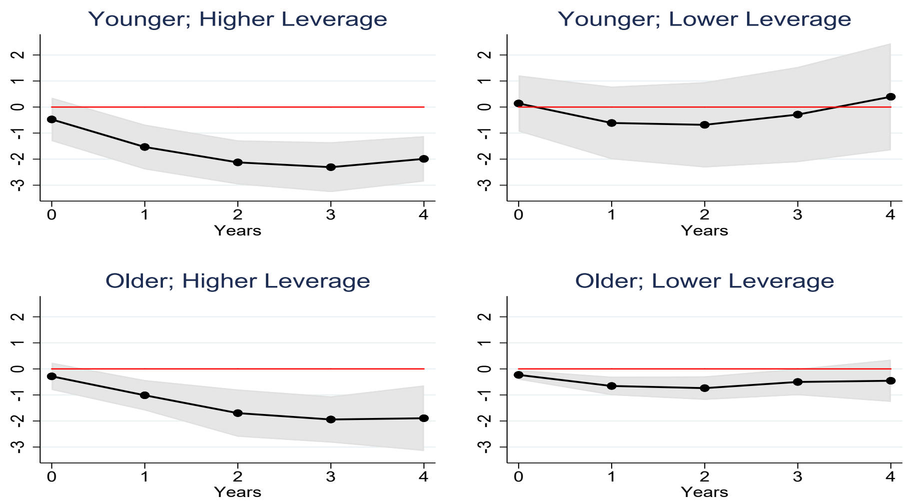
Figure A22: Level Effects on Employment by Age and Leverage: Weighted by Employment



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis – see specification 1. All the responses are %-deviations. This regression weights the firm observations by lagged employment, to align their weight in the sample with their contribution to aggregate employment. Administrative microdata is taken from the *Business Structure Database* from the *Office For National Statistics* (ONS), covering total employment by companies in the same industries as the baseline regression. The share of total employment for these companies accounted for by different firm size groups is calculated for the following employment bins: 1-9,...,90-99,100-149,...,950-999,1000-1999,...,19000-20000,20000+. The share of observations in our baseline regression sample accounted for by each firm size bin is also calculated. Weights are then constructed for each size bin using these two set of numbers, to ensure that the weight placed on each group in our regression matches their contribution to aggregate employment. This work was produced using statistical data from ONS. The use of the ONS statistical data in this work does not imply the endorsement of the ONS in relation to the interpretation or analysis of the statistical data. This work uses research datasets which may not exactly reproduce National Statistics aggregates.

E.5 Age x Leverage: Director Beta Sample

Figure A23: Level Effects on Employment by Age and Leverage: Director Beta Sample

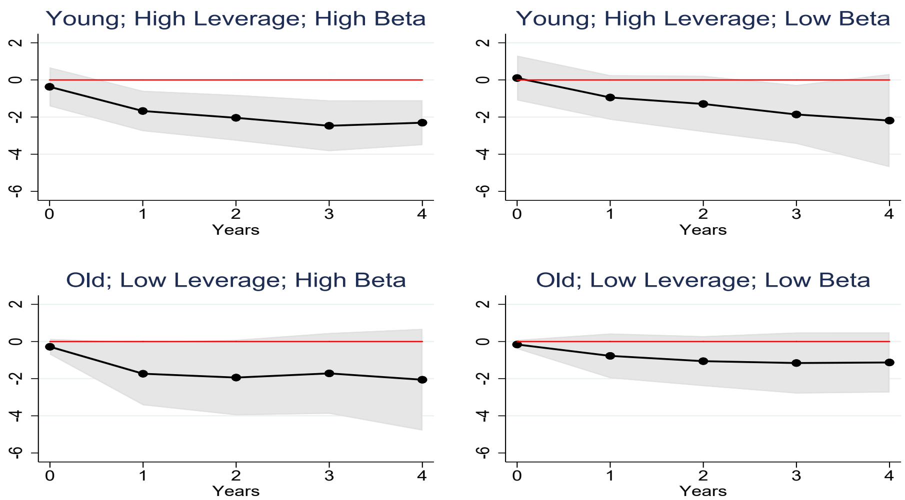


Notes: The figure shows firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis-see specification 1. Younger is defined as less than 15 years old, and higher leverage is defined as above the median leverage by year. This regression restricts to the sample of firms for which the average director beta can be calculated.

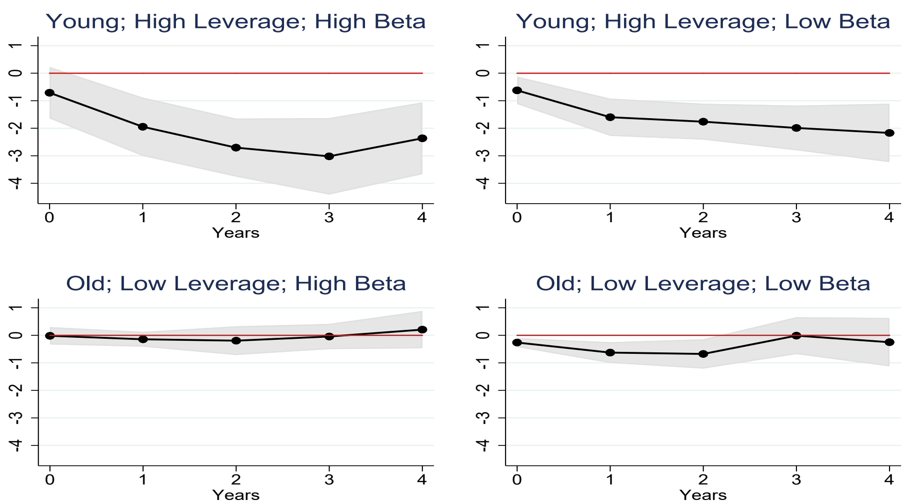
E.6 Splitting Sample at Director Real Estate to Total Assets of 15%

Figure A24: Effects on Employment by Age, Leverage and Director Beta

(a) Director Real Estate <15% Total Assets



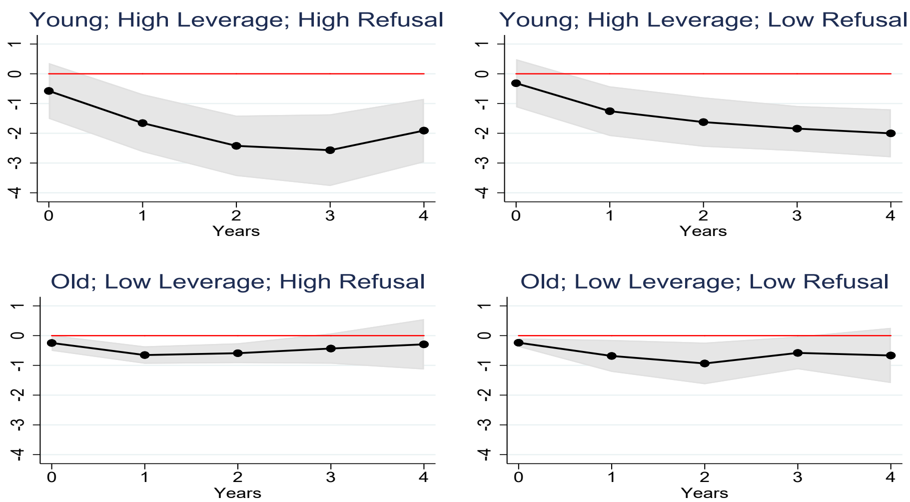
(b) Director Real Estate $\geq$ 15% Total Assets



Notes: The figure shows firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. Panels a and b both show the results for specification 1. Younger is defined as less than 15 years old, and higher leverage is defined as above the median leverage by year. Panel a restricts to the subsample of firms where the total value of director real estate is worth less than 15% of the firms' balance sheet; Panel b restricts to the sample of firms where director real estate is above this threshold.

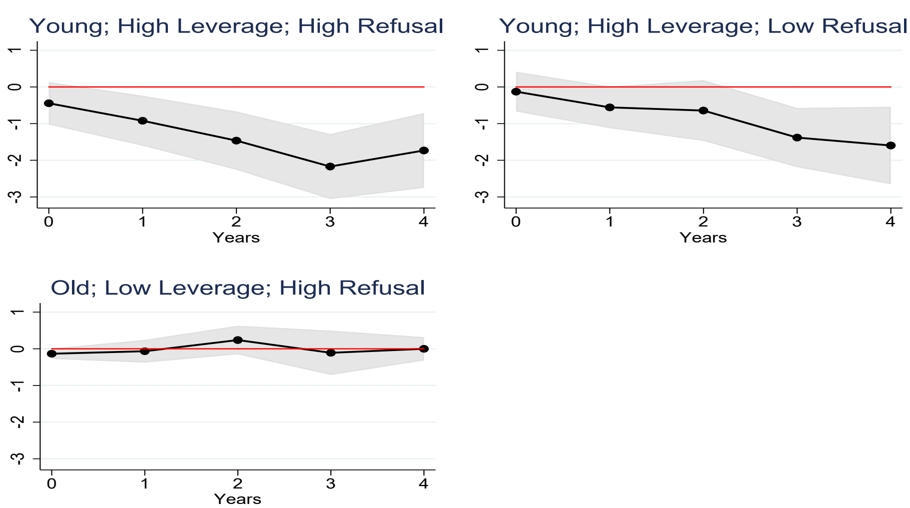
E.7 Using Refusal Rates

Figure A25: Level Employment Effects by Age, Leverage and Director Region Refusal Rates, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis – see specification 1. All the responses are %-deviations.

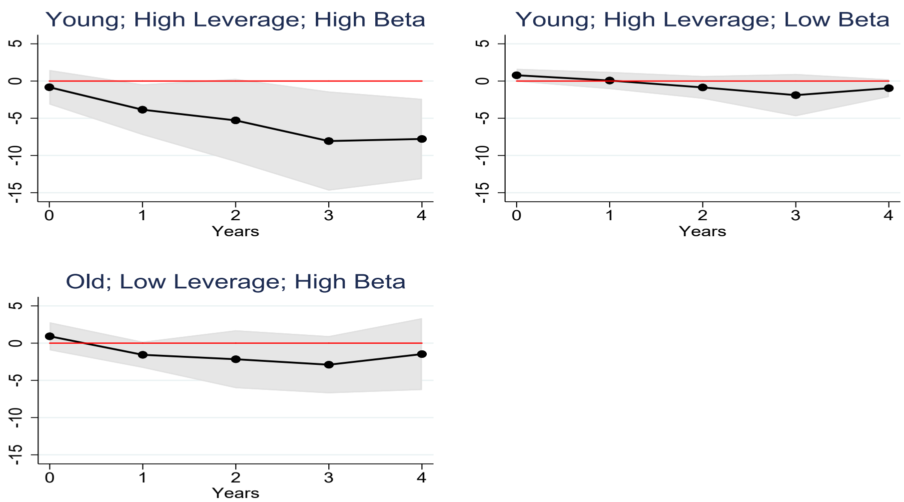
Figure A26: Relative Employment Effects by Age, Leverage and Director Region Refusal Rate, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. All the responses are relative to the group of older and more levered firms in low refusal rate region (omitted given the inclusion of industry-month and NUTS1-month fixed effects – see specification 2).

E.8 Response of Total Debt

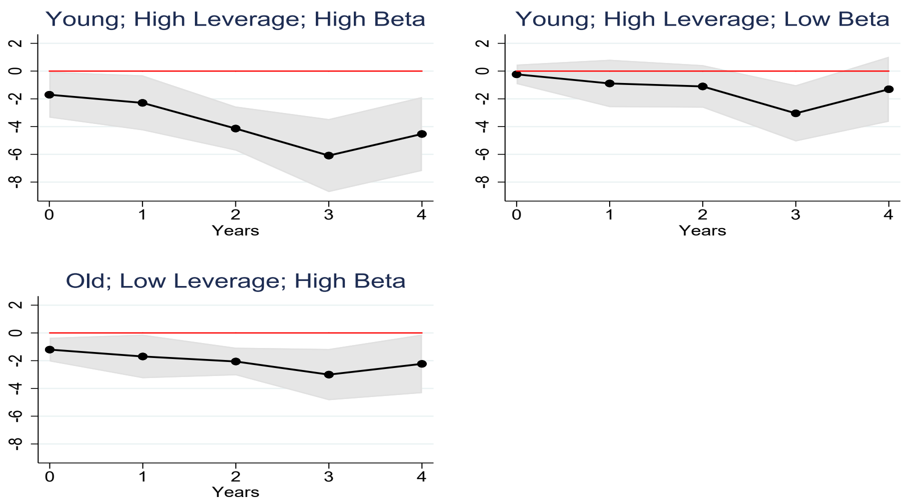
Figure A27: Relative Effect on Total Debt by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Total Debt from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. All the responses are relative to the group of older and more levered firms in low-β region (omitted given the inclusion of industry-month and NUTS1-month fixed effects – see specification 2).

E.9 Response of Prepaid Expenses

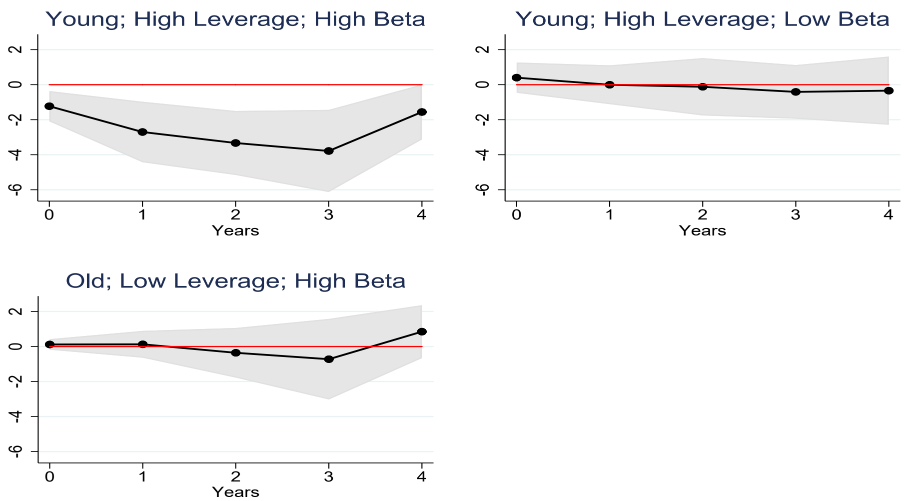
Figure A28: Relative Effect on Prepaid Expenses by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Prepaid Expenses (*Current Assets* less *Bank Deposits* less *Trade Debtors*) from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. All the responses are relative to the group of older and more levered firms in low-β region (omitted given the inclusion of industry-month and NUTS1-month fixed effects – see specification 2).

E.10 Response of Fixed Assets

Figure A29: Relative Effect on Fixed Assets by Age, Leverage and Director Beta, Triple Sorted



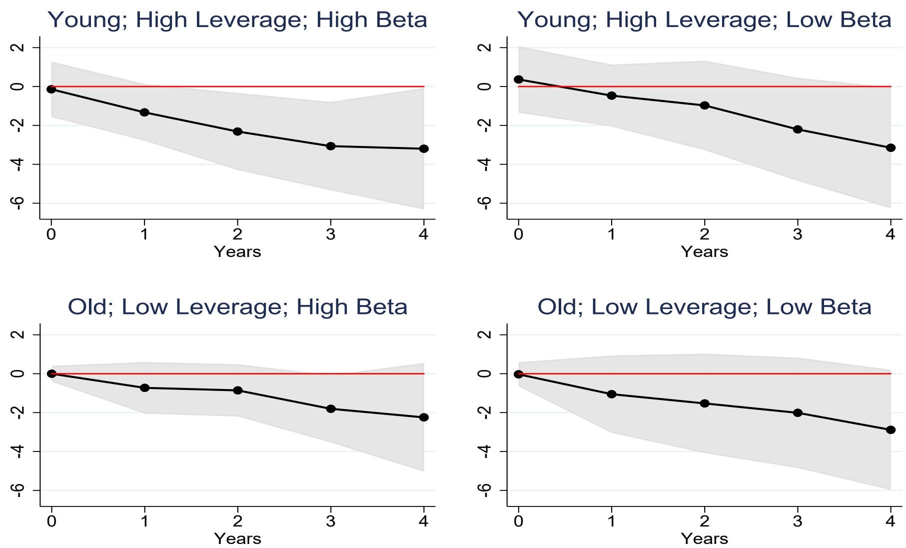
Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Fixed Assets from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. All the responses are relative to the group of older and more levered firms in low-β region (omitted given the inclusion of industry-month and NUTS1-month fixed effects – see specification 2).

F Alternative Mechanisms

F.1 Local Demand

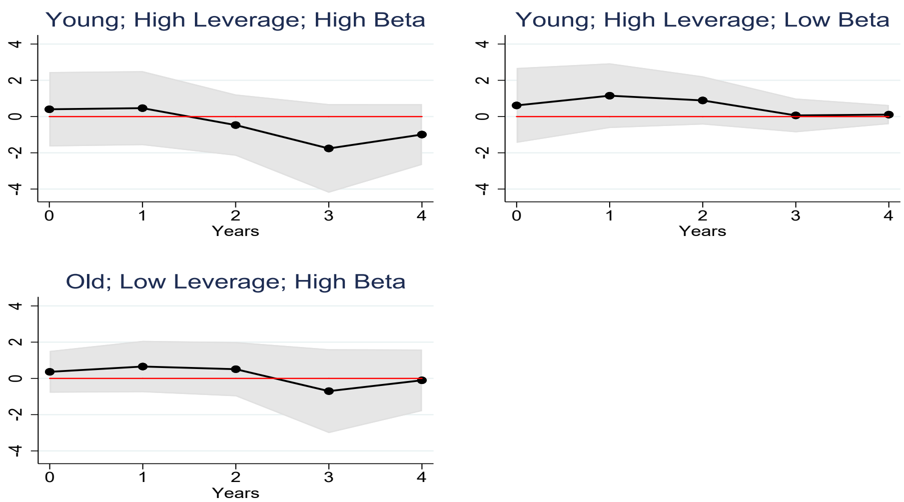
F.1.1 Response of Turnover

Figure A30: Level Effects on Turnover by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Turnover from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis – see specification 1. All the responses are %-deviations.

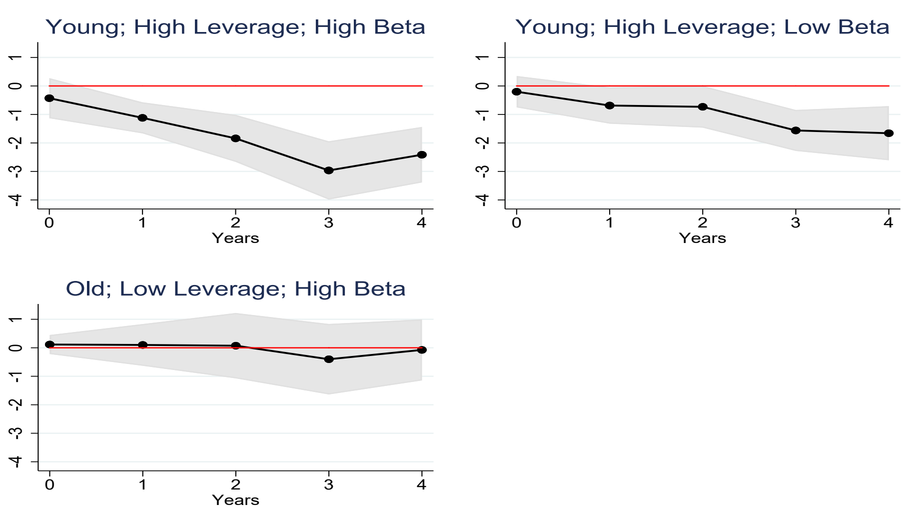
Figure A31: Relative Effect on Turnover by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Turnover from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. All the responses are relative to the group of older and more levered firms in low-β region (omitted given the inclusion of industry-month and NUTS1-month fixed effects – see specification 2).

F.1.2 Adding Region-Year Fixed Effects

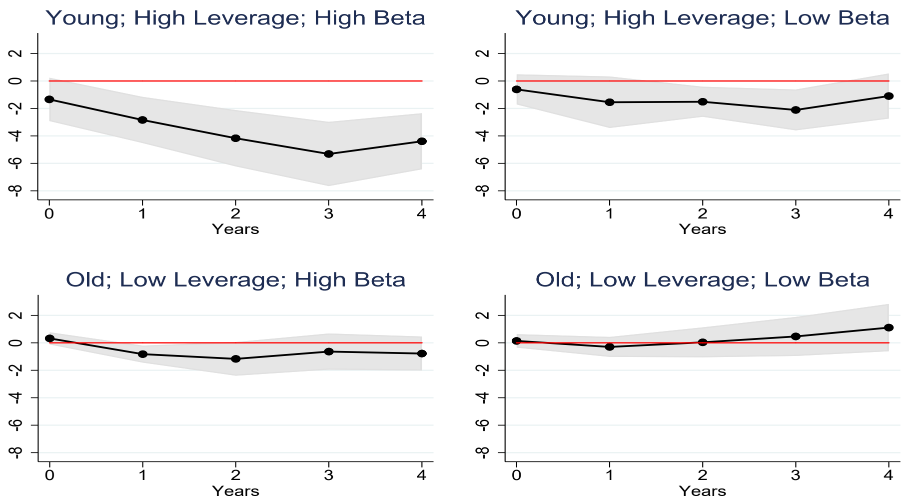
Figure A32: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. All the responses are relative to the group of older and more levered firms in low-β region (omitted given the inclusion of industry-month and *region-year* fixed effects – see specification 2).

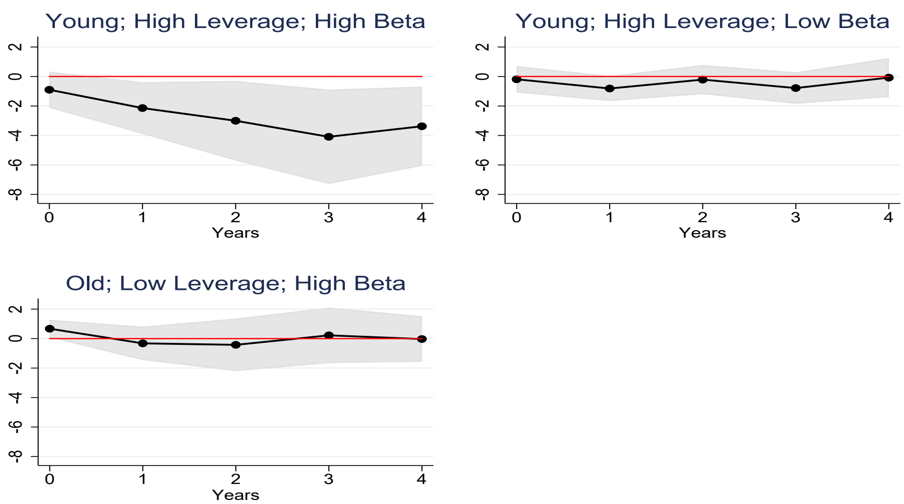
F.1.3 Directors Who Live 30 Miles Away

Figure A33: Level Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis – see specification 1. All the responses are %-deviations.

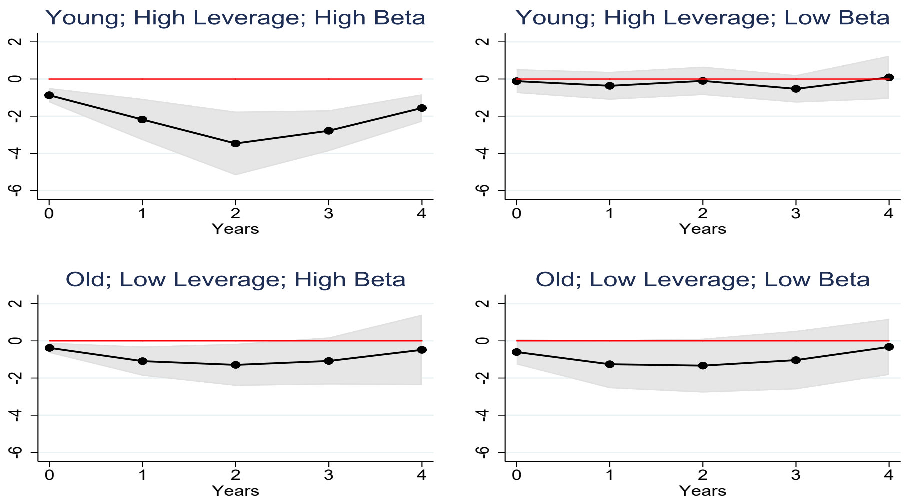
Figure A34: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. All the responses are relative to the group of older and more levered firms in low-β region (omitted given the inclusion of industry-year and NUTS1-year fixed effects – see specification 2).

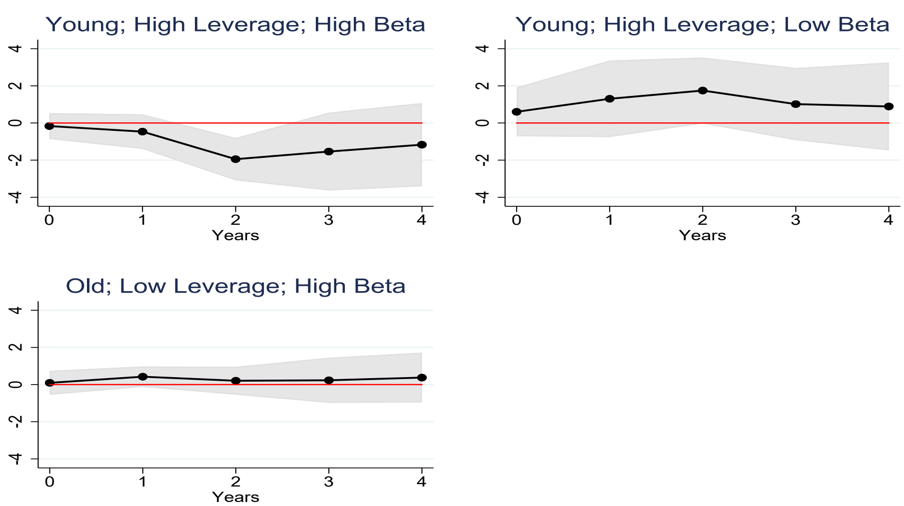
F.1.4 Excluding Non-Tradeable Sectors

Figure A35: Level Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis – see specification 1. All the responses are %-deviations. The sample only includes firm operating in the tradeable goods sector.

Figure A36: Relative Effects on Employment on by Age, Leverage and Director Beta, Triple Sorted

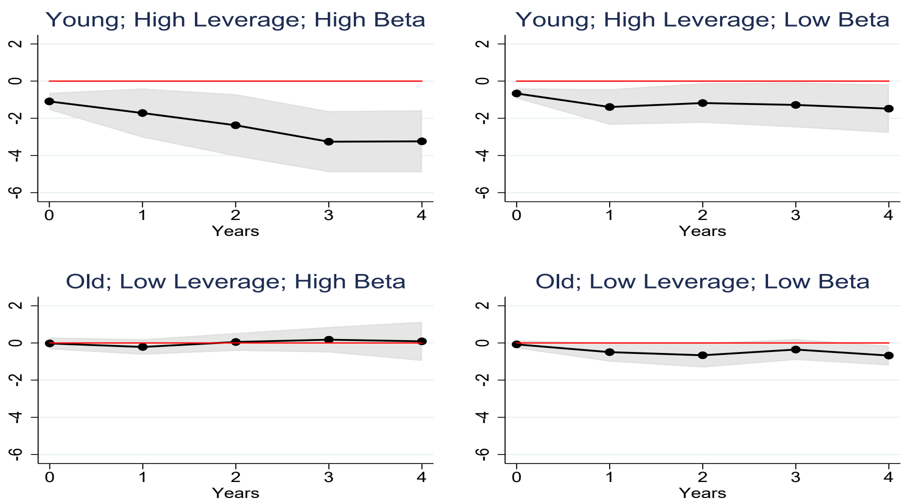


Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. All the responses are relative to the group of older and more levered firms in low-β region (omitted given the inclusion of industry-month and NUTS1-month fixed effects – see specification 2). The sample only includes firm operating in the tradeable goods sector.

F.2 Director Characteristics

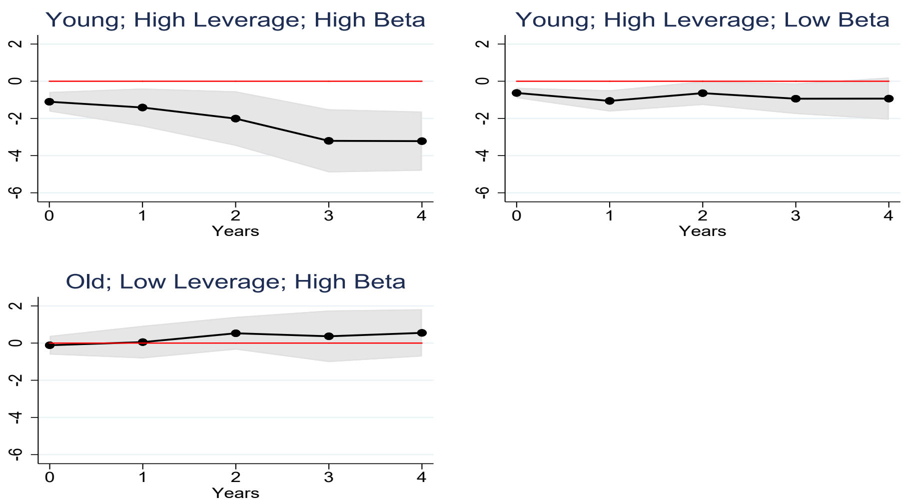
F.2.1 Fixing Director Beta in 1997

Figure A37: Level Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis – see specification 1. This sample holds the firm-average of the director betas fixed in 1997.

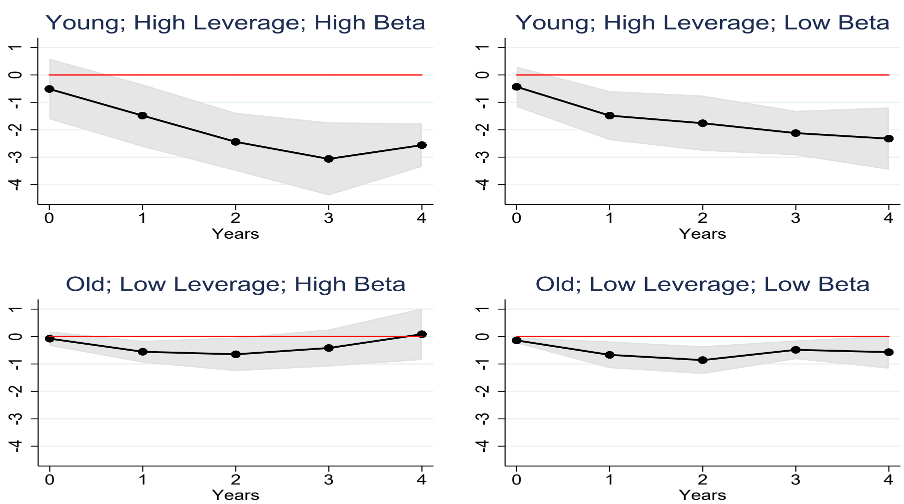
Figure A38: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. All the responses are relative to the group of older and more levered firms in low-β region (omitted given the inclusion of industry-month and NUTS1-month fixed effects – see specification 2). This sample holds the firm-average of the director betas fixed in 1997.

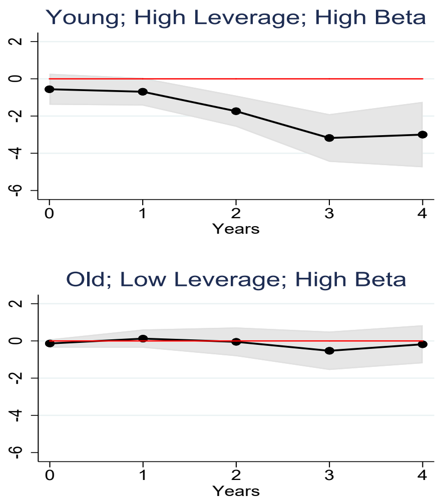
F.2.2 Excluding Directors Living In London

Figure A39: Level Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis – see specification 1. This sample excludes directors living in the 32 boroughs of London when constructing the firm-average of director betas.

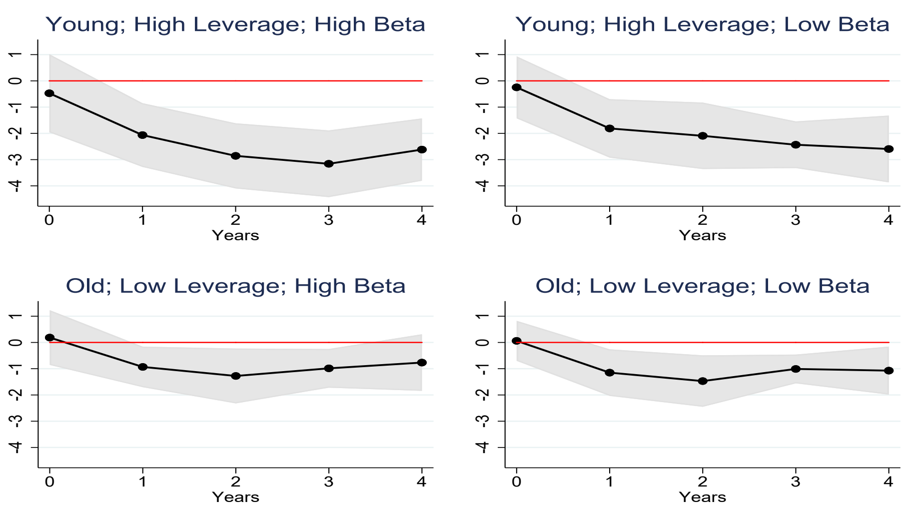
Figure A40: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. All the responses are relative to the group of older and more levered firms in low-β region (omitted given the inclusion of industry-month and NUTS1-month fixed effects – see specification 2). This sample excludes directors living in the 32 boroughs of London when constructing the firm-average of director betas.

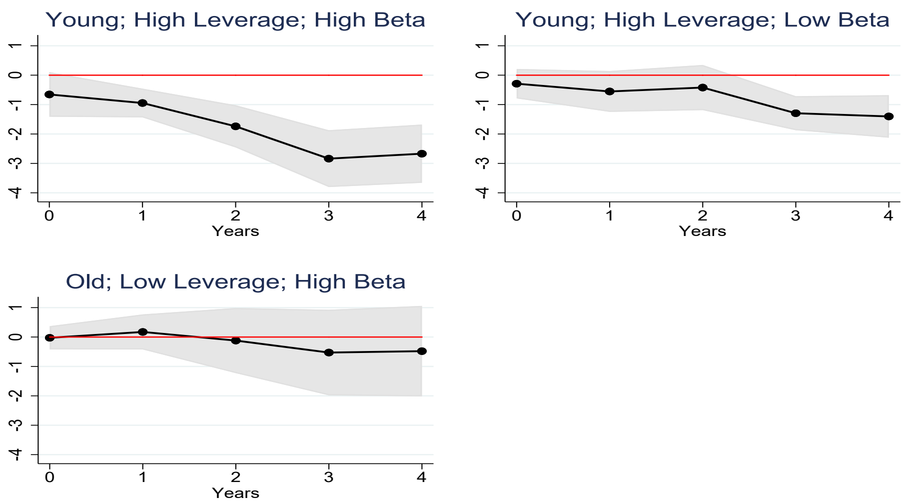
F.2.3 Including Director Characteristics

Figure A41: Level Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis – see specification 1.

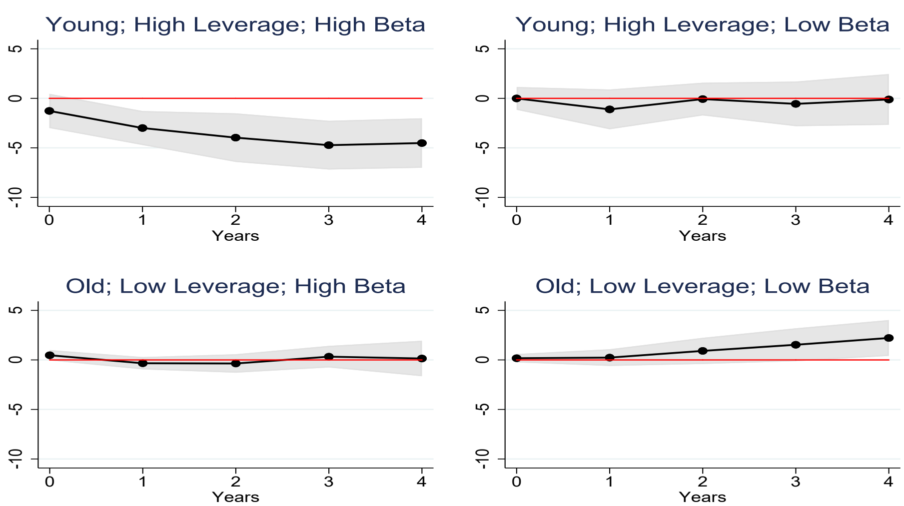
Figure A42: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. All the responses are relative to the group of older and more levered firms in low-β region (omitted given the inclusion of industry-month and NUTS1-month fixed effects – see specification 2).

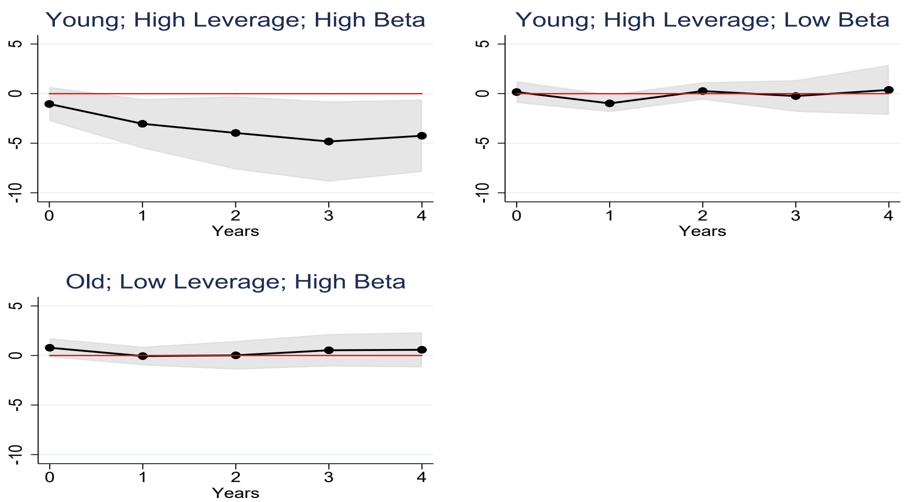
F.2.4 Shareholder Directors

Figure A43: Level Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis – see specification 1. All the responses are %-deviations.

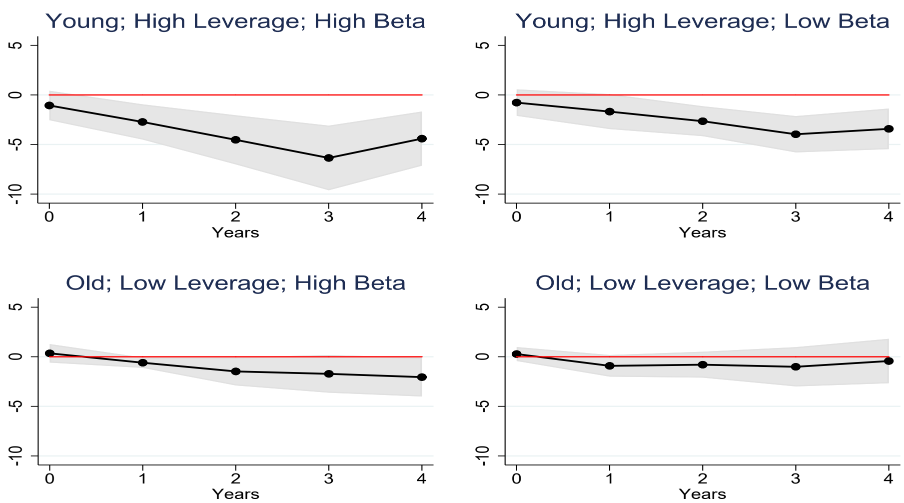
Figure A44: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. All the responses are relative to the group of older and more levered firms in low-β region (omitted given the inclusion of industry-year and NUTS1-year fixed effects – see specification 2).

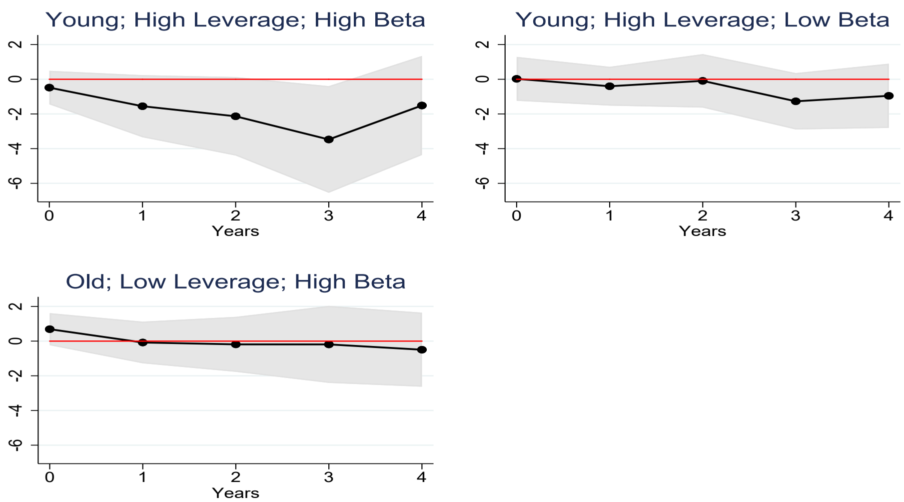
F.2.5 Non-Shareholder Directors

Figure A45: Level Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis – see specification 1. All the responses are %-deviations.

Figure A46: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. All the responses are relative to the group of older and more levered firms in low-β region (omitted given the inclusion of industry-year and NUTS1-year fixed effects – see specification 2).

F.3 Director Cash Flow Proxies

We can proxy for the size of director cash flow shocks due to monetary policy, by merging director information with administrative mortgage data from the UK.[53] The most natural experiment would be to compare the share of directors on fixed vs variable rate mortgages. However, in the UK, the vast majority of fixed-rate mortgages are fixed for a short period of time, typically 2 or 3 years. Thus, even directors on fixed rate mortgages at the time of the monetary policy shock may experience cash flow shocks throughout the horizon of our regressions, when they have the chance to remortgage. Instead, we use both directors' average mortgage size and mortgage size relative to average salary[54] to proxy for the cash flow shock, with directors with relatively larger mortgages likely to experience a greater shock. Cash flow shocks are more likely to affect firms that are financially constrained, so we interact the firm age x leverage buckets with dummies for three tertiles of the cash flow shock, including this control in the regression both linearly, and interacted with the monetary policy shock. As shown in Figures A47–A48 (average director mortgage size) and Figures A49–A50 (average director mortgage to

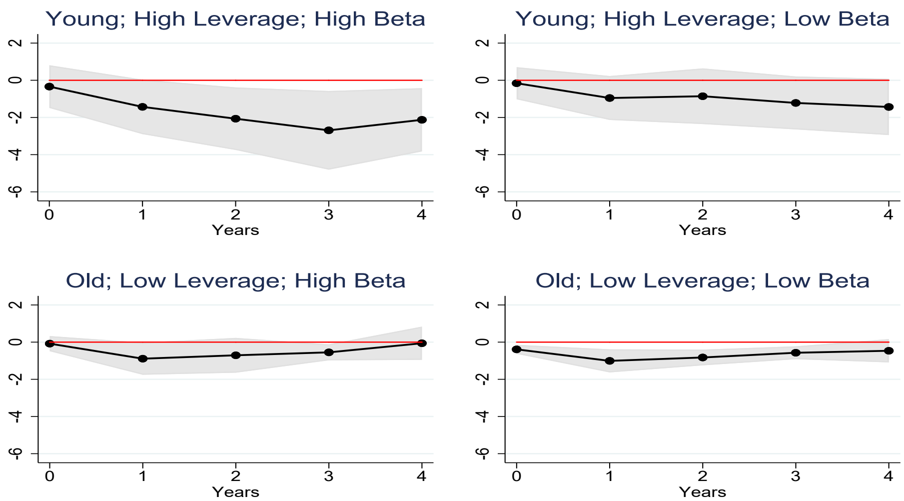
[53]We use the Financial Conduct Authority's *Product Sales Database.* Both this dataset, and the director data, contain the full date of birth of the individual and the full postcode of the property (an area of around 17 properties on average), allowing for an accurate merge between the two. See Online Appendix F of Bahaj, Foulis, and Pinter 2018 for further details on the measurement of director mortgages.

[54]The average director salary is measured as the sum of *Directors' Remuneration* and *Dividends* to the number of directors.

income), our baseline results are robust to controlling for these director cash flow proxies. As a final test, in Figures A51–A52 we proxy director cash flow with the average share of properties in the director's region bought with a mortgage, with similar results.

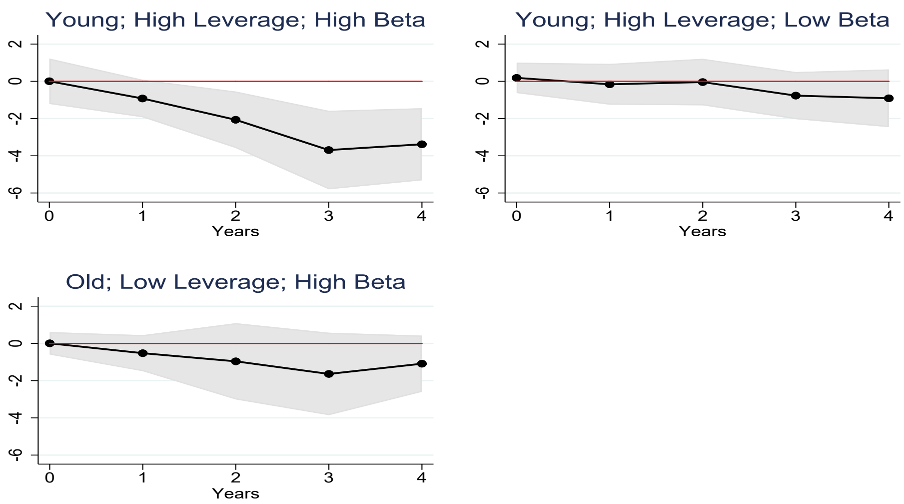
F.3.1 Controlling for Average Mortgage Size

Figure A47: Level Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis – see specification 1. All the responses are %-deviations.

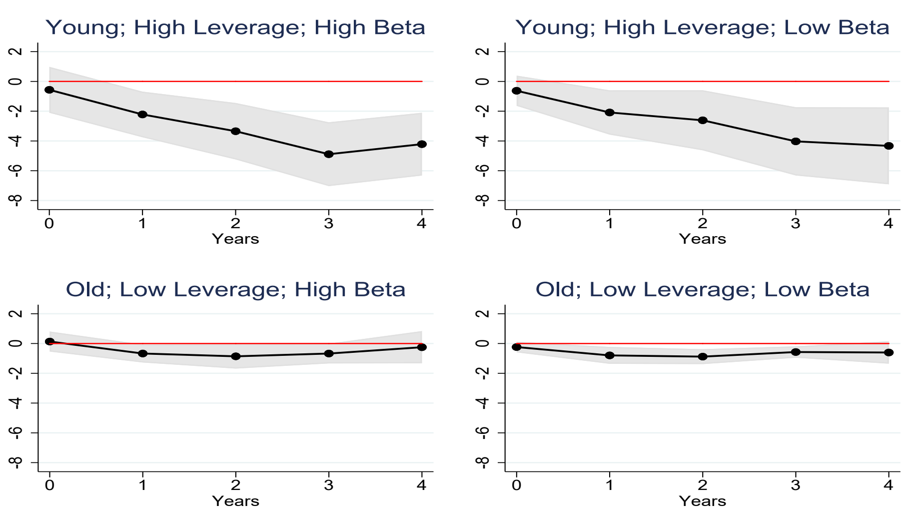
Figure A48: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. All the responses are relative to the group of older and more levered firms in low housing exposure region (omitted given the inclusion of industry-month and NUTS1-month fixed effects – see specification 2).

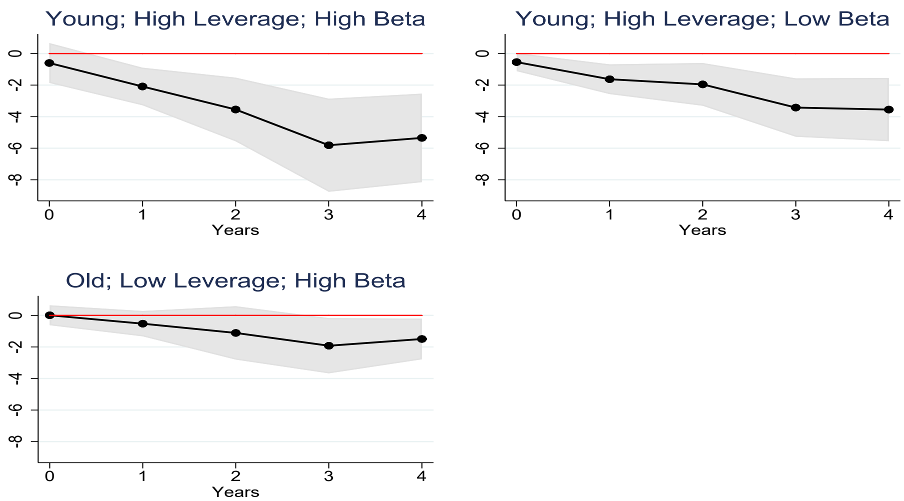
F.3.2 Director Cash Flow Proxy: Controlling for Average Mortgage Size to Average Income

Figure A49: Level Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis – see specification 1. All the responses are %-deviations.

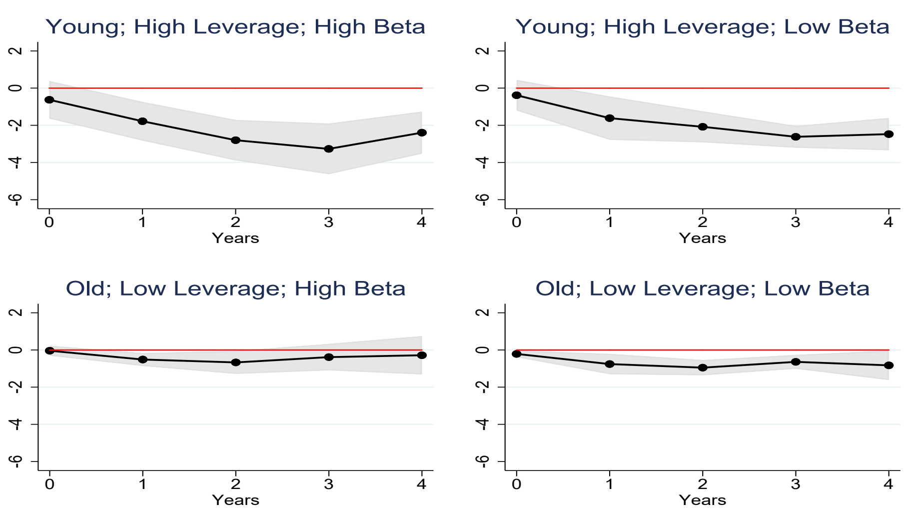
Figure A50: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. All the responses are relative to the group of older and more levered firms in low housing exposure region (omitted given the inclusion of industry-month and NUTS1-month fixed effects – see specification 2).

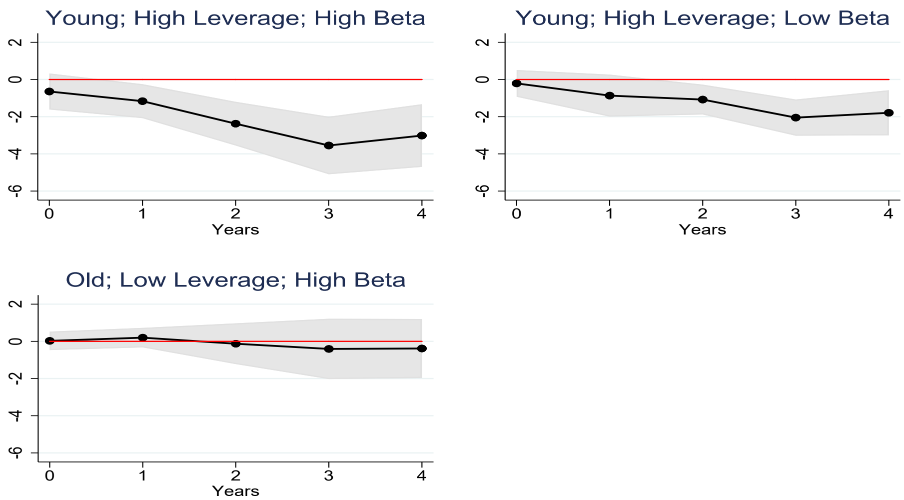
F.3.3 Controlling for Share of Purchases in Director's Region With Mortgage

Figure A51: Level Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis – see specification 1. All the responses are %-deviations.

Figure A52: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted

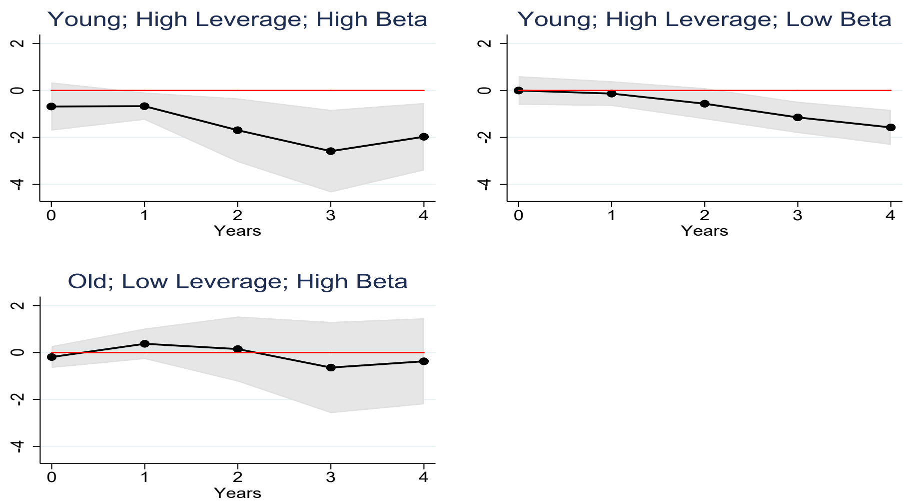


Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. All the responses are relative to the group of older and more levered firms in low housing exposure region (omitted given the inclusion of industry-month and NUTS1-month fixed effects – see specification 2).

F.4 Bank Lending Channel

F.4.1 Adding Bank-Combination x Year Fixed Effects

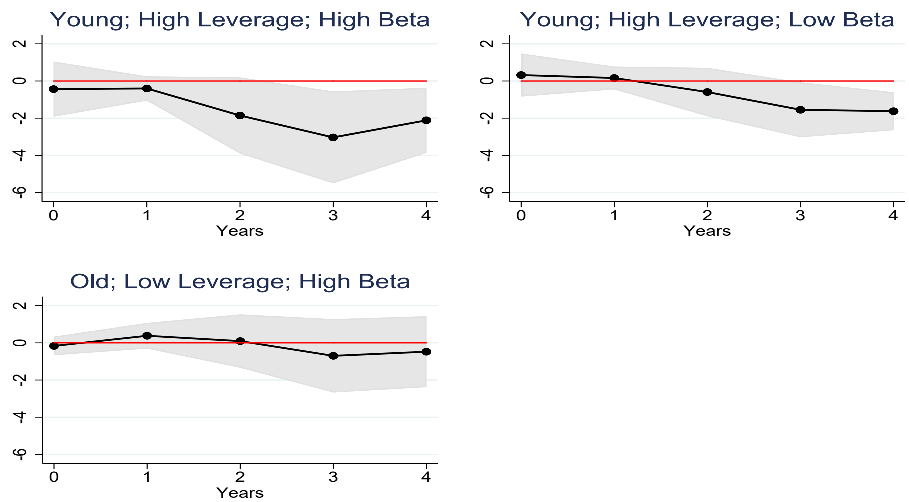
Figure A53: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. All the responses are relative to the group of older and more levered firms in low-β region (omitted given the inclusion of industry-month and NUTS1-month and *bank-combination x year* fixed effects – see specification 2).

F.4.2 Adding Firm Age x Bank-Combination x Year Fixed Effects

Figure A54: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted

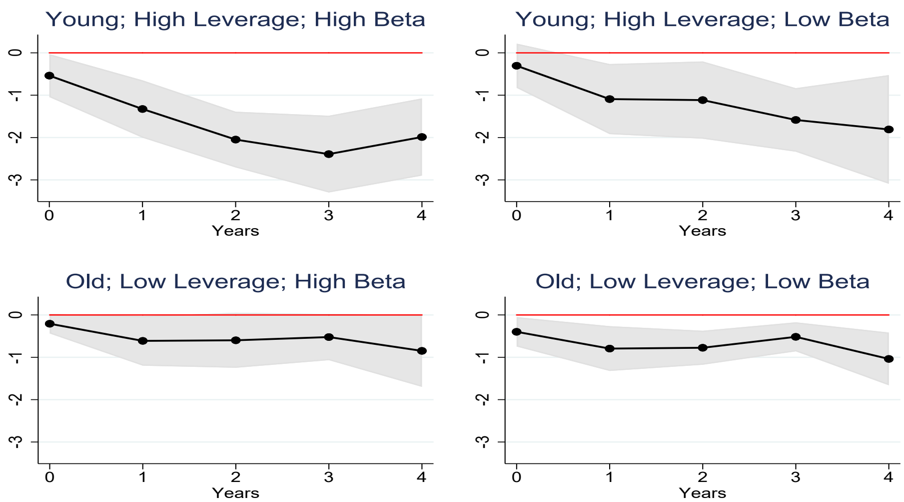


Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. All the responses are relative to the group of older and more levered firms in low-β region (omitted given the inclusion of industry-month and NUTS1-month and *firm age x bank-combination x year* fixed effects – see specification 2).

F.5 Hiring Frictions and Wage Rigidity

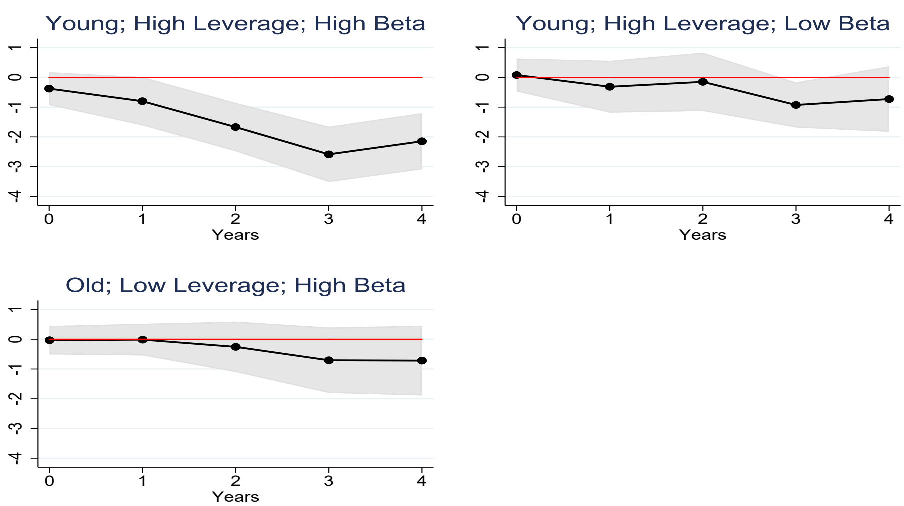
F.5.1 Controlling for Age x Leverage x Average Wage

Figure A55: Level Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis – see specification 1. All the responses are %-deviations.

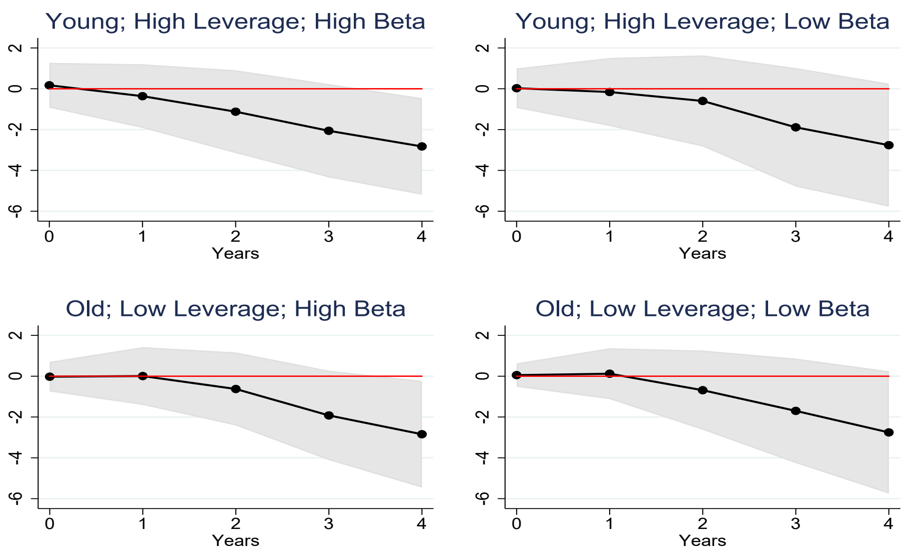
Figure A56: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. All the responses are relative to the group of older and more levered firms in low-β region (omitted given the inclusion of industry-month and NUTS1-month fixed effects – see specification 2).

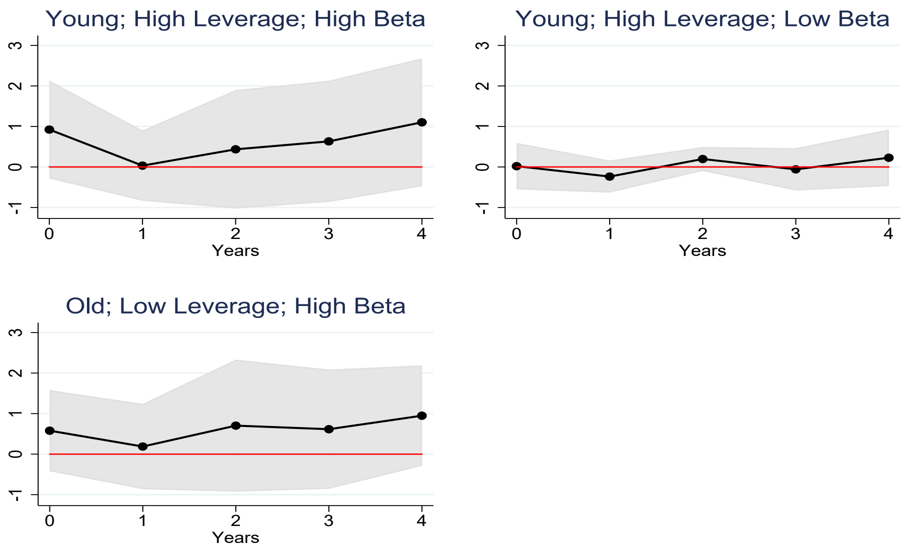
F.5.2 Average Wages as a Dependent Variable

Figure A57: Level Effects on Average Wages by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Average Wages (*Remuneration* divided by *Number of Employees*) from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis – see specification 1. All the responses are %-deviations.

Figure A58: Relative Effects on Average Wages by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Average Wages (*Remuneration* divided by *Number of Employees*) from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis – see specification 1. All the responses are relative to the group of older and more levered firms in low-β region (omitted given the inclusion of industry-month and NUTS1-month fixed effects – see specification 2).

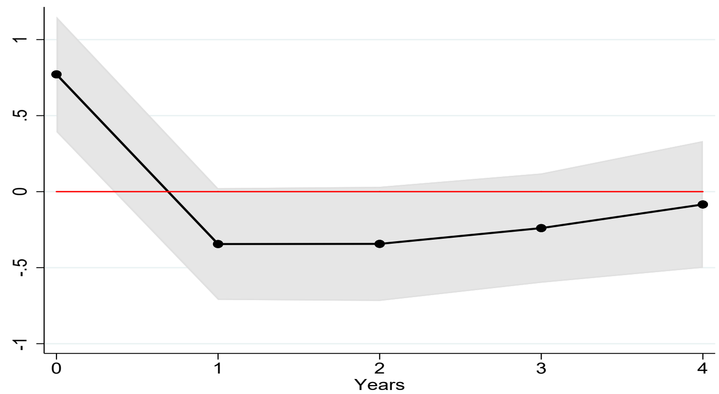
F.6 Exit Rates

This section examines how monetary policy shocks affect firm exit. Company death is timed using the first accounting date at which the "Company Status" is recorded as *dissolved*. The sample construction follows Section 3.1, without the restriction that employment growth from $t-1$ to $t+4$ is reported. In particular, to be in the sample, firms have to be alive and reporting employment, leverage, and their age at time $t-1$. We focus on a point in time measure of exit from one period to the next; specifically a dummy taking value 0 at $t+h$ if the firm is still alive; 1 if the firm exits between $t+h-1$ and $t+h$; and missing if the firm was dead at $t+h-1$. This exit measure is thus conditional on having being alive in the previous period, so there are fewer observations at longer horizons.

Figure A59 shows the average response across all firms. There is a statistically significant increase in firm exit of around 0.7% in the first period, and an insignificant effect on subsequent firm exits for the firms that survive the first period. Figures A60–A61 show that the initial jump in the exit rate is more pronounced among young, high leverage firms (at over 1%), than old, low leverage firms. However, within the young, high leverage firms, there is little difference in the response between the firms with directors living in high vs low beta regions, consistent with the small difference in house price responses between high and low beta regions at this horizon (Figure A4 in Appendix A.4).

F.6.1 Exit Rates: Linear Effects

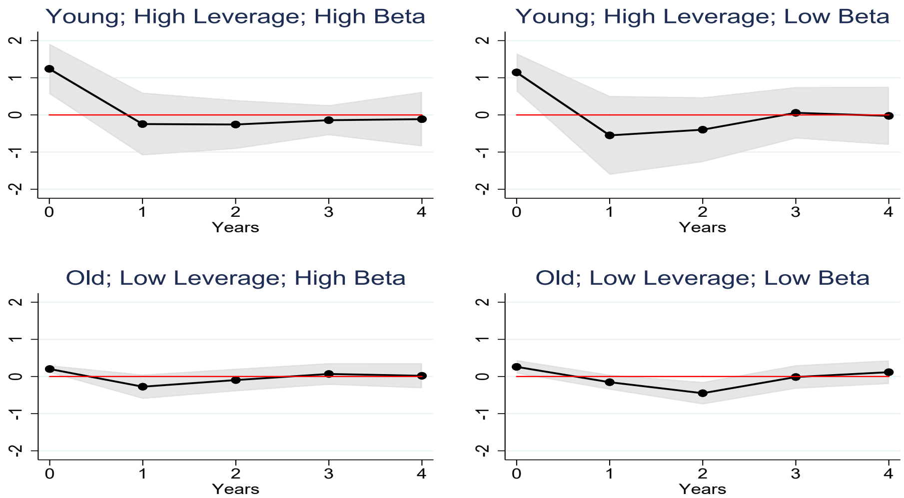
Figure A59: Linear Effect of Monetary Policy on Firm Exit



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is a dummy variable for firm exit, taking the value 0 at $t+h$ if a firm that was alive at $t-1$ is still alive at $t+h$, and taking value 1 if the firm was alive at $t-1$, $t+h-1$, and is dead at $t+h$, i.e., the firm has died between $t+h$ and the prior period.

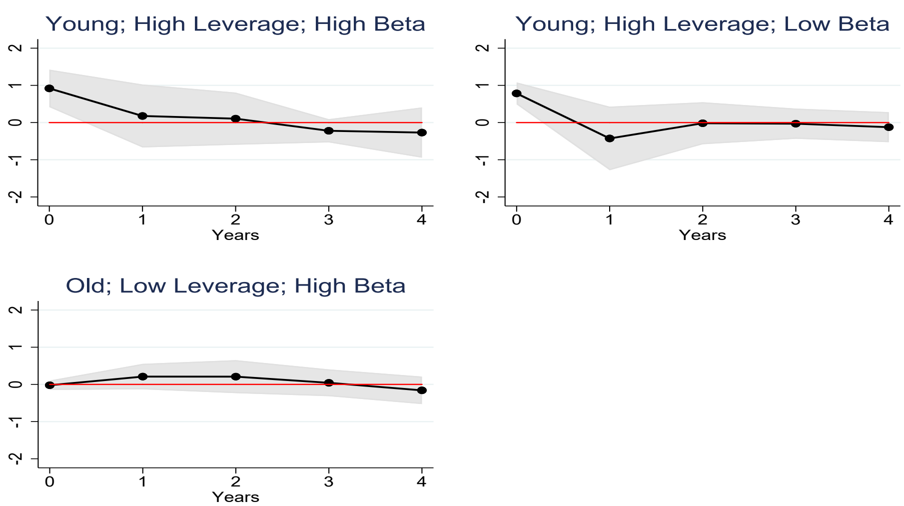
F.6.2 Exit Rates: Age x Leverage x Director Beta

Figure A60: Level Effects on Firm Exit by Age, Leverage and Director Beta



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is a dummy variable for firm exit, taking the value 0 at $t+h$ if a firm that was alive at $t-1$ is still alive at $t+h$, and taking value 1 if the firm was alive at $t-1$, $t+h-1$, and is dead at $t+h$, i.e., the firm has died between $t+h$ and the prior period.

Figure A61: Relative Effects on Firm Exit by Age, Leverage and Director Beta

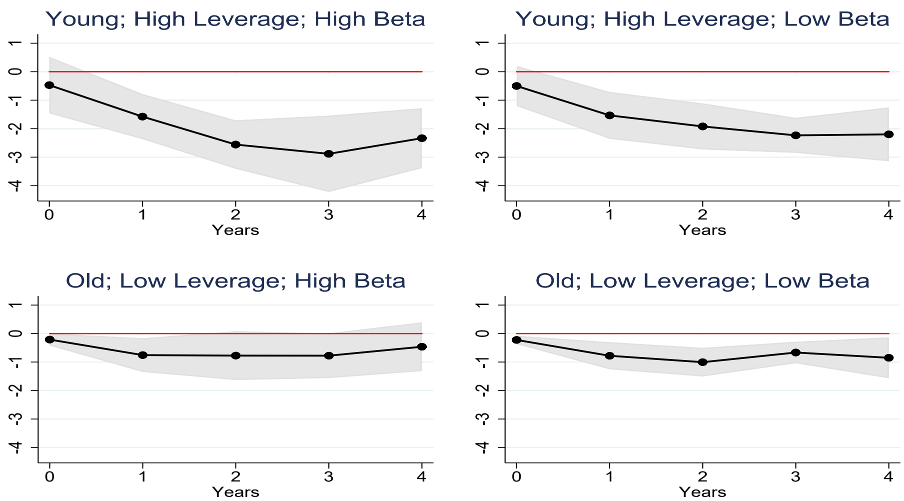


Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is a dummy variable for firm exit, taking the value 0 at $t+h$ if a firm that was alive at $t-1$ is still alive at $t+h$, and taking value 1 if the firm was alive at $t-1$, $t+h-1$, and is dead at $t+h$, i.e., the firm has died between $t+h$ and the prior period. All the responses are relative to the group of older and more levered firms in low-β region (omitted given the inclusion of industry-month and NUTS1-month fixed effects – see specification 2).

G Further Robustness

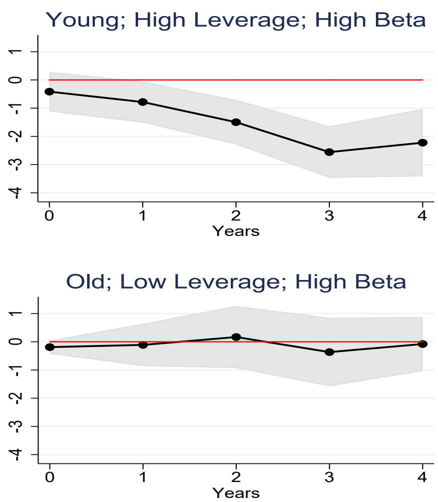
G.1 Measuring House Price Sensitivity at 36 Months

Figure A62: Level Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis – see specification 1. All the responses are %-deviations. In this regression high and low beta regions are classified based upon the house price responsiveness after 36 months (as opposed to 24 months in the baseline).

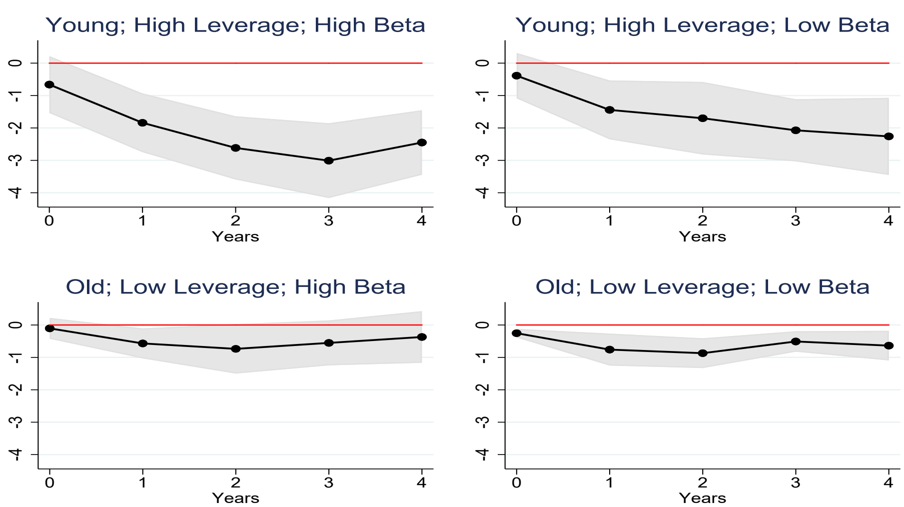
Figure A63: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. All the responses are relative to the group of older and more levered firms in low-β region (omitted given the inclusion of industry-month and NUTS1-month fixed effects – see specification 2). In this regression high and low beta regions are classified based upon the house price responsiveness after 36 months (as opposed to 24 months in the baseline).

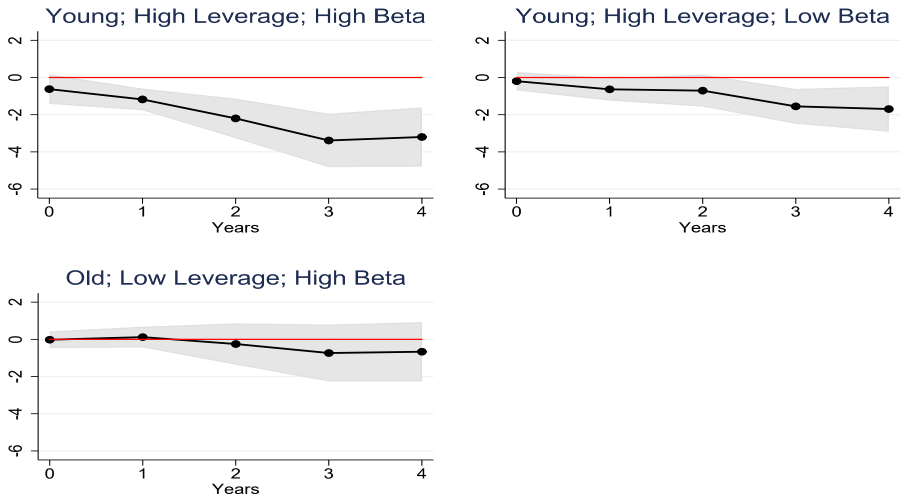
G.2 Adding Firm Controls

Figure A64: Level Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis – see specification 1. All the responses are %-deviations. This regression adds a lag of leverage, a lag of log total assets and the lagged ratio of current to total assets to the baseline regression as controls.

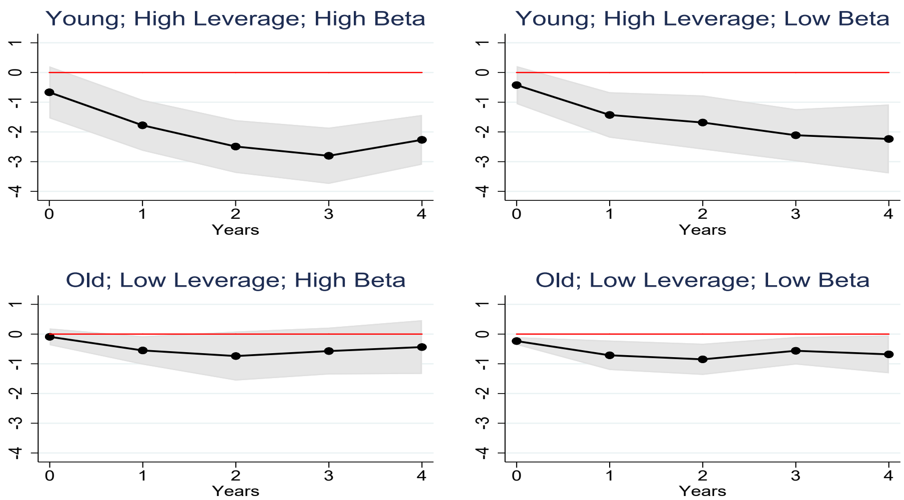
Figure A65: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. All the responses are relative to the group of older and more levered firms in low-β region (omitted given the inclusion of industry-month and NUTS1-month fixed effects – see specification 2). This regression adds a lag of leverage, a lag of log total assets and the lagged ratio of current to total assets to the baseline regression as controls.

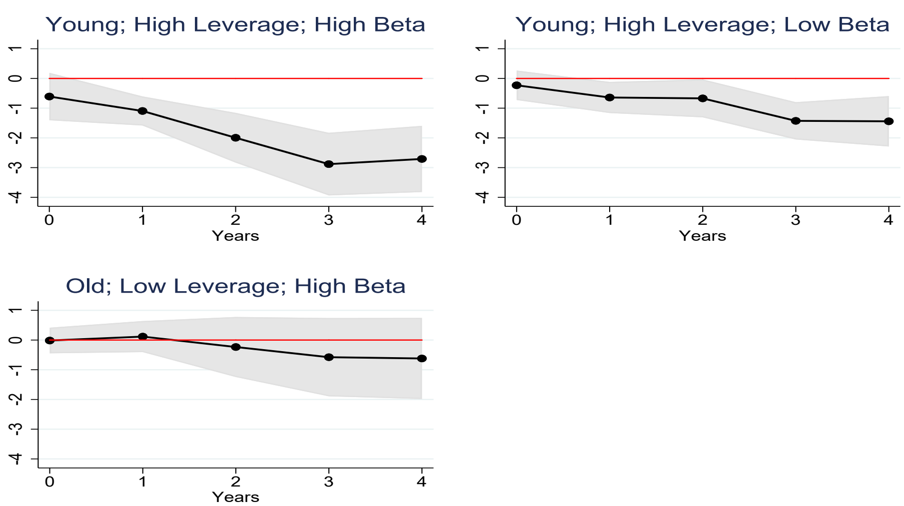
G.3 Davis-Haltiwanger Employment Growth

Figure A66: Level Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative Davis-Haltiwanger growth rate of employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis, i.e. $\frac{emp_{t+h}-emp_{t-1}}{0.5(emp_{t+h}+emp_{t-1})}$.

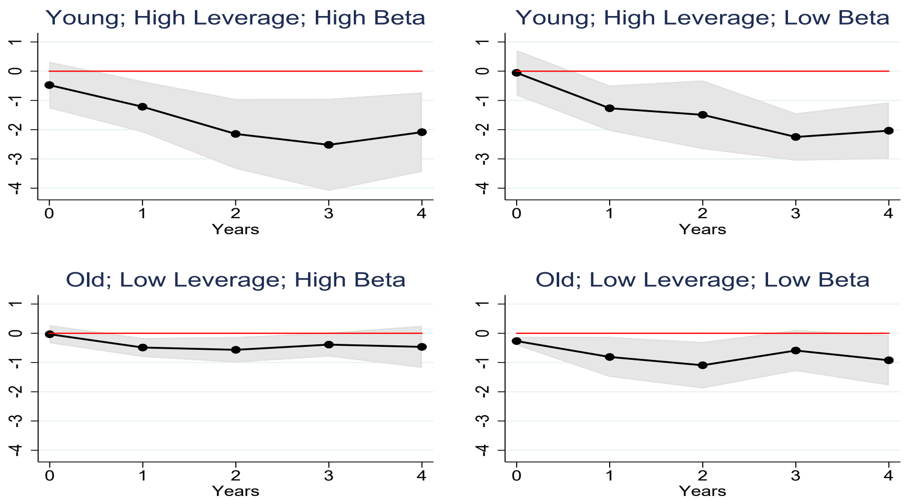
Figure A67: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative Davis-Haltiwanger growth rate of employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis, i.e. $\frac{emp_{t+h}-emp_{t-1}}{0.5(emp_{t+h}+emp_{t-1})}$. All the responses are relative to the group of older and more levered firms in low-β region (omitted given the inclusion of industry-month and NUTS1-month fixed effects – see specification 2).

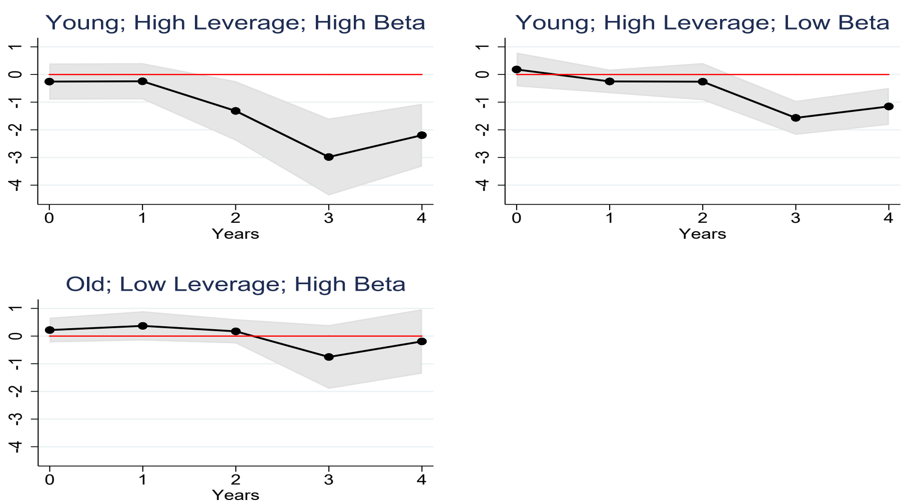
G.4 Non-Rectangularised Sample

Figure A68: Level Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis – see specification 1. All the responses are %-deviations. This specification doesn't restrict the sample to employment growth from t-1 to t+4 being non-missing.

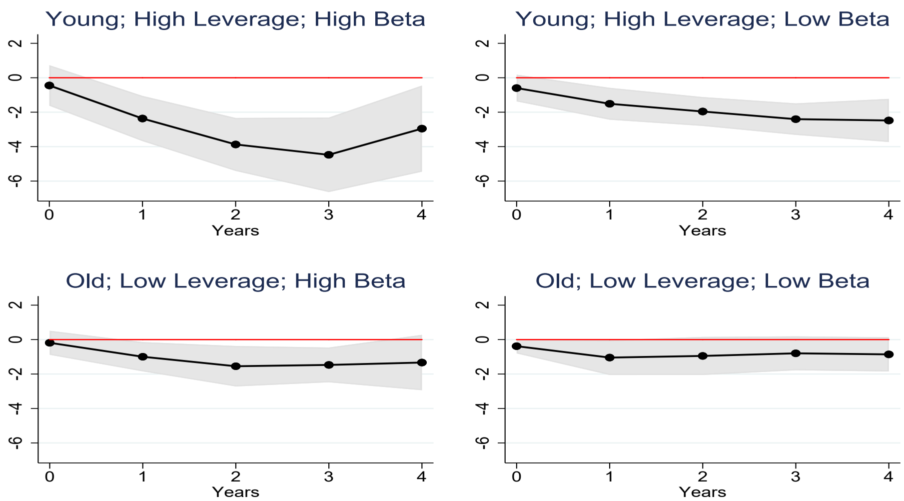
Figure A69: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. All the responses are relative to the group of older and more levered firms in low-β region (omitted given the inclusion of industry-month and NUTS1-month fixed effects – see specification 2). This specification doesn't restrict the sample to employment growth from t-1 to t+4 being non-missing.

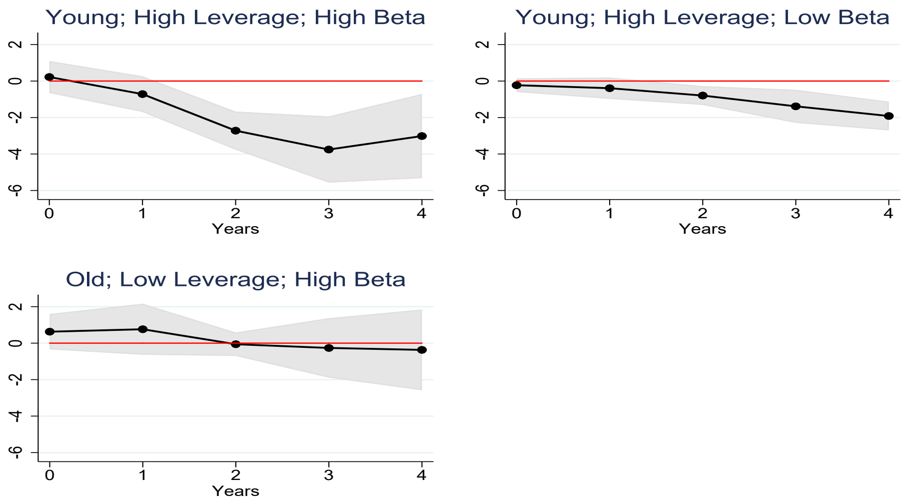
G.5 Weighting by Employment

Figure A70: Level Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis – see specification 1. All the responses are %-deviations. This regression weights the firm observations by lagged employment, to align their weight in the sample with their contribution to aggregate employment. Administrative microdata is taken from the *Business Structure Database* from the *Office For National Statistics* (ONS), covering total employment by companies in the same industries as the baseline regression. The share of total employment for these companies accounted for by different firm size groups is calculated for the following employment bins: 1-9,...,90-99,100-149,...,950-999,1000-1999,...,19000-20000,20000+. The share of observations in our baseline regression sample accounted for by each firm size bin is also calculated. Weights are then constructed for each size bin using these two set of numbers, to ensure that the weight placed on each group in our regression matches their contribution to aggregate employment. This work was produced using statistical data from ONS. The use of the ONS statistical data in this work does not imply the endorsement of the ONS in relation to the interpretation or analysis of the statistical data. This work uses research datasets which may not exactly reproduce National Statistics aggregates.

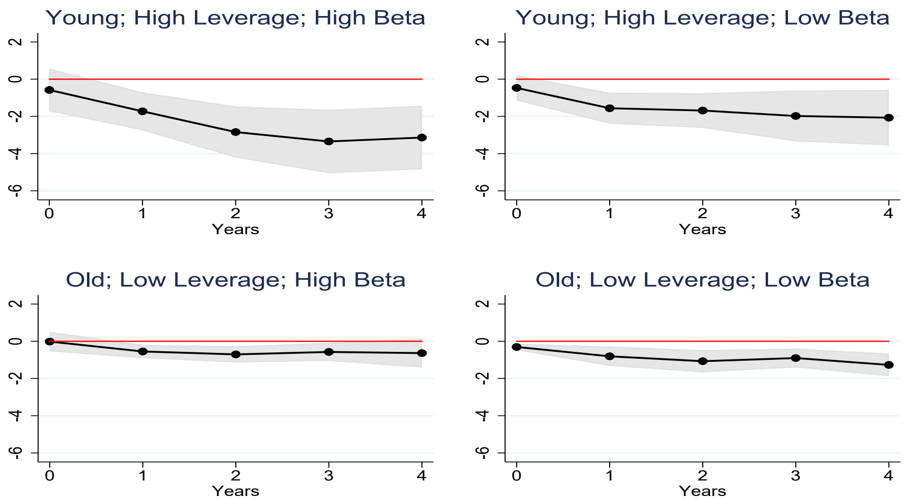
Figure A71: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. All the responses are relative to the group of older and more levered firms in low-β region (omitted given the inclusion of industry-month and NUTS1-month fixed effects – see specification 2). This regression weights the firm observations by lagged employment, to align their weight in the sample with their contribution to aggregate employment. Administrative microdata is taken from the *Business Structure Database* from the *Office For National Statistics* (ONS), covering total employment by companies in the same industries as the baseline regression. The share of total employment for these companies accounted for by different firm size groups is calculated for the following employment bins: 1-9,...,90-99,100-149,...,950-999,1000-1999,...,19000-20000,20000+. The share of observations in our baseline regression sample accounted for by each firm size bin is also calculated. Weights are then constructed for each size bin using these two set of numbers, to ensure that the weight placed on each group in our regression matches their contribution to aggregate employment. This work was produced using statistical data from ONS. The use of the ONS statistical data in this work does not imply the endorsement of the ONS in relation to the interpretation or analysis of the statistical data. This work uses research datasets which may not exactly reproduce National Statistics aggregates.

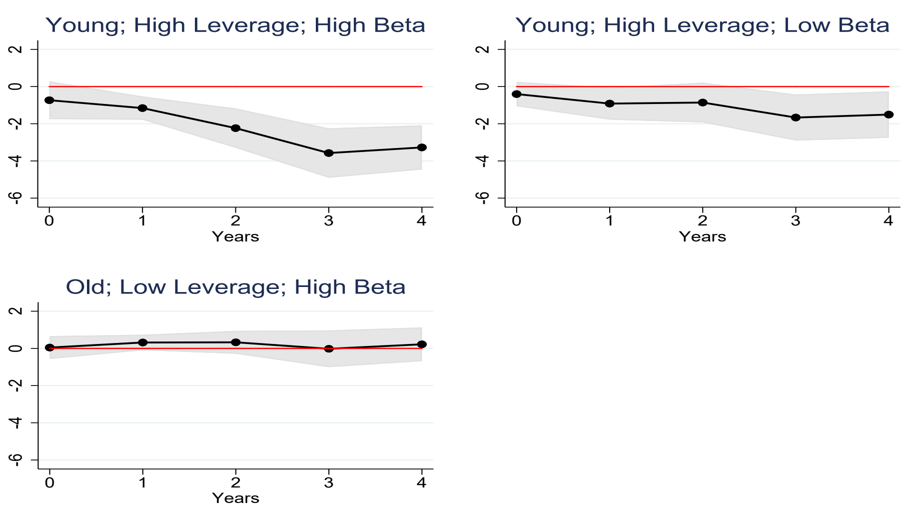
G.6 Adding Firm Fixed Effects

Figure A72: Level Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis – see specification 1. All the responses are %-deviations. All regressions include *firm fixed effects*.

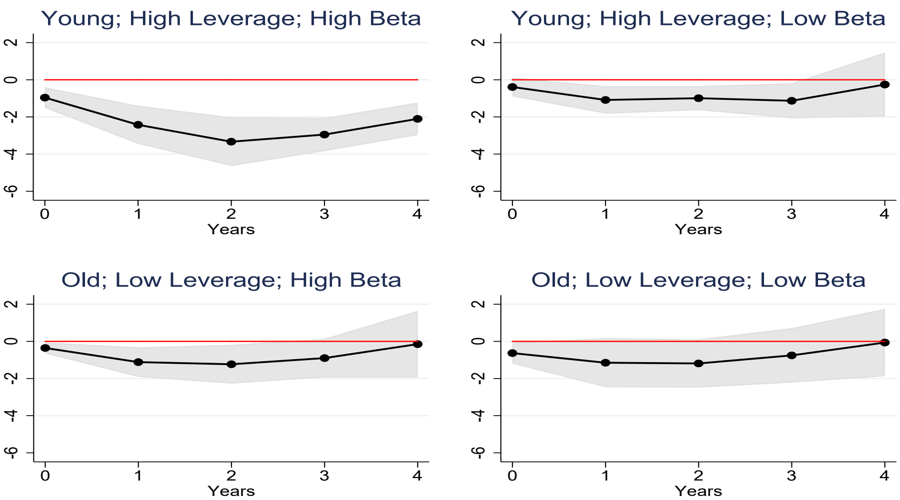
Figure A73: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. All the responses are relative to the group of older and more levered firms in low-β region (omitted given the inclusion of industry-month and NUTS1-month fixed effects – see specification 2). All regressions include *firm fixed effects*.

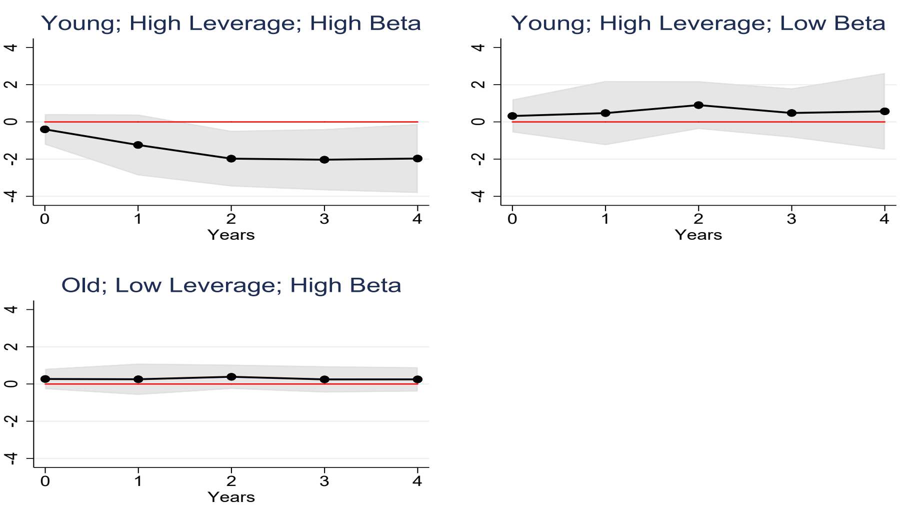
G.7 Firm Region Responsiveness: Tradable Firms

Figure A74: Level Effects on Employment by Age, Leverage and Firm Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis – see specification 1. All the responses are %-deviations. The sample is restricted to firms in the tradeables sector, and βs are measured based on the firm location (instead of the firm's directors' location.

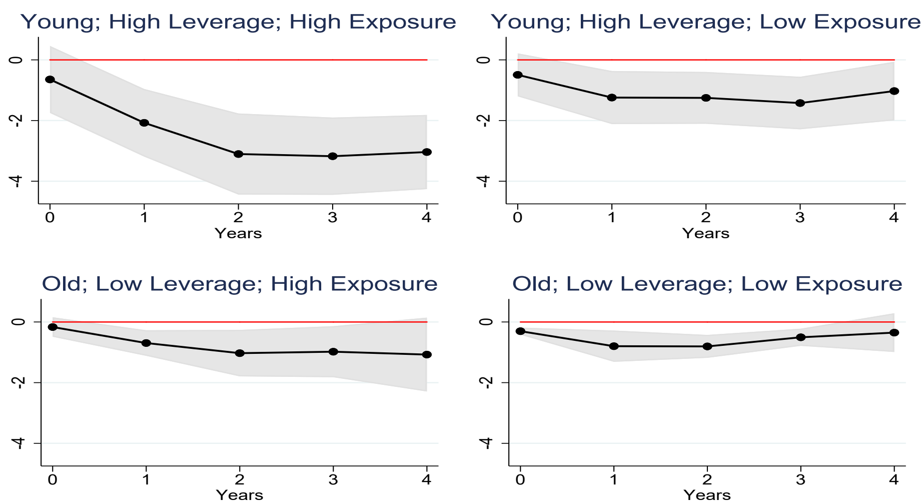
Figure A75: Relative Effects on Employment by Age, Leverage and Firm Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. All the responses are relative to the group of older and more levered firms in low-β region (omitted given the inclusion of industry-month fixed effects – see specification 2). The sample is restricted to firms in the tradeables sector, and βs are measured based on the firm location (instead of the firm's directors' location).

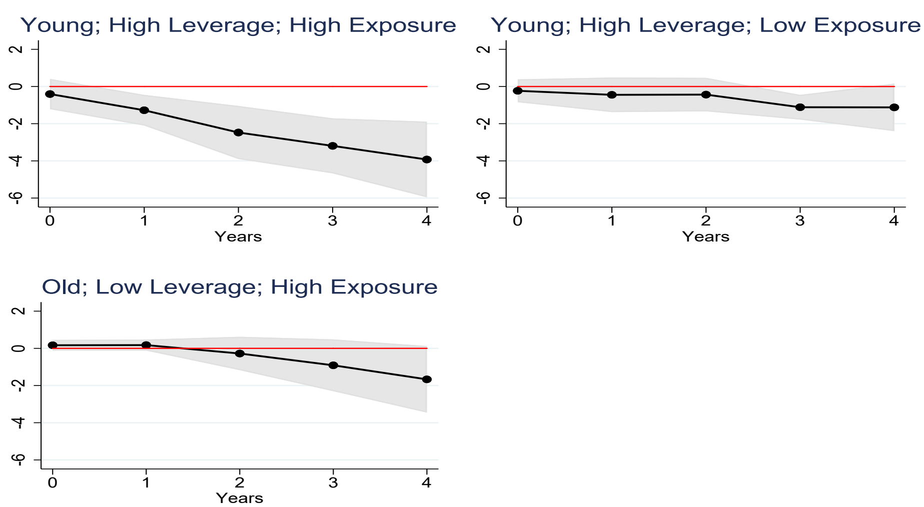
G.8 Value Based Measure

Figure A76: Level Effects on Employment by Age, Leverage and Director Housing Value, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis – see specification 1. All the responses are %-deviations.

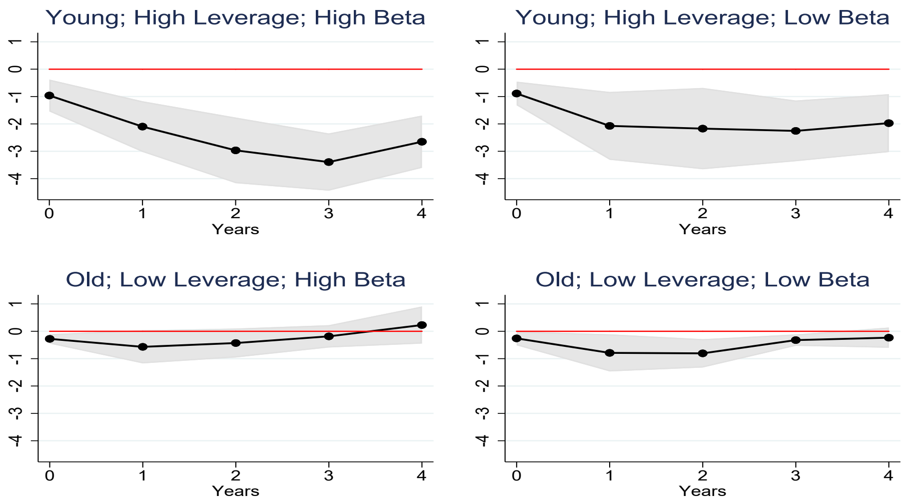
Figure A77: Relative Effects on Employment by Age, Leverage and Director Housing Value, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. All the responses are relative to the group of older and more levered firms in low housing exposure region (omitted given the inclusion of industry-month and NUTS1-month fixed effects – see specification 2).

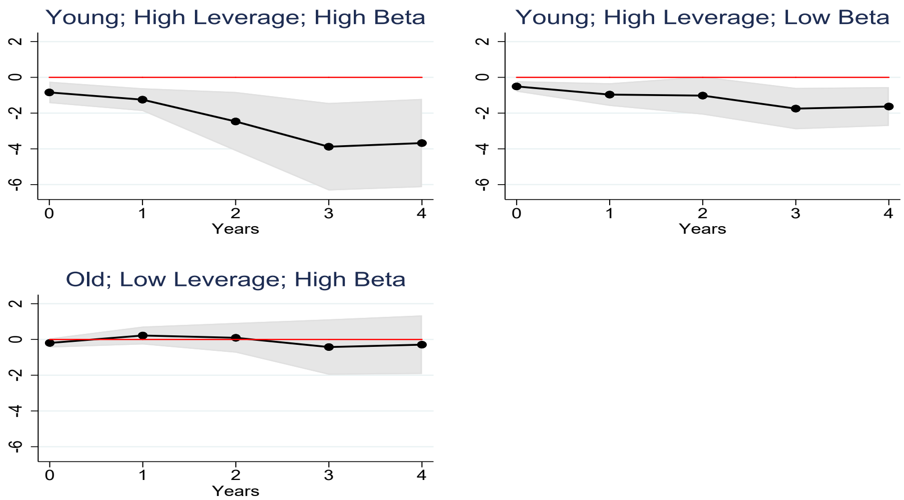
G.9 Excluding Zero Lower Bound Period

Figure A78: Level Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis – see specification 1. All the responses are %-deviations. The estimation excludes the period post-2008.

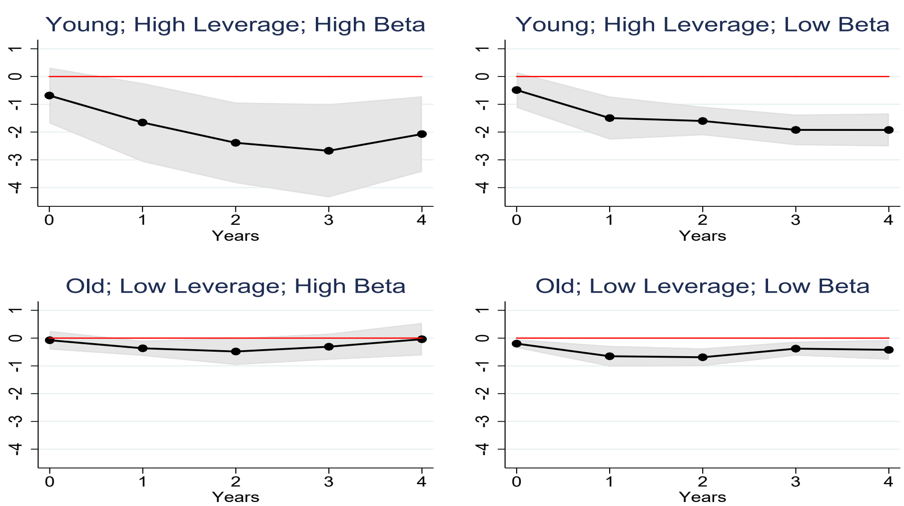
Figure A79: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. All the responses are relative to the group of older and more levered firms in low-β region (omitted given the inclusion of industry-month and NUTS1-month fixed effects – see specification 2). The estimation excludes the period post-2008.

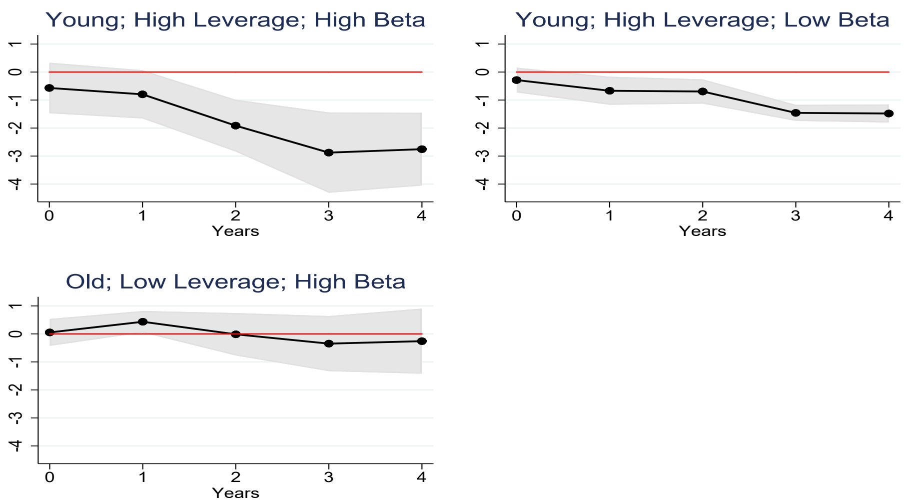
G.10 Controlling for Inflation and GDP Forecast Surprises

Figure A80: Level Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis – see specification 1. All the responses are %-deviations.

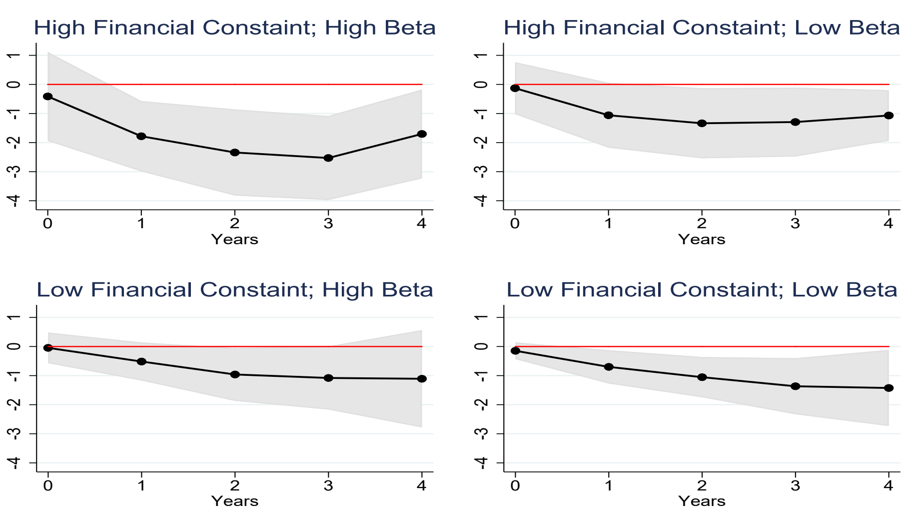
Figure A81: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. All the responses are relative to the group of older and more levered firms in low-β region (omitted given the inclusion of industry-month and NUTS1-month fixed effects – see specification 2).

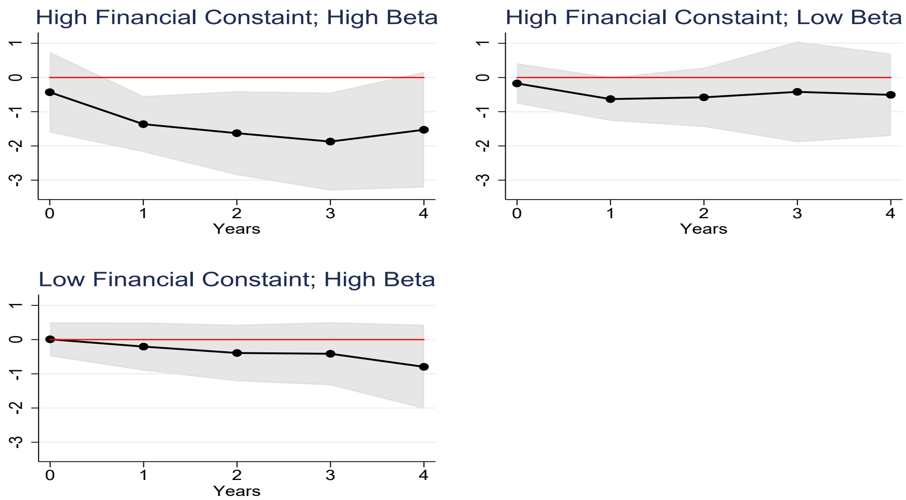
G.11 Using A Financial Constraint Index

Figure A82: Level Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis – see specification 1. All the responses are %-deviations.

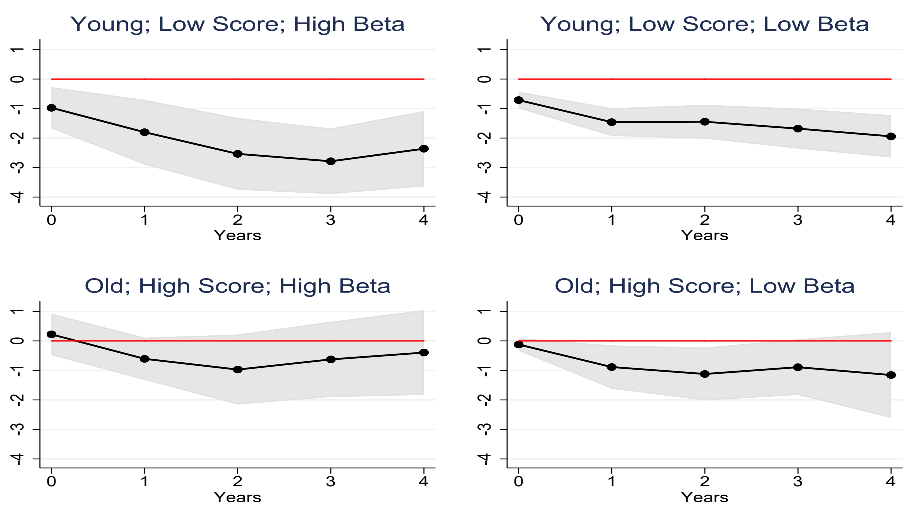
Figure A83: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. All the responses are relative to the group of low financial constraint index firms in the low-β region (omitted given the inclusion of industry-month and NUTS1-month fixed effects – see specification 2).

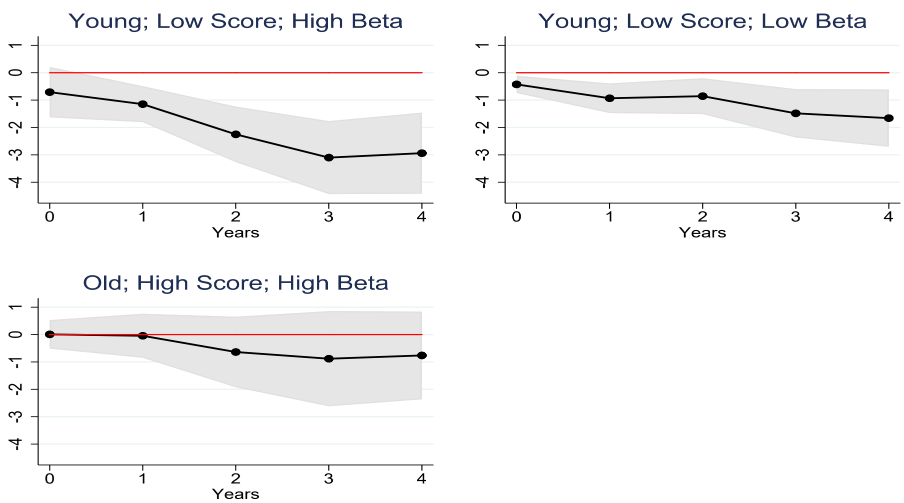
G.12 Using Credit Score As Alternative To Leverage

Figure A84: Level Effects on Employment by Age, Credit Score and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis – see specification 1. All the responses are %-deviations. Younger is defined as less than 15 years old, and higher score is defined as credit score above 60.

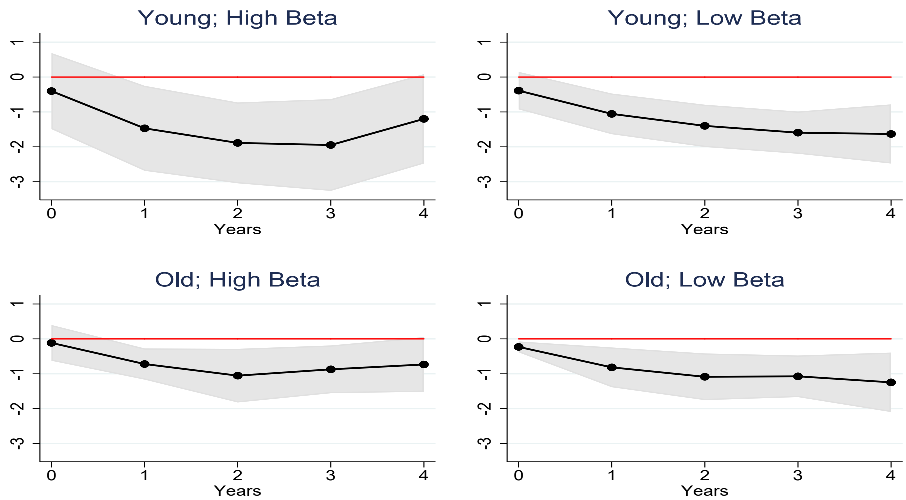
Figure A85: Relative Effects on Employment by Age, Credit Score and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. All the responses are relative to the group of older and higher credit score firms in low-β region (omitted given the inclusion of industry-month and NUTS1-month fixed effects – see specification 2). Younger is defined as less than 15 years old, and higher score is defined as credit score above 60.

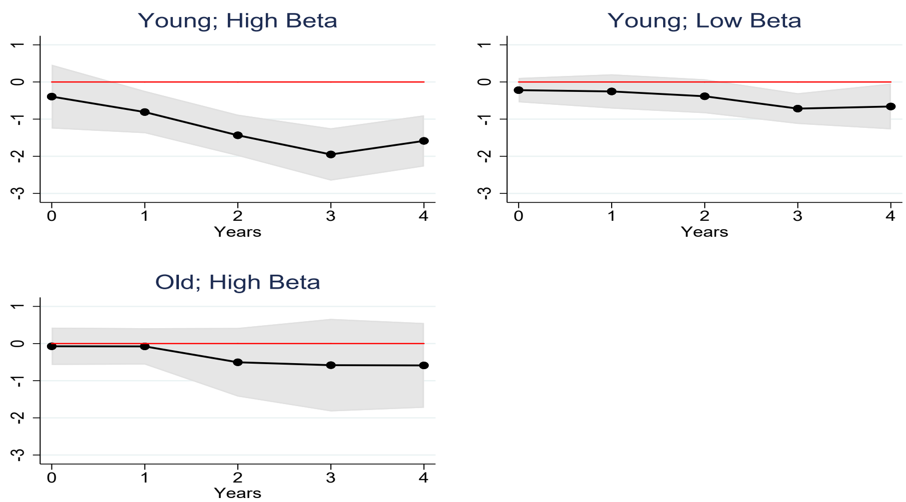
G.13 Using Firm Age Alone

Figure A86: Level Effects on Employment by Age and Director Beta



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis – see specification 1. All the responses are %-deviations. Younger is defined as less than 15 years old.

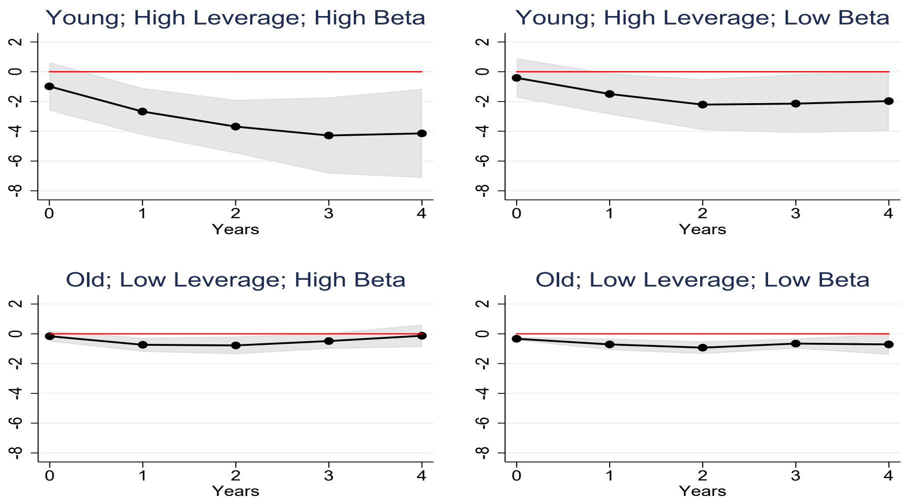
Figure A87: Relative Effects on Employment by Age and Director Beta



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. All the responses are relative to the group of older firms in low-β region (omitted given the inclusion of industry-month and NUTS1-month fixed effects – see specification 2). Younger is defined as less than 15 years old.

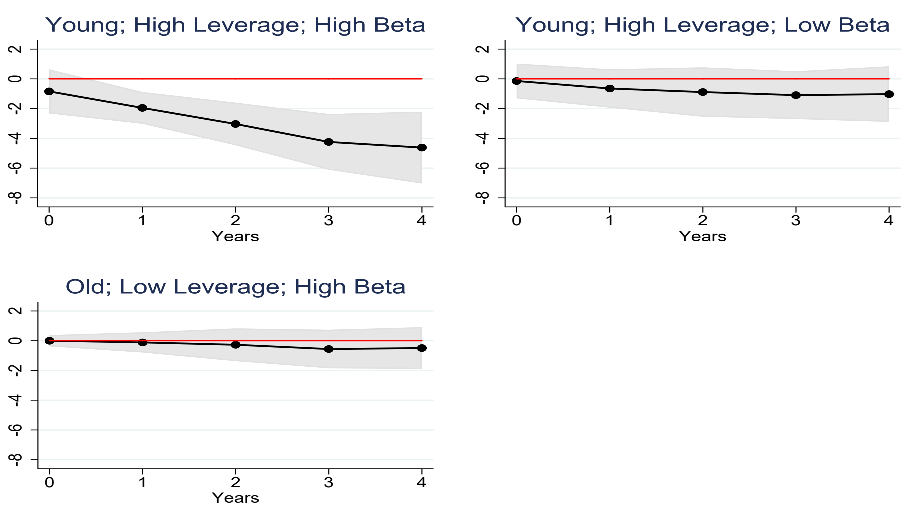
G.14 Alternative Firm Age Cut at 5 Years Old

Figure A88: Level Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis – see specification 1. All the responses are %-deviations. Younger is defined as less than 5 years old, and higher leverage is defined as above the median firm leverage by year.

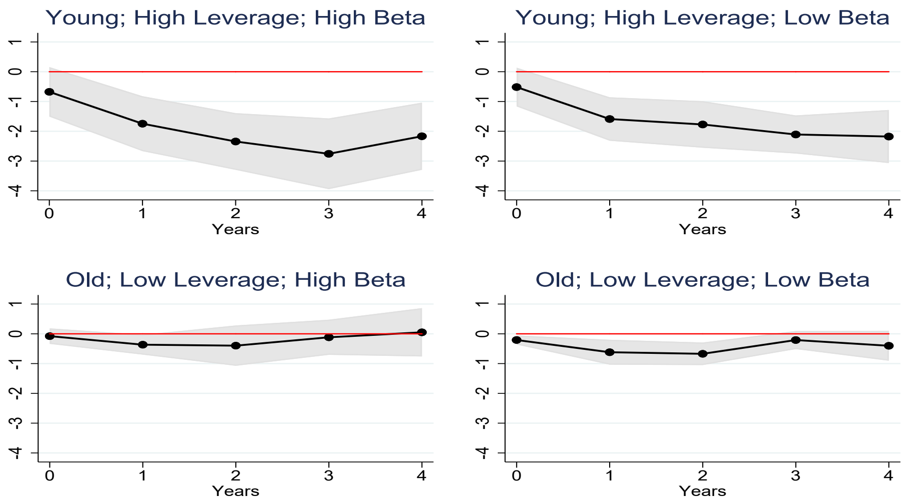
Figure A89: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. All the responses are relative to the group of older and more levered firms in low-β region (omitted given the inclusion of industry-month and NUTS1-month fixed effects – see specification 2). Younger is defined as less than 5 years old, and higher leverage is defined as above the median firm leverage by year.

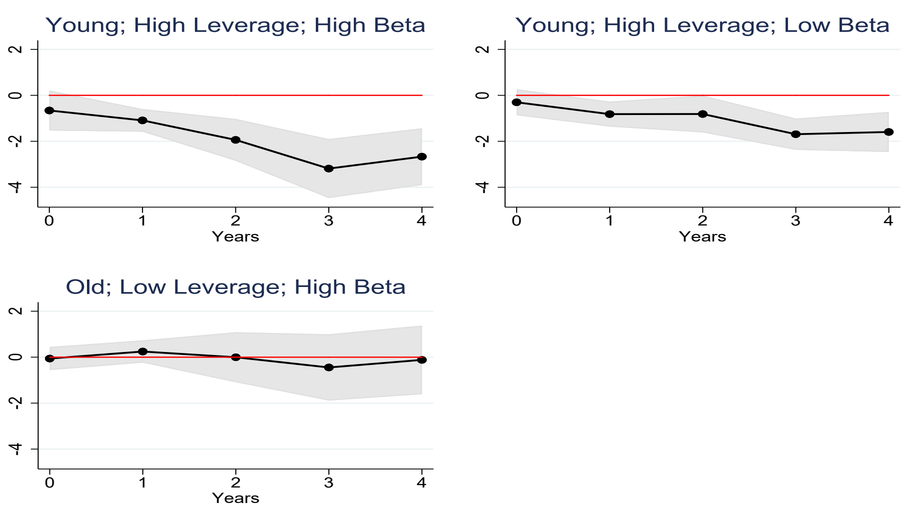
G.15 Restricting to SMEs

Figure A90: Level Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis – see specification 1. All the responses are %-deviations. The sample excludes firms with more than 250 employees.

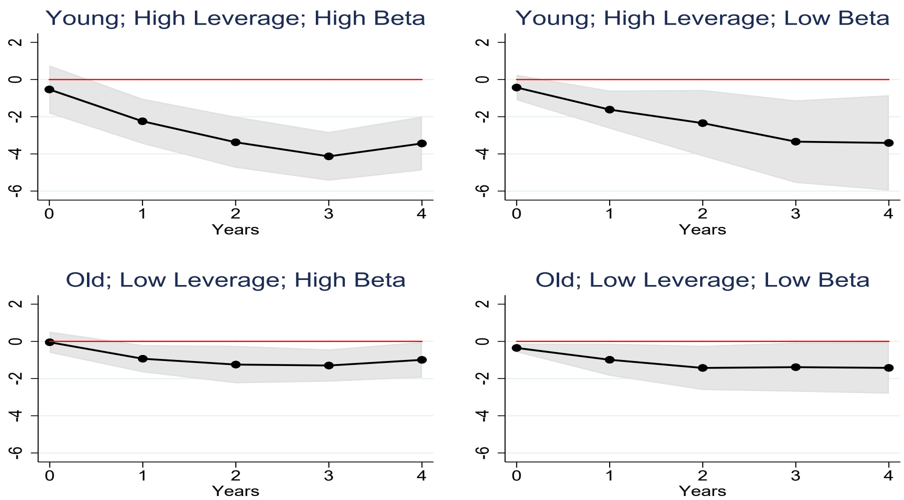
Figure A91: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. All the responses are relative to the group of older and more levered firms in low-β region (omitted given the inclusion of industry-month and NUTS1-month fixed effects – see specification 2). The sample excludes firms with more than 250 employees.

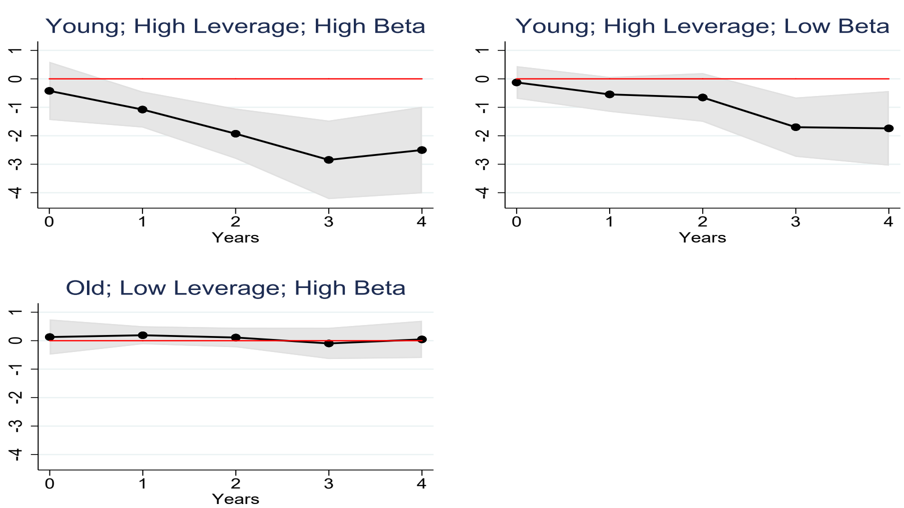
G.16 Controlling for Firm Size x Director Beta

Figure A92: Level Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis – see specification 1. All the responses are %-deviations.

Figure A93: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



Notes: Firm-level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock and h is the x-axis. All the responses are relative to the group of older and more levered firms in low-β region (omitted given the inclusion of industry-month and NUTS1-month fixed effects – see specification 2).