Employment and the Collateral Channel of Monetary Policy

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10th May 2019

Abstract

This paper uses a detailed firm-level dataset to show that monetary policy propagates via asset prices through corporate debt collateralised on real estate. Our research design exploits the fact that many small and medium sized firms use the homes of the firm's directors as a key source of collateral, and directors' homes are typically not in the same region as their firm. This spatial separation of firms and firms' collateral allows us to separate the propagation of monetary policy via fluctuations in collateral values from that via demand channels. We find that younger and more levered firms who have collateral values that are particularly sensitive to monetary policy show the largest employment response to monetary policy. The collateral channel explains a sizeable share of the aggregate employment response.

*We are grateful for helpful comments to Andy Blake, Giancarlo Corsetti, V.V. Chari, Simon Gilchrist, Erik Hurst, Sebnem Kalemli-Ozcan, Greg Kaplan, Yueran Ma, Fred Malherbe, Silvia Miranda-Agripinno, Michael McMahon, Ricardo Reis, Adam Szeidl, Harald Uhlig, Gianluca Violante, Jasmine Xiao and Peter Zorn. We also thank discussants and seminar participants at the 2018 CEBRA workshop, the 2018 NBER Summer Institute, the 2018 Barcelona GSE Summer Forum, the 2018 AEA Meetings, the Sciences Po Workshop on Empirical Monetary Economics, the QMQM Workshop, the 2017 RES Conference, the CCBS Chief Economists' Workshop, and the 2017 CCBS-MacCalm Macro-finance Workshop. Bahaj: saleem.bahaj@bankofengland.co.uk; Foulis: angus.foulis@bankofengland.co.uk; Pinter: gabor.pinter@bankofengland.co.uk, Bank of England and Centre for Macroeconomics. Surico: psurico@london.edu, London Business School and CEPR. Surico gratefully acknowledge financial support from the European Research Council (Consolidator Grant Agreement No. 647049). This paper contains the views of the authors and not necessarily those of the Bank of England, the MPC, the FPC or the PRA.

1 Introduction

Conditions in the labour market are a lodestar for assessing the appropriateness of monetary policy. While empirical evidence based on macroeconomic time-series shows that monetary policy can influence aggregate employment (Christiano, Eichenbaum, and Evans, 1999), a more recent literature has emphasised that there is substantial heterogeneity in firm-level employment dynamics that is masked by aggregate data (Davis, Haltiwanger, and Schuh 1996; Fort, Haltiwanger, Jarmin, and Miranda 2013; Dinlersoz, Kalemli-Ozcan, Hyatt, and Penciakova 2018). Yet, the contribution of monetary policy to these heterogenous dynamics and the implications for the transmission mechanism has been less studied. At same time, a separate strand of literature has documented that, at the firm-level, fluctuations in asset and collateral values interact with financial frictions to meaningfully influence firm behaviour and alter the dynamic response of firms to aggregate shocks (Chaney, Sraer, and Thesmar, 2012; Adelino, Schoar, and Severino, 2015; Bahaj, Foulis, and Pinter, 2018). It is well known that monetary policy can influence asset prices (Bernanke and Kuttner, 2005). However, despite the central role asset prices play in key theories (Kiyotaki and Moore, 1997; Bernanke, Gertler, and Gilchrist, 1999), how this interacts with firm-level financial conditions to determine the response to monetary policy has received little attention in the empirical literature.

The goal of this paper is to bring these disparate strands of literature together. Using a variety of different micro-datasets, we document three facts. First, firm-level employment responds heterogeneously to an identified monetary policy shock, with firms who are younger and more levered being particularly sensitive. Second, we present survey evidence to show that these types of firms are particularly reliant on asset based borrowing - and in particular real estate collateral – to finance their activities. Third, we show that monetary policy has a large and spatially heterogeneous effect on the value of this form of collateral. In light of these facts, our key result is that the response of younger, more levered firms is much stronger when collateral values are also sensitive to monetary policy (the same is not true for older, less levered firms that are less reliant on collateralised borrowing). This finding is mirrored by the response of corporate debt to monetary policy shocks.

We argue that these findings are consistent with monetary policy transmitting via asset prices through collateral constraints on specific firms. Furthermore, this interaction between collateral values, monetary policy and firm-level characteristics is of quantitative importance. It is large enough both to explain most of the observed firm level heterogeneity in response to monetary shocks *and* to explain a sizeable share of the aggregate employment response to monetary policy.

Our firm-level dataset covers the period 1997-2017 and contains annual income statement and balance sheet information on a sample of UK firms, dominated by small and medium sized enterprises (SMEs), as documented in Bahaj, Foulis, and Pinter (2018). To identify monetary policy shocks, we use high-frequency variation in the price of UK interest rate futures contracts within a 30-minute window of monetary policy announcements (Gurkaynak, Sack, and Swanson, 2005; Gertler and Karadi, 2015). Following a contractionary monetary policy shock that raises the interest rate by 25bp on average over the firm's accounting year, the average firm cuts employment by about 1% two years after the shock hits. Following the literature, we explore heterogeneity along three dimensions: firm size (Gertler and Gilchrist, 1994; Crouzet and Mehrotra, 2017), firm age (Cloyne, Ferreira, Froemel, and Surico, 2018) and firm leverage (Ottonello and Winberry, 2018; Jeenas, 2018). We find that the sensitivity of firms to monetary policy is near monotonically decreasing in age and exhibits a discontinuity of increased sensitivity for more-levered firms. However, the sensitivity is non-monotonic in size and, among the SMEs (with less than 250 employees) that dominate our sample, size seems like a less relevant characteristic. Taken together, we find that the employment response of younger and more levered firms is larger and more significant when compared to any other group.

Using a survey of five major UK banks, we show that younger, more-levered firms are reliant on asset based finance. In particular, as noted by Bahaj, Foulis, and Pinter (2018), the housing wealth owned by firm directors represents an important source of collateral for the corporate sector. Approximately two thirds of loans to younger, more levered firms are guaranteed by their directors' assets. This is crucial as it provides an empirical strategy allows us to separate fluctuations in the collateral values that firms face from other mechanisms by which monetary policy affects firm activity, such as via affecting demand for firms' goods and services. Our dataset contains detailed information on firm directors and we are able to match each firm in our dataset to the regions where the firm's directors live. Approximately 60% of directors live in a different region from their firm's. We then estimate how sensitive each region's house price index is to exogenous variations in monetary policy and compute the average across directors to measure the sensitivity of real estate collateral to monetary policy. This means we can compare two firms who operate in the same region (and industry) and exhibit similar characteristics, but differ along one key dimension: how sensitive the house value of their directors are to a monetary policy shock.

Further splitting firms along the dimension of collateral value sensitivity, we find the largest employment response is generated by younger, more-levered firms whose real estate collateral values are most sensitive to monetary policy shocks. In contrast, for older, less levered firms the sensitivity of collateral values does not alter the monetary policy response. Consistent with the idea that we are detecting the relevance of monetary policy for relaxing collateral constraints, we also consider the effect on firm debt, and find the same pattern of responses. Taking this idea further, in the next section, we consider a stylised model of firm hiring under short term financial constraints and show that it predicts a pattern of heterogeneous responses in line with our empirical exercises.

It is well known that asset values affect demand and through that employment (Mian and Sufi 2011, Mian and Sufi 2014). Key for our results is to disentangle 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 the 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 preventing 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, note also that, directors who only have a managerial role have much less incentive than owners to pledge personal assets in order to support their firm. Hence if the collateral channels 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 heterogeneity is driven entirely by directors who are also shareholders in their firms.

Related Literature Our paper contributes to the empirical monetary economics literature that has studied the role of financing constraints in explaining the monetary policy transmission at the firm-level (Gertler and Gilchrist 1994; Kudlyak and Sanchez 2017; Ottonello and Winberry 2018; Jeenas 2018; Cloyne, Ferreira, Froemel, and Surico 2018 amongst others). Our work differs from these papers in three important ways. First, we use a near-representative sample, covering both the listed and non-listed sectors across all industries in the economy, that is dominated by SMEs – firms that are most likely to be financially constrained. Most existing firm-level studies on the monetary policy transmission use datasets (e.g. Compustat, Worldscope) that contain information only on large publicly listed firms, thereby limiting their focus on a small 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 employment dynamics in the aggregate. 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 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) confirmed the importance of financial frictions in explaining business cycle fluctuations. Our firm-level evidence corroborates the importance of financial frictions in the monetary policy transmission mechanism and supports a body of theoretical work that has explored how these frictions shape optimal monetary policy. (Faia and Monacelli, 2007; Gertler, Gilchrist, and Natalucci, 2007; Kolasa and Lombardo, 2014; Curdia and Woodford, 2016).

Our work is also connected 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; Fort, Haltiwanger, Jarmin, and Miranda, 2013; Crouzet and Mehrotra, 2017; Decker, Haltiwanger, Jarmin, and Miranda, 2018). Compared to these papers, our contribution is to 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 the recent literature which emphasises that shocks to real estate prices affect firm activity by relaxing financial constraints (Gan, 2007; Chaney, Sraer, and Thesmar, 2012; Catherine, Chaney, Huang, Sraer, and Thesmar, 2018; Bahaj, Foulis, and Pinter, 2018). We use insights from this literature to identify the collateral channel of monetary policy in the present paper. Finally, our results are linked 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). Our paper connects firm finance directly with the monetary policy transmission mechanism.

Structure of the paper The paper is organised as follows: Section 2 presents a simple theoretical framework which guides our research design; Section 3 explains our data sources; Section 4 describes our empirical strategy; Section 5 presents the main results; Section 6 provides further explorations of the mechanism, and Section 8 concludes. Appendix A–H contains further details on the data and a comprehensive list of sensitivity analyses.

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.[1]

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 complementarity to labour in production (e.g. physical capital) and third, 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.[2][3]

A number of papers in the macroeconomic 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 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. 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 de-

[1]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 to capital in production then we would obtain similar predictions.

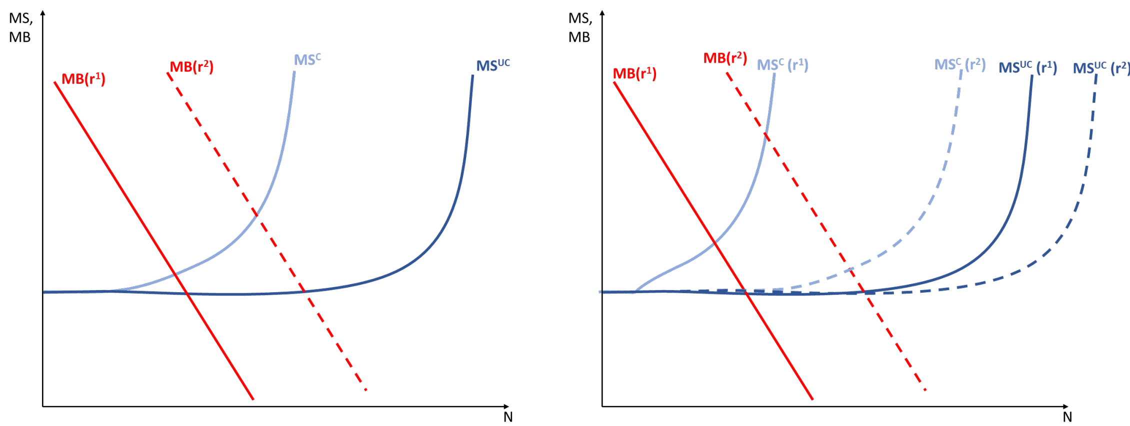
[2]The MB curve is downward sloping due to a production function with decreasing returns to scale in labour.

[3]The sensitivity of firms to these channels, i.e. how much the red curve in Figure 1 shifts, may be heterogenous. Indeed Gorodnichenko and Weber (2016) show that equity value of firms within industries with sticky prices are particularly sensitive to monetary policy shocks. However, to the extent the firms within the same industry face similar demand and input prices, and 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.

gree 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 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.

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

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



The 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.

Testable Predictions 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 described the data used to test these predictions.[4]

3 Firm-Level Data and Research Design

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 companies 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 vary by company characteristics such as size.[5] 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 dependant on asset-based borrowing (Liam and Ma, 2018). Third, firms from all sectors of the economy are covered, in particular, both manufacturing 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 company-*the company directors*-including their name, date of birth, appointment and resignation dates, whether they're a shareholder, and, crucially, their home 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 3.3.

Whilst the BvD dataset has these advantages, a significant limitation is that it's 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

[4]Note also that the theory predicts that an expansionary monetary policy shock reduces 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.

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

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.[6] In effect, our dataset is annual due to the frequency at which firms file their accounts. However, a key 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 Appendix Figure 14, 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.

3.2 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.[7] 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. While this implies that our estimates are conditional on survival, it is worth noting that to the extent that a tightening in monetary policy increases the probability of exit by firms more affected by financial frictions, our results may be interpreted as a lower bound for the heterogeneous effects of monetary policy on employment.[8]

[6]For a thorough description of the archival process followed in the construction of our dataset see Section 2 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.

[7]Specifically we exclude firms of the following types: "Economic European Interest Grouping", "Guarantee", "Industrial/Provident", "Limited Liability Partnership", "Not firms Act", "Other", "Royal Charter", "Unlimited", "Public Investment Trust", thereby ensuring that our sample contains only limited liability firms to which the firms 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).

[8]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%

In Table 1, we present summary statistics for the full sample used in our firm level regressions. Our sample contains 188,184 firm level observations on 37,029 unique firms. The upper panel of Table 1 shows that the median firm in our sample has 52 employees, just above the UK small firm threshold of fewer than 50 employees. Furthermore, the lower quartile of firms have 9 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 reflects an upper tail of relatively large firms, whose average asset value is £92.9 million compared to £3.8 million for the median firm. 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 even dispersion of firm leverage (measured as the ratio of total liabilities to total assets), with a median leverage ratio of 61% and an interquartile range running from 40% to 80%. The table also highlight the geographical dispersion between directors and their firms with 60% of directors living in a different region to their firm and the average director living over 25 miles away. As discussed in Section 3.3, this geographical dispersion is useful for our research design.

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) 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 5.1 we show that being younger and more levered are the best (combined) predictor of a larger employment response to monetary policy shocks.

3.3 Exposure to Collateral Value Fluctuations

In keeping with previous literature, we focus on a number of traditional proxies for the presence of financial frictions such as age and leverage. Relative to earlier studies, however, we also

of aggregate employment in the industries in question and tracks the business cycle dynamics of aggregate employment well (see Figures 12 and 13 in Appendix A.1). Furthermore, age and leverage are commonly used proxies for financial frictions and, as shown in Appendix Table 3, 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.

Table 1: Regression Sample Summary Statistics

Full Sample Summary Statistics				
Variable	**Mean**	**Median**	**25%tile**	**75%tile**
Number of Employees	517	52	9	122
Total Assets (£'000s)	92,893	3,765	834	9,056
2-year Real Asset Growth (%)	2.1	1.5	-2.3	6.2
2-year Employment Growth (%)	1.5	0.0	-1.0	3.9
Age (years)	22	15	6.9	29
Leverage (% assets)	78	61	40	80
Director living in different region (%)	60	100	0	100
Director average distance (miles)	26	10	4.1	26
188,184 Firm-Year Observations on 37,029 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]	28	68	57	47	40	551
Total Assets (£'000s)[a]	2,485	4,794	4342	3234	3149	35362
2-year Real Asset Growth (%)[a]	1.9	1.2	1.5	1.4	1.5	1.4
2-year Employment Growth (%)[b]	2.2	0.8	1.2	1.8	1.6	1.1
Age (years)[a]	6.8	29	21	11	15	20
Leverage (%	70	54	41	79	.61	.61
Director living in different region (	61	58	59	61	58	71
Director average distance (miles)[b]	27	25	27	26	24	39

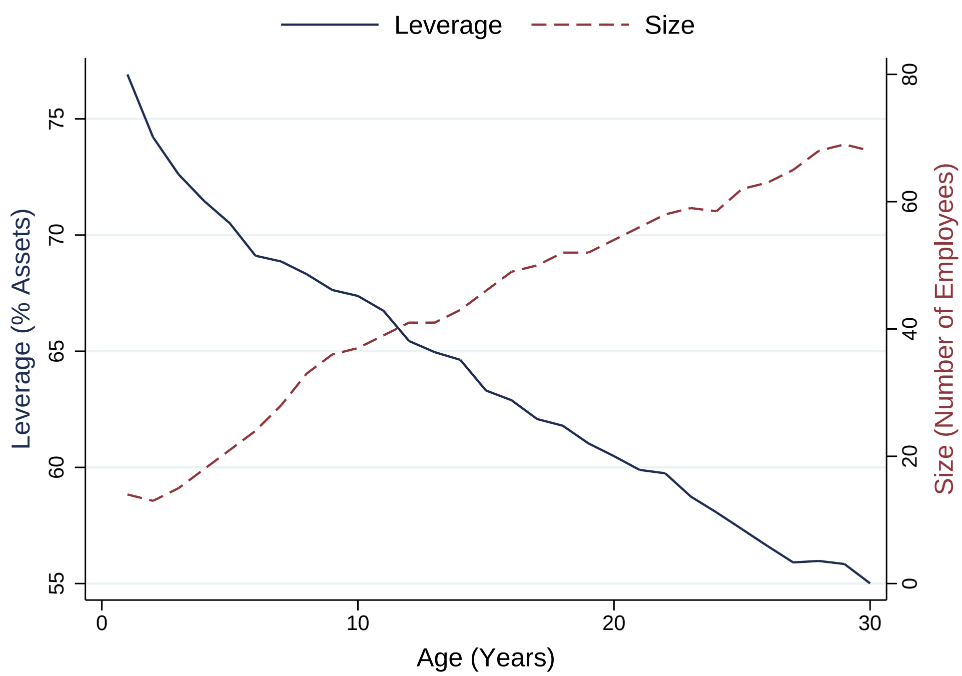
a = median, b = mean

Notes: 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". 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.

exploit variation in the tighteness of financial constraints over the business cycle, by measuring the sensitivity of firms' collateral values to monetary policy shocks.[9] We do this by focusing on real estate, for three main reasons which we exploit and document in this section. 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 further show that the borrowing of younger and more levered companies is particularly dependent on collateral values. Second, monetary policy has a significant effect on real estate prices (JarociÅski 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 collateral values.

[9]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.

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.

3.3.1 The Role of Personal Guarantees

The ideal experiment would exploit variation in the value of a firm's collateral that is independent of its business opportunities. Whilst an increase in local real estate prices leads to an increase in firm activity by relaxing financial constraints (Gan 2007 and Chaney, Sraer, and Thesmar 2012), this is 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.[10] 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 director causes the average firm to add one job (Bahaj, Foulis, and Pinter, 2018). Crucially, over half of the directors in our sample live in a different region to their firm, reducing the correlation between collateral values

[10] 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).

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.[11] There are two key takeaways from the table. First, borrowing against personal guarantees is very prevalent, being used as security by 50% of firms. Second, there is significant heterogeneity across firms. In Section 5.1, 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 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 groups 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.[12]

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	52%	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.

[11] 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.

[12] 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.

3.3.2 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 the 172 regions in England and Wales, using the Land Registry's monthly repeat sales house price index from 1995-2016.[13] 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. To compute a firm-level measure of house price sensitivity to monetary policy, we average the estimated responses across the regions where each of the firm's directors live. In Appendix Figure 16, we report the correlation between the sensitivity of a firm's region with the average sensitivity of its director's regions, broken down by the average distance between the firm and its director's houses.[14] Across all firms, (first bar on the left) the correlation is 75% but it falls substantially as the average distance increases. For a quarter of firms, their directors live an average of at least 30 miles away (see Table 1) and the correlation is below 40%. We exploit this low correlation in a robustness test below.

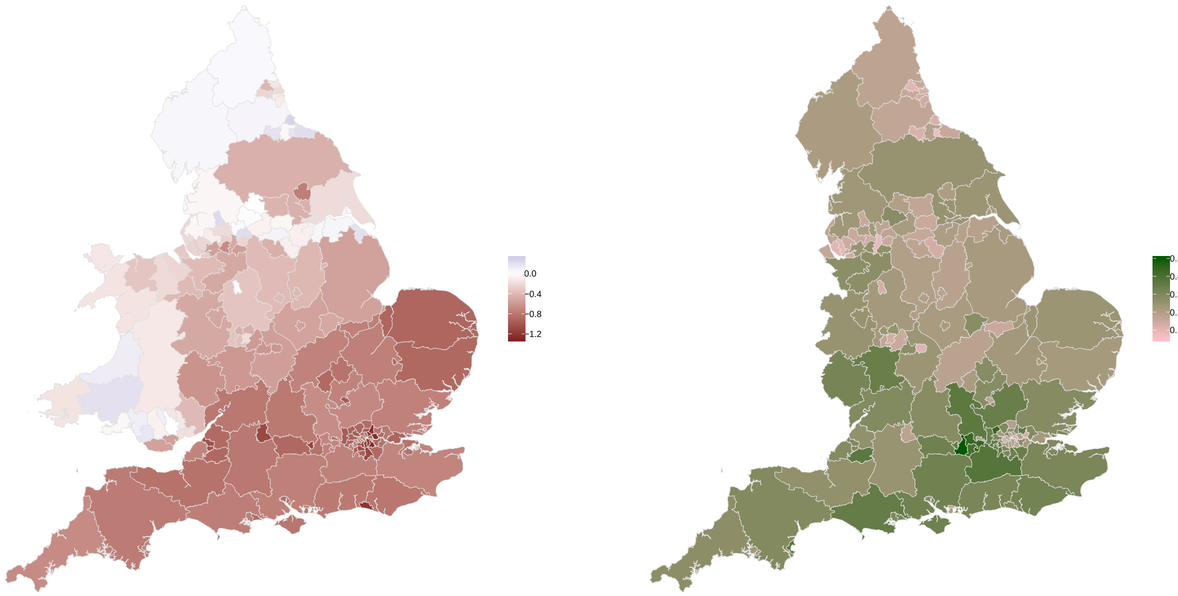
We consider two alternatives to this baseline approach. First, we calculate a measure of housing *exposure*, which interacts the house price sensitivity of a director's region with the *value of their house*, before summing across all directors at a firm.[15] This adds an additional source of variation: 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. Second, as an alternative to these model-based estimates of house price sensitivities, we use a regulation-based measure: the regional refusal rates of planning applications for residential projects, taken from Hilber and Vermeulen (2016). The idea is that the increase in housing demand associated with an expansionary monetary policy shock will be translated into a greater increase in housing prices in regions with a greater refusal rate, as the housing supply response will be weaker. Appendix A.3 describes the data on refusal rates in greater detail. The right panel of Figure 3

[13] Appendix A.3 describes the estimation procedure in detail. 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 further details on the Land Registry's repeat sales house price index see http://pro.landmarkanalytics.co.uk/Land-Registry-House-Price-Index-Methodology-1995.pdf. The house price sensitivities are not calculated for Scotland as the regional house price indicies do not exist prior to 2004.

[14] 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%.

[15] To estimate the value of a director's house we match 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. For a detailed discussion of this matching procedure see Online Appendix 4 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.

Figure 3: Regional Variation in House Price Sensitivity 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 summarized by the point estimates at the two-year horizon. 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.

demonstrates substantial regional variation in refusal rates.[16] Both measures of regional house price heterogeneity in Figure 3 record higher (absolute) values in the South. In a robustness check of Section 7, we will confirm that our results are not driven by a handful of southern regions or the Greater London area.

4 Empirical Framework

In this section we describe the identification strategy used to isolate 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.

4.1 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,

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

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.[17] To convert the surprises to a monthly variable, they sum all the surprises within the same month. The monthly series is plotted in Figure 17 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.[18]

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) for the same industries covered by our firm level data. This is to obtain a comparable aggregate benchmark for the employment response to a monetary policy shock.

The F-statistic from the regression of the VAR residuals on the proxy is 12.2. This is, in effect, the first stage regression of our empirical model and the F-statistic represents the most conservative measure of instrument relevance. 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 Gerko and Rey (2017) series.

Figure 19 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.

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

[18] 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 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.

4.2 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 are 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:

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

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.[19] 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 4.1.[20]

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. $\Delta r_t = 25bp$), allowing direct comparison with the aggregate employment results in Figure 19.

[19] 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.

[20] We can also estimate an over-identified model using the 12 shocks that occur over the firms accounting year as separate instrument. However, this is computationally intensive and the results, available upon request, for our main specification are near identical.

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

$$ln(EMP_{t+h,i}) - ln(EMP_{t-1,i}) = \delta^h_{j,s} + \gamma^h_{l,s} + \sum_{g=1}^{G} \tilde{\alpha}^h_g \times Dg_{i,t-1} + \sum_{g=1}^{G-1} \tilde{\beta}^h_g \times Dg_{i,t-1} \times \Delta r_t + v^h_{i,t}. \quad (2)$$

In this context, $\delta^h_{j,s}$ 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, $\gamma^h_{l,s}$ 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 focus on the specification in Equation (2) when conducting inference over differences between groups both because estimation uncertainty over the linear effect of the shock is absorbed and because the fixed effects enable tighter identification of the mechanism of interest. Since the linear effect of Δr_t is absorbed by the time fixed effects, the term $\tilde{\beta}^h_g$ 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 $\tilde{\beta}^h_{g_1} = \tilde{\beta}^h_{g_2}$.

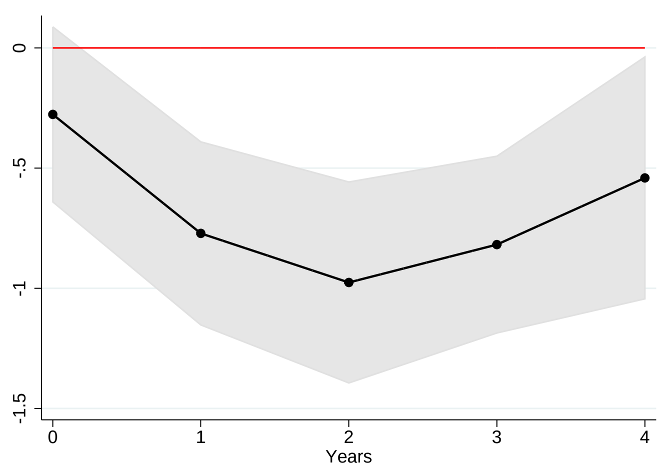
When constructing cumulative growth rates, $log(EMP_{i,t+h}) - log(EMP_{i,t-1})$, we (i) omit observations in the 99th and 1st percentiles of observations in order to prevent outliers distorting the results, (ii) omit observations where any accounting period in the window between $t-1$ and $t+h$ is not 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 from 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. 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 (see Figure 22 in the Appendix). For the same reason it is not necessary to include firm level 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 23 in the Appendix, which shows a similar if slightly larger employment impact, though the effect of monetary policy on firm level employment is more persistent.

4.3 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.[21] Our results suggest that the contractionary shock brings about a 0.3% decline in firm-level employment on impact[22], 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 before the recovery starts. Importantly, we can compare these firm-level employment responses to the aggregate responses in Figure 19. The aggregate response displays a very similar hump shaped pattern but the size of the effect is diminished. The simple explanation for this discrepancy is that the aggregate response is effectively equivalent to the employment weighted average response rather than the simple average across firms. Indeed, if we run the employment-weighted firm-level response, the peak impact on employment is -0.6%, which is very similar to the aggregate response. The next sections turns to heterogeneous characteristics that affect the firm-level response to monetary policy shocks.

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.

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

[22]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.

5 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. Section 6 then examines the response of several firm balance sheet variables, including net worth and borrowing, to shed further light on the transmission mechanism of monetary policy to firm employment, through collateral value fluctuations and borrowing constraints.

5.1 Employment Responses by Firm Characteristics

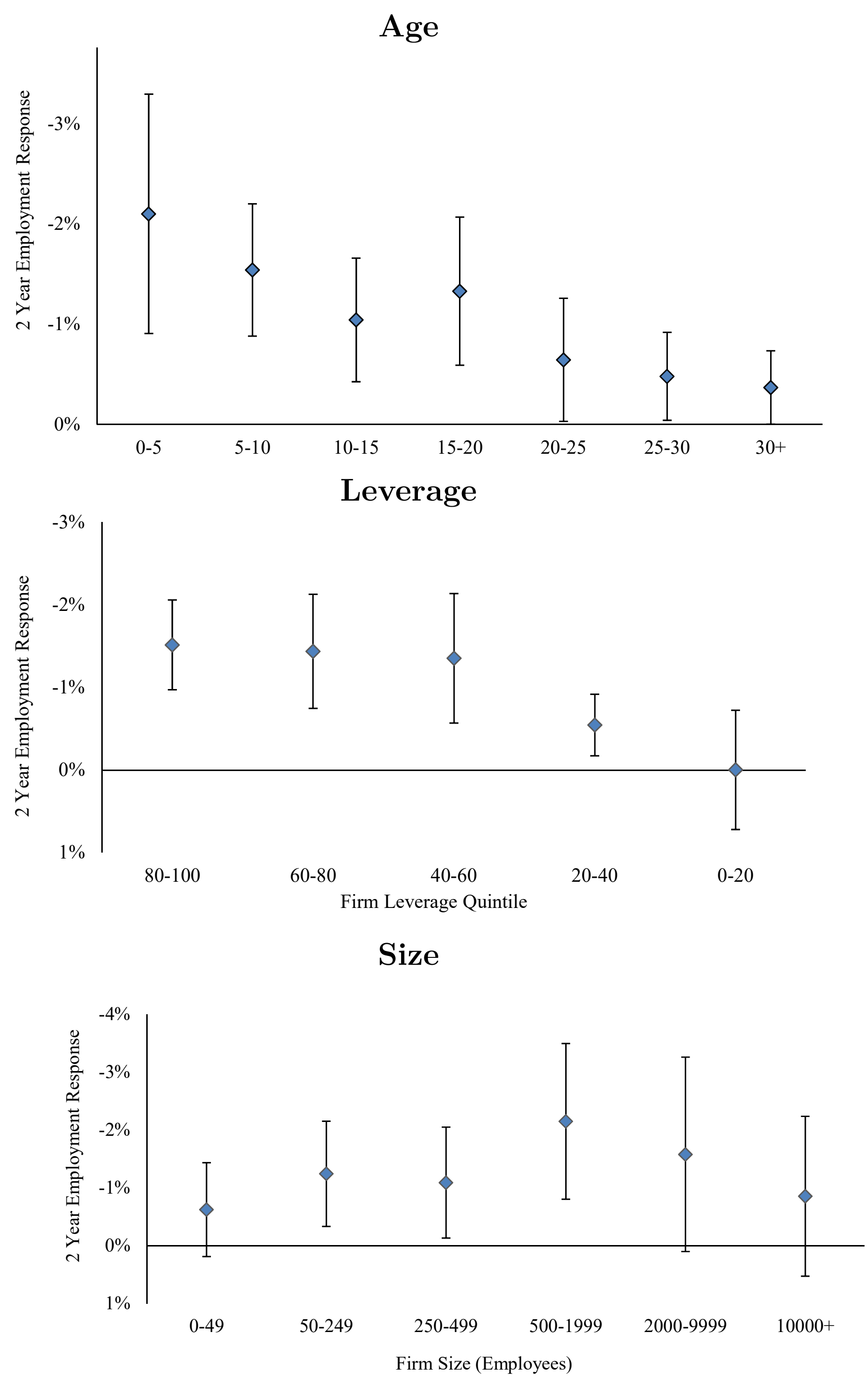
Figure 5 shows the two year employment response cut by alternative firm age, leverage, and size groups (for the full dynamic responses see Figures 24, 25, and 26 in Appendix E). Starting with age on the top row, we find that firms established less than five years prior to the monetary policy shock clearly respond the most whereas the oldest firms (more than 30 years old) respond the least. 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 very 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;[23] 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

[23] Crouzet and Mehrotra, 2017 don't categories 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.

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



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.

more responsive over the business cycle.[24] Moreover, Figure 5 shows that among among SMEs

[24]Kudlyak and Sanchez (2017) find that, following the financial crisis of 2008, the sales and short-term

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 higher-levered (above the median in a given year) and lower-levered (below the median in a given year) firms. In a balancing act between exploring 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.

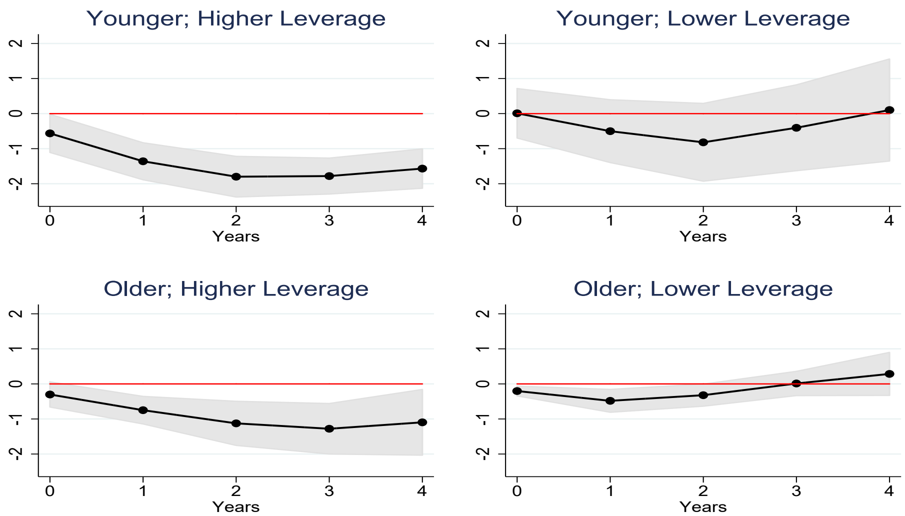
The result of the double cut by age and leverage is reported in the four panels of Figure 6a. The top (bottom) row refers to the younger (older) group whereas the most left (right) column represents higher-levered (lower-levered) firms. A comparison of the IRFs across columns highlights the marginal 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, lower-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 higher-leveraged 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

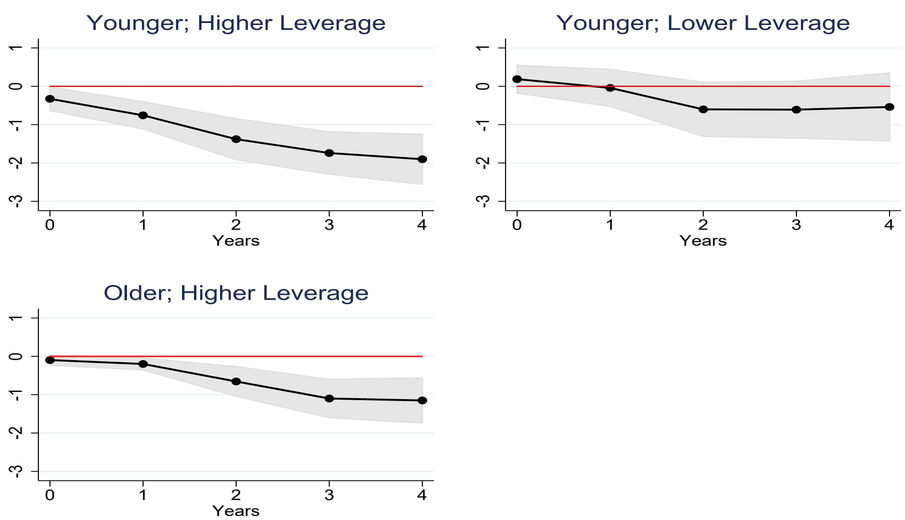
debt of large firms contracted much more than for small firms. Updating the dataset of Gertler and Gilchrist (1994), Chari, Christiano, and Kehoe (2013) find that the response of small and large firms are similar following recessions. Moscarini and Postel-Vinay (2012) find that large firms contract employment 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.

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.

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 companies 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 appears then responsible for about half of the peak average employment response to monetary policy shocks. By contrast, whilst the older and lower levered firms represent over 30% of employment, they account for less than 10% of the peak employment response.

How the contributions to the *average* response in Figure 4 map into contributions to the *aggregate* response depends upon what one assumes about the behaviour of firms that do not report employment. In the Appendix, we show that –on average– non-reporting companies tend to be even younger and more levered that reporting ones, suggesting that the 50% contributions to the average response computed above is most likely a lower bound for the contribution of the group of younger and more levered firms to the aggregate response. Under the extreme (and arguably implausible) assumption that non-reporting firms do not adjust their employment at all following a monetary policy shock, the contribution of younger and more levered firms to the aggregate response would still be a significant 20%. Finally, in the intermediate case in which the composition of non-reporting firms is not dissimilar from the composition of companies reporting their number of employees, then the contribution of 50% to the average response for this group will coincide with their contribution to the aggregate response.

5.2 Employment Responses by Regional House Prices Sensitivity

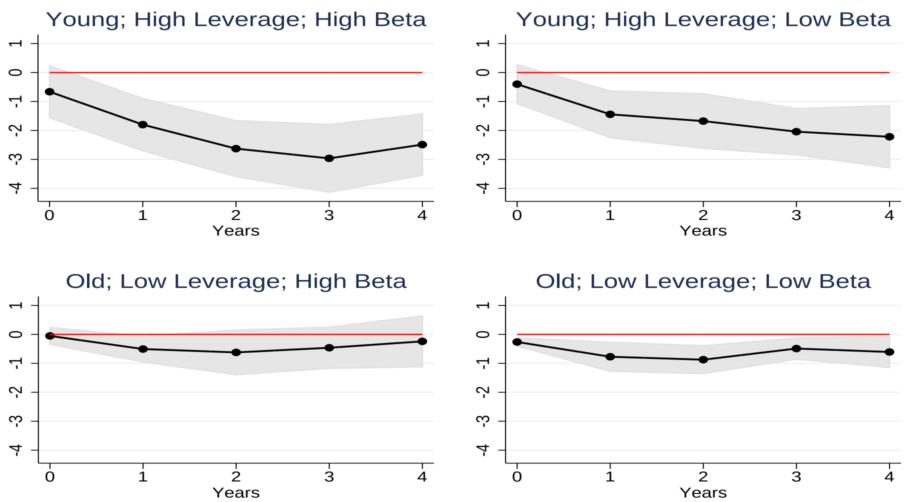
As described in Section 2, if financially constrained firms respond *more* to monetary shocks this implies a key role for collateral constraints and asset price fluctuations. In this section, we exploit regional heterogeneity in the sensitivity of real estate values to monetary policy shocks and ask: 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. 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.

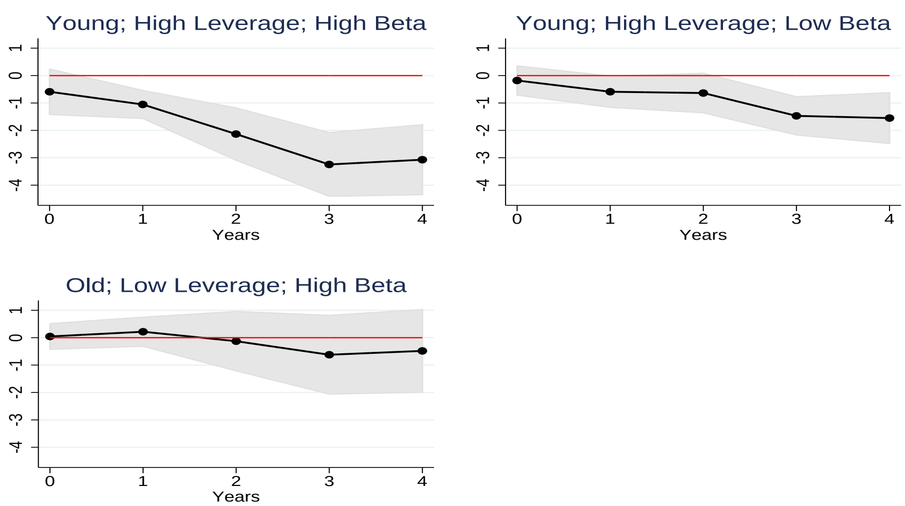
Three main findings emerge from Figure 7. First, our key result: among younger, higher-levered firms (the top row in Figures 7a--7b), the employment of firms with directors living in high sensitivity regions (left column) contracts more than the employment of similar firms whose directors are located 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 in more sensitive regions experience a employment response approximately 1-1.5 percentage points greater than firms with directors in less house price sensitive regions. Appendix A.3 shows that the magnitude of this differential response is consistent with prior firm-level estimates of the impact of director house values on firm employment (Bahaj, Foulis, and Pinter, 2018) and the estimated difference in house price responses between high and low beta regions. Formal hypothesis tests based on the coefficients in the top row of Figure 7b yield p-values of less than 1% at 2- and 3-year horizons. This finding is consistent with the prediction that monetary policy transmission partly works through altering the collateral value of financially constrained firms.

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

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, high 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 financial constrained.

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 whether the firm's 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 are very similar to our baseline case (Figures 52 and 53 in Appendix G.1). Specifically, the formal hypothesis testing of Figure 53 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, thereby corroborating the heterogeneity uncovered in Figures 7 and 7b based on the estimated regional house price sensitivity sample split.

5.3 Identification: Local Demand and Director Characteristics

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. 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 demand on firms' behaviour.

In our baseline regressions, the definition of the region is at the NUTS-1 level, which is relatively coarse. In Figure 27 of the Appendix, we add region-year 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 level, 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.

The region-time fixed effects only capture the average responsiveness of firms to local demand. Firms may have heterogeneous responsiveness to shocks to local demand generated by monetary policy; for example, young firms with a less established consumer base may be more affected. This may also explain our results. To address this we augment the baseline specification by interacting the firm age-leverage buckets with the house price beta of the *firm's* region, including these linearly, and interacted with the monetary policy shocks.[25] Figures 28–29 of Appendix F.2 show that the house price sensitivity of the directors' regions has a significant effect on the employment responsiveness of young, high leverage firms, even while allowing for firms of different ages and leverage ratios to respond differentially to the house price sensitivity in the firm's region (and any associated local demand effect).

To further address this concern, we can exploit the fact that some directors live far away from their firms. In Figures 30–31 of Appendix F.3.1, 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 16, 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 under 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.

To 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 in order to support the firm. Hence if the collateral channel lies behind the heterogeneous response of employment to 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. 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 32–33 of Appendix F.3.2 (for shareholder directors) and Figures 34–35 of Appendix F.3.3 (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.[26]

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

[25]The spatial separation of firms and directors makes this specification possible: if all directors lived in the same region as their firm we would not be able to separately estimate the effect of the directors' and firm's betas.

[26]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.

and house price sensitivities in the directors' regions if the relative locations of the director and the firm reflect local patterns of commuting.[27] To further ensure that local demand spillovers are not driving our results, in Figures 36–37 of Appendix F.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).[28] 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.

These additional results 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: directors living in high-beta regions may be inherently different and run different types of firms. Whilst the shareholder results show that director location does not matter *per se*, it may be that directors who also own the firm have a greater say in how it is run.

One specific 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 38 and 39 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. To address this concern we saturate the regression with a large number of director characteristics, capturing their age, experience, and directorship history.[29] We average 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 40–41 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.

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

[28]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.

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

5.4 Identification: Bank Lending Channel

Another threat to the identification of the collateral channel of monetary policy is the behaviour of banks. Monetary policy can also affect banks, and our results could be confounded if bank lending to different types of firm 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 banks that are regionally specialised in the region where the director lives, the sensitivity of bank credit supply to monetary policy shocks could be correlated with the house price sensitivity of the director's region.

This concern may be less relevant for the U.K., 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. Nevertheless we address this concern using information on the identity of lenders: for companies 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-combination x year fixed effects[30] in the regression to control for any effects that may be due to bank credit supply.[31] The results, shown in Figure 42 of Appendix F.7, are similar to the baseline estimates.

Including bank-time fixed effects just removes the average impact of bank behaviour on firms in a given year. 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). Figure 43 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.

As a final test to differentiate between the bank lending channel and the collateral channel of monetary policy, we exploit information on the value of *individual director homes*. To do this, we use the methodology described in Section 3.3 to compute a measure of housing *exposure* to monetary policy shocks, interacting the individual house value with the regional sensitivity to monetary policy shocks. We would expect a regional bank lending channel to be more sensitive to the average response of regional house prices; by contrast a collateral channel running through the houses of company directors should be more sensitive to the housing exposure of their individual houses. As shown by Figures 44–45 in Appendix F.9, when firms are split by the exposure of their directors' houses to monetary policy shocks, there is greater heterogeneity for

[30]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.

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

young, high leverage firms, with a peak difference at the second and third horizons of around 2pp (as compared to 1.5pp in the baseline). This provides further corroborating that it is the sensitivity of the house prices of individual directors to monetary policy shocks that matters.

5.5 Identification: Director Cash Flow

In the U.K. monetary policy shocks can have a direct impact on the cash-flows of many individuals, due to the prevalence of variable rate mortgage contracts. Such a cash-flow effect on company directors could also affect the employment decisions of their firms. This could also be correlated with the regional house price responsiveness to monetary policy shocks: regions with a greater proportion of individuals on variable rate mortgage contracts could experience a greater change in local demand and house prices.

However, the size of these cash-flow shocks on company directors are 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-flow 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 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.

Beyond these considerations on magnitude, we can also proxy for the size of director cash-flow shocks due to monetary policy, by merging director information with administrative mortgage data from the UK.[32] The most natural experiment would be to compare the share of directors on fixed vs variable rate mortgages. However, in the U.K., 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 both use directors' average mortgage size, and mortgage size relative to average salary,[33] 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

[32] 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.

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

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 46–47 (average director mortgage size) and Figures 48–49 (average director mortgage to income), our baseline results are robust to controlling for these director cash-flow proxies. As a final test, in Figures 50–51 we proxy director cash flow with the average share of properties in the director's region bought with a mortgage, with similar results.

5.6 Summary

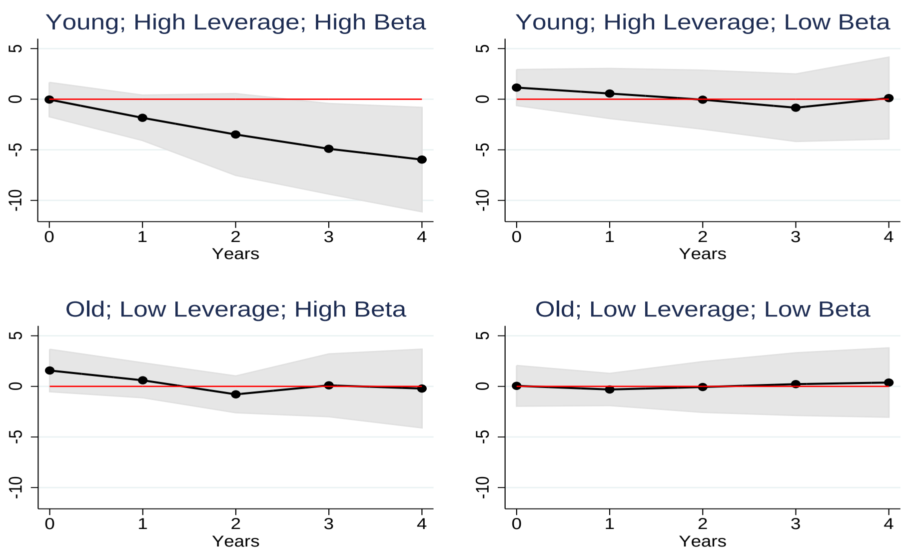
In this section, we have shown pervasive heterogeneity in the employment adjustment to monetary policy across firms. More specifically, we have documented that younger and more levered companies are characterized by a significantly larger response and account for about half of the movement in aggregate employment following an interest rate change. The estimated heterogeneity is even more pronounced when we focused on younger and more levered firms whose directors live in a region with a higher house price sensitivity to monetary policy or with a higher planning application refusal rate. Furthermore, we have been able to rule out heterogeneity in local demand, the bank lending channel, and director cash-flow effects as the driver of the observed heterogeneity in the employment responses, using a number of alternative strategies. Of course, these findings do not imply that these other channels have no effect in 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. The next section uses a number of other firm-level variables to further explore the collateral channel.

6 Further Exploration of the Mechanism

In this section, we dig deeper into the data and consider alternative left-hand-side variables at the firm-level, which allows us to sharpen our understanding of the mechanism generating the heterogeneity in our baseline results. We consider four different accounting variables: the firm's indebtedness, the value of its current assets, the value of its fixed assets, and its turnover.

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 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 8, 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 8 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 region compared to similar firms whose directors live in low sensitivity regions. Figure 74 in the Appendix shows the same model with the time fixed effects.

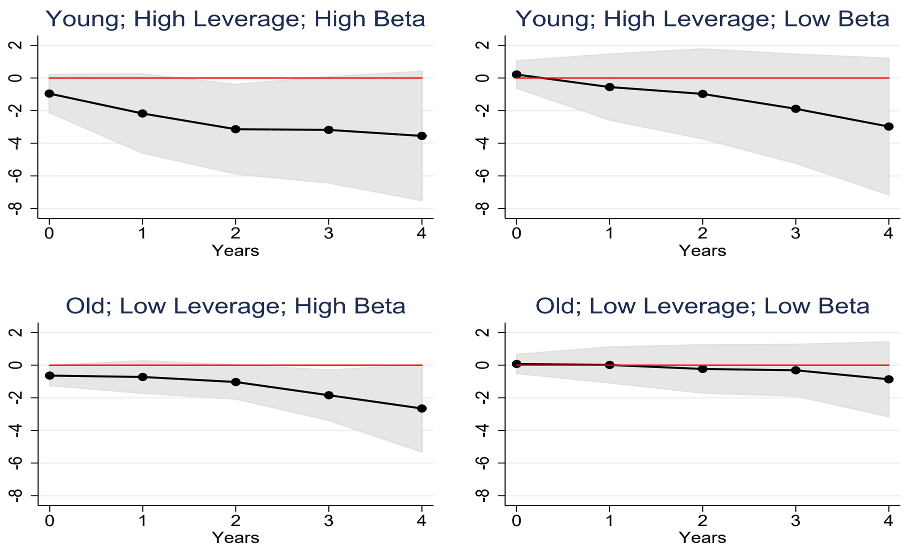
Figure 8: Level Effects on Total Debt by Age, Leverage and Director Beta, Triple Sorted



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.

Current Assets 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 is recorded as current assets in the firms' accounts. If our results partially reflect a collateral driven working capital constraint, we would expect that firms whose employment is particularly responsive to monetary policy shocks should have particularly responsive current assets. In Figure 9, we explore this by altering our left-hand-size variable, replacing employment growth with current asset growth (with the relative effects shown in Figure 75 in the Appendix). The results again confirm that current assets of younger more levered firms, whose directors live in high house price sensitivity regions, respond the most.

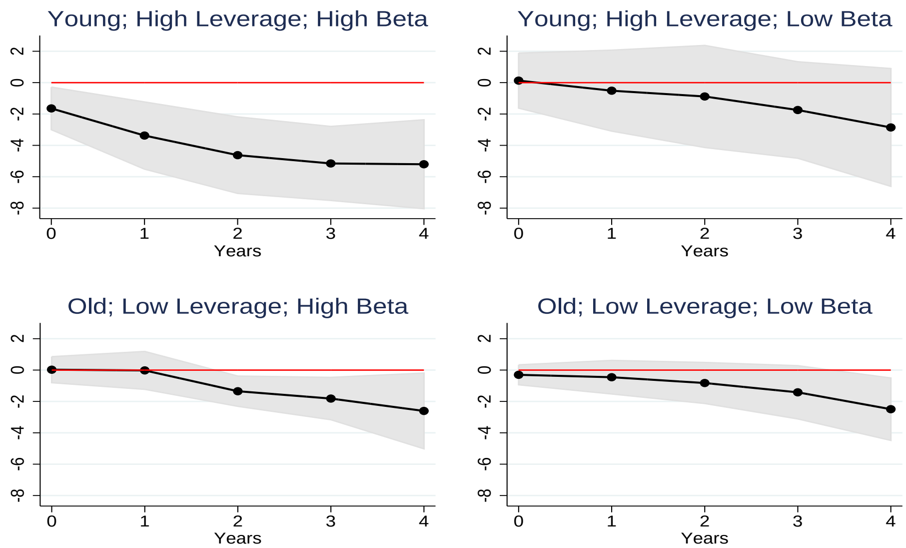
Figure 9: Level Effects on Current Assets by Age, Leverage and Director Beta, Triple Sorted



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 Current 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.

Fixed Assets However, 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' hiring. 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 10 we use the cumulative growth of fixed assets as a left-hand-side variable (with the relative effects shown in Figure 76 in the Appendix). Again, we find that the patterns of heterogeneity in the investment response maps that of our baseline employment response.

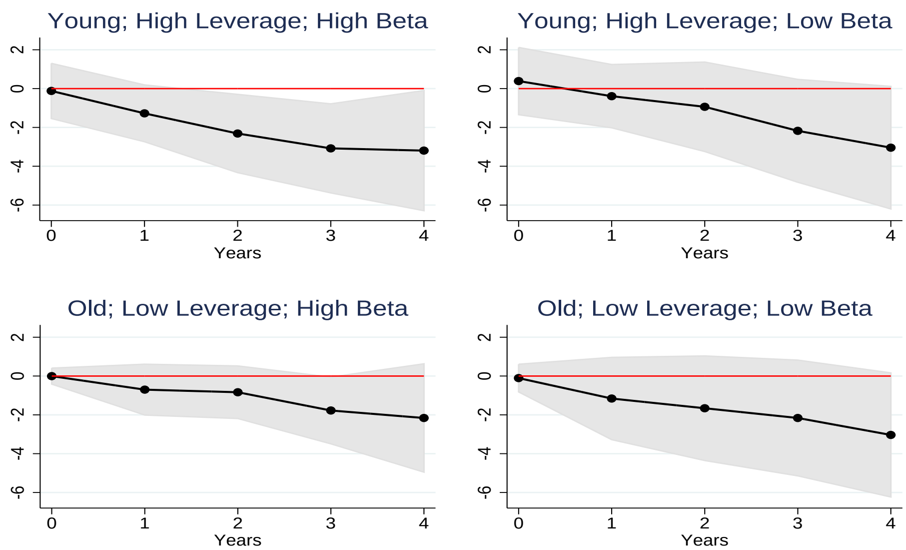
Figure 10: Level Effect on Fixed Assets by Age, Leverage and Director Beta, Triple Sorted



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.

Turnover Last, we argued in Section 5.3 that our results are not driven by heterogeneity in demand conditions. To further reinforce this finding, 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. Figure 11 shows that monetary policy shocks have a significant effect on turnover across all firm groups (relative effects shown in Figure 77 in the Appendix), consistent with a decline in aggregate demand. Yet, there is no obvious 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.

Figure 11: 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.

Summary In this section, we have explored further the mechanism through which monetary policy affects firm-level employment via the housing collateral value. More specifically, we have 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 employment and whose prepaid expenses among current assets (which feature prominently wage bills) respond the most to interest rate changes. In contrast, the adjustments in sales after a monetary policy shock are more homogenous across firm groups, suggesting that aggregate demand effects are unlikely to account for the heterogeneity documented in Section 6.

7 Sensitivity Analysis

In Appendix G, we subject our main result from Section 5.2 to an extensive range of robustness analysis. To preview the results, no alternative cut of the data overturns our findings.

As with the linear model, adding firm controls has little effect on either the point estimates or the error bands (Figures 54 and 55). As discussed in Section 4, it is not necessary to add firm fixed effects due to the orthogonality of the monetary policy shock. It is also demanding of the data as it involves estimating firm-specific trends in employment growth for each horizon.

Nevertheless, in Figures 56 and 57, we estimate the level and relative models also including firm fixed effects, resulting in very similar estimates to the baseline model and a clear economic and statistical difference between the employment response of younger, higher leverage firms whose directors live in more and less house price sensitive regions.

Firms also borrow using their own commercial real estate as collateral (Chaney, Sraer, and Thesmar, 2012), hence we can consider heterogeneity in the house price sensitivity of the firm's region. This is less well-identified and we can not use region-time fixed effects. However, cutting the data on this dimension (rather than on our baseline specification using the directors' region), and restricting to firms in the tradables sector to mitigate local demand concerns, gives similar results (see Figures 58 and 59 in Appendix G.4).

One may be concerned with what is being captured by our monetary policy shock. One concern is that our results could be driven by the period when interest rates were stuck against the zero lower bound. In Figures 60–61 of Appendix G.5, 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 5.2. 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 the central bank rather than a random fluctuation in interest rates (see 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 sum of 4-quarter ahead forecast 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 62 and 63, 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 64 and 65, 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.[34] Figures 66–67 confirm that the pattern of heterogeneity along the dimension of

[34] 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

collateral price sensitivity continues to resemble our baseline when using credit score in place of leverage. Finally, 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. 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 68–69 in Appendix G.9.

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 70 and 71 in Appendix G.10. 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, and included linearly, and interacted with the monetary policy shock. As shown by Figures 72 and 73, the baseline results are robust to the inclusion of this additional control.

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

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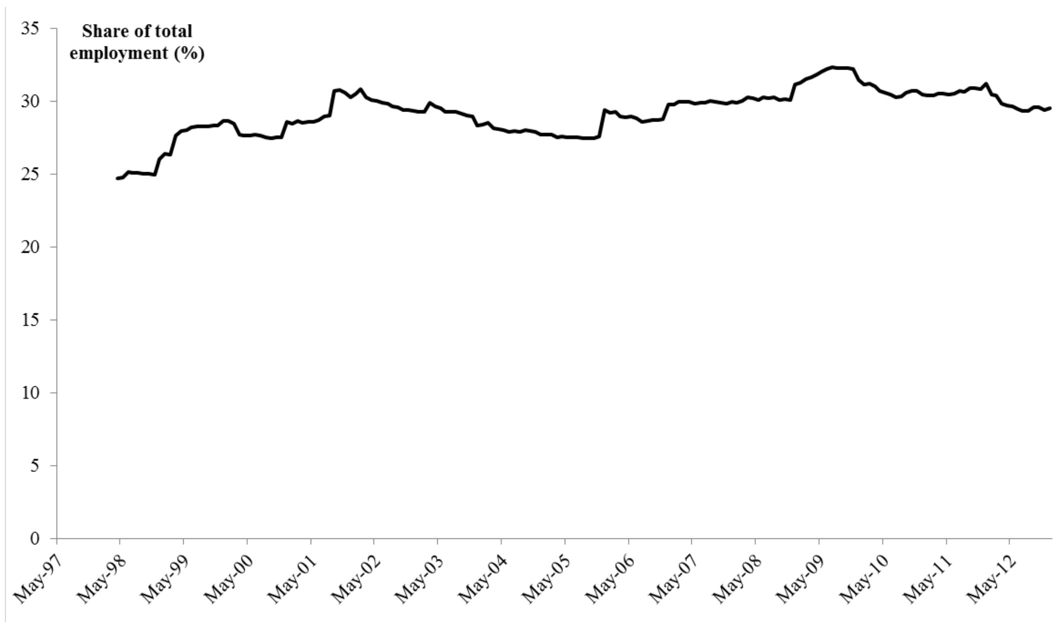
Appendix

A Data Construction and Sample Selection

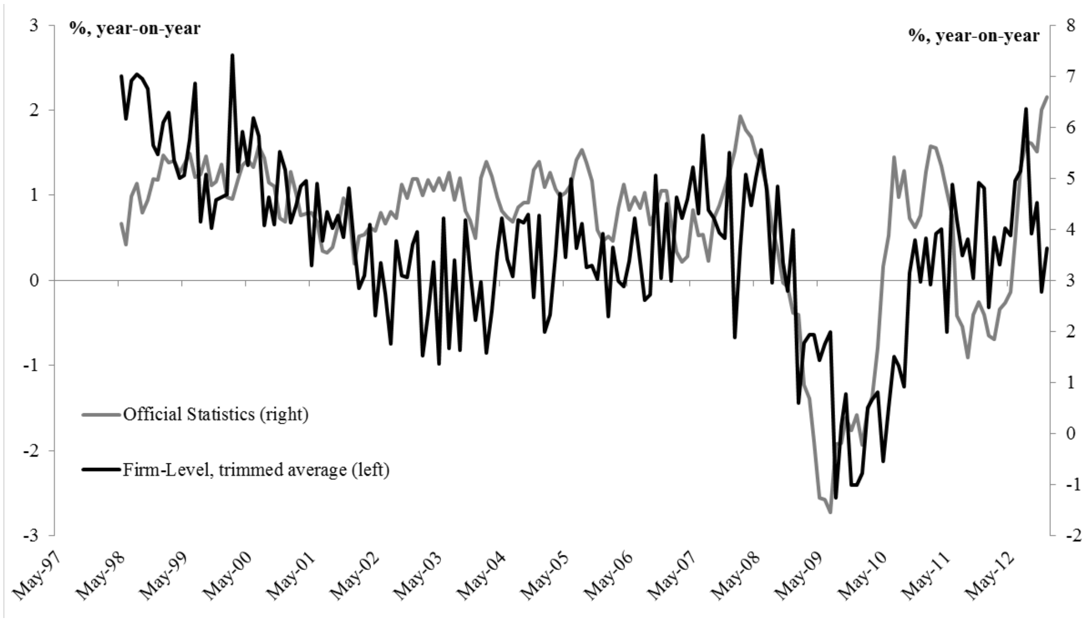
A.1 Sample Selection

Figure 12: Sample Coverage of Total Employment



Notes: The figure presents the share of aggregate employment (from the same industries, sourced from the ONS) from the firms in our regression sample. The exact calculation is the rolling sum of employment who filed accounts in the past 12 months over aggregate employment in the month.

Figure 13: Employment Growth at the Firm and Aggregate Level



Notes: The figure presents the aggregate employment growth (year-on-year, from the same industries, sourced from the ONS, grey line right) against the unweighted average (trimmed at 1/99%) employment growth of firms in the regression sample that file in the same aggregate month (black line, right).

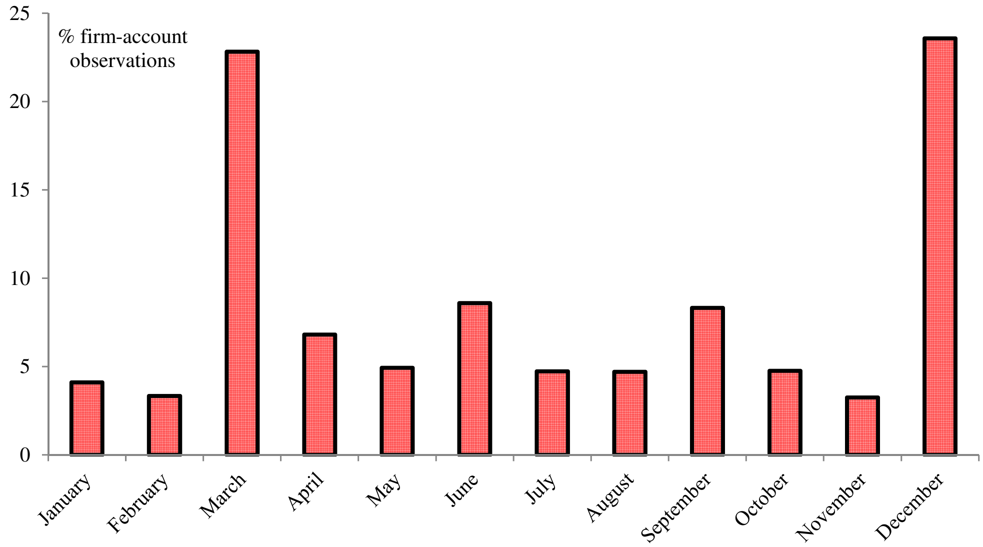
Table 3: Summary Statistics of Firms That Do and Do Not Report Employment

Summary Statistics				
	Age (Years)		Leverage (% Assets)	
	Mean	**Median**	**Mean**	**Median**
All Firms	7	4	93	77
Regression Sample	22	15	78	61

Notes: Age is defined as the number of years elapsed from the date of incorporation date. 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. The second row presents summary statistics for the firms in our baseline regression sample. This includes the additional restriction that firms report employment growth over a four year horizon.

A.2 Filing Months

Figure 14: Distribution of Filing Dates by Month



Notes: The Figure presents the distribution across months in which firms file their accounts.

A.3 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:

$$\log(P_{t+h}) - \log(P_{t-1}) = a + \beta^h \times MP_t + controls_t + \varepsilon_t^h, \tag{3}$$

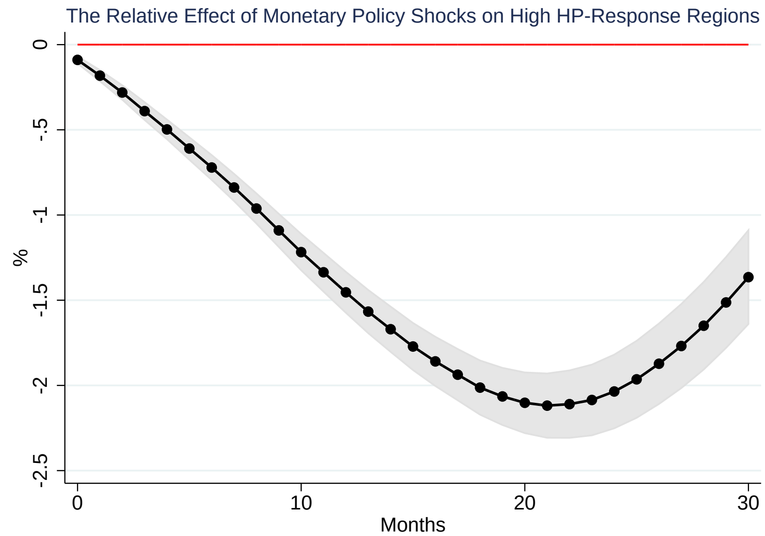
where h is the horizon (in months) over which the local projection model is estimated, and P_t is a monthly repeat sales real estate price index, obtained from the Land Registry's Price Paid dataset, covering 172 regions in England and Wales.[35] As controls, we include a linear and a quadratic time trend. For each region j, we estimate 3 up to horizon $h = 24$, and sum the estimated βs to obtain a region-specific measure of house price sensitivity:

$$B_j = \sum_{i=1}^{h} \beta^i. \tag{4}$$

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

[35] As mentioned in the main text the one area omitted is the *Square Mile* financial district in London, in which there is very little residential property and no house price index is calculated.

Figure 15: The Relative Response of House Prices to Monetary Policy in High-Sensitivity Regions



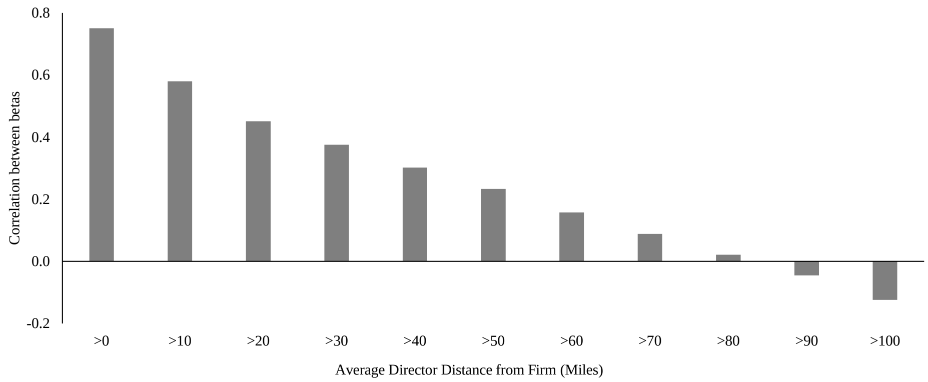
Notes: Regional house prices responses to a contractionary monetary policy shock that raises the five-year interest rate by 25bps on average over a year. Black lines are point estimates. The graph shows the effect on the top tertile of house price responsive regions, relative to the bottom tertile. The 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.

$$\log\left(P_{j,t+h}\right) - \log\left(P_{j,t-1}\right) = a_j + \mu_t + \beta^h \times D_j^{HP} \times \Delta r_t + \varepsilon_t^h, \tag{5}$$

where the subscript j denotes the region $(j = 1, 2, \ldots, 172)$, a_j is a region fixed effect, μ_t is a time fixed effect, D_j^{HP} is a dummy variable taking value 1 if the given region has a high (top tertile) value of B_j (as given by Equation 4), and Δr_t is the annual change in the interest rate, instrumented by the sum of monetary policy shocks over the previous year. Figure 15 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. 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 financial accelerator mechanism.

We can combine these number with prior research to corroborate the baseline estimates. Bahaj, Foulis, and Pinter (2018) use firm-level data and individual director housing price data to estimate the impact of an increase in director home values on firm employment. They estimate that the contemporaneous effect is that an extra £1.1m of combined director real estate leads to a net employment increase of one worker, within the first year. This effect increases through time, and extending this estimate, after three years, an increase of £147k in the value of director real estate leads to the net addition of one worker. The median total

Figure 16: Correlation between Firm and Director Betas

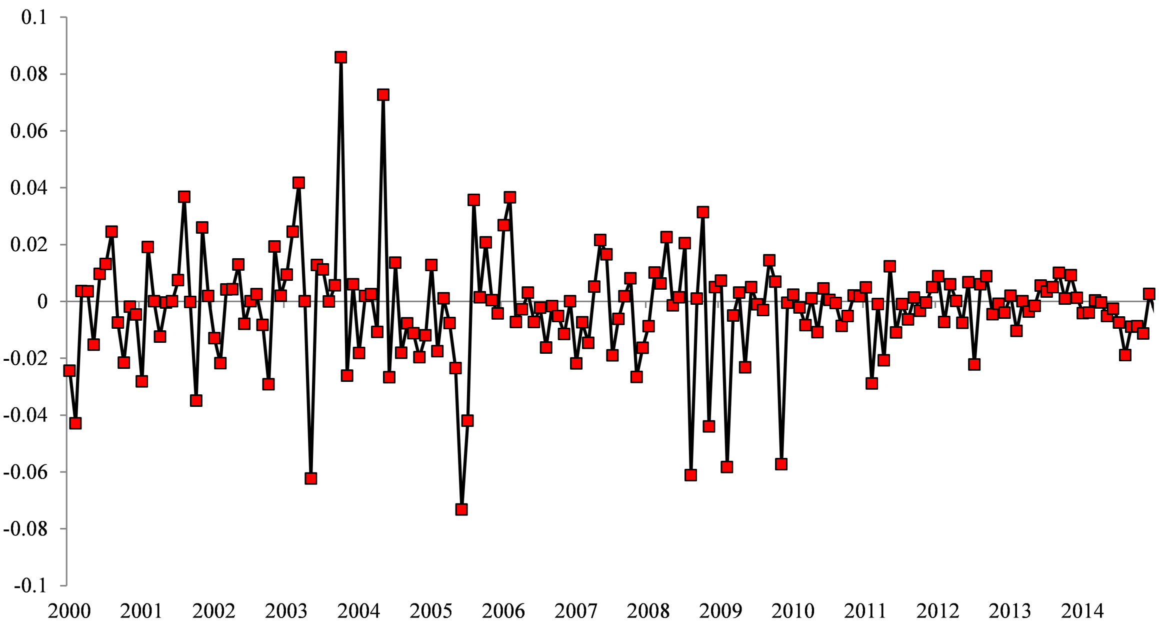


value of director real estate for the firms in our regression sample is £1.5m. Using the estimate above, a 25bps increase in interest rates on average for a year will result in the peak increase in real estate values being £31.5k higher in high beta than low beta regions, leading to the hiring of around 0.2 of a worker. The median young firm in our sample has 28 employees, so this amounts to an employment differential of around 0.8pp between high and low beta regions, which is of a similar order of magnitude to the difference in the baseline estimate in Figure 7a.

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. 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.

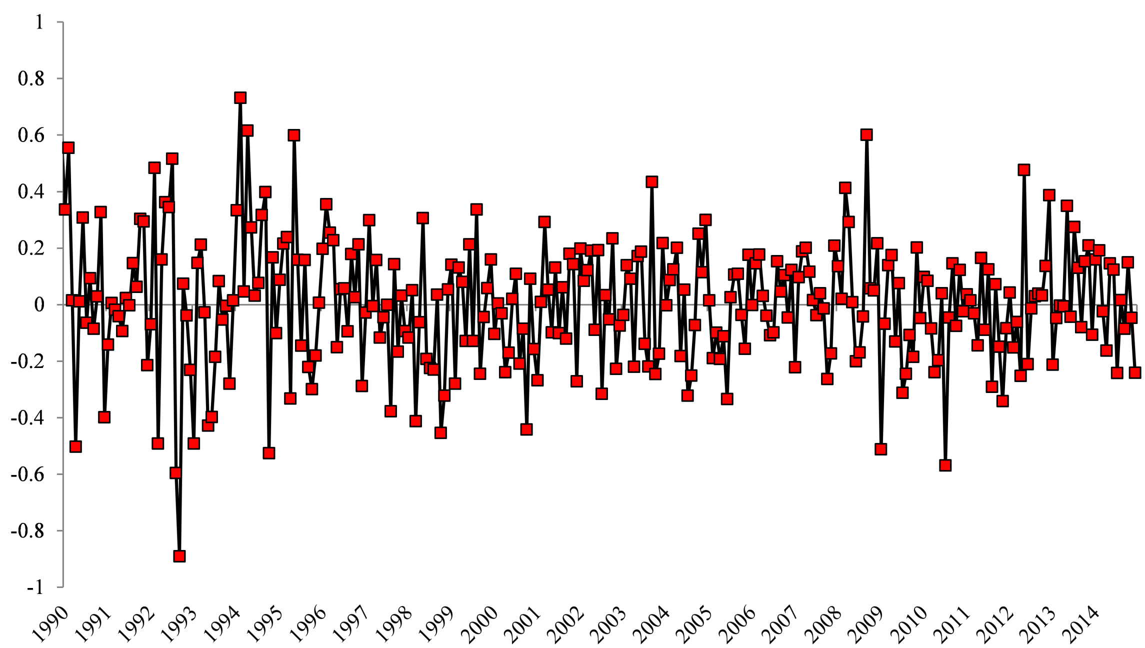
B Monetary Policy Surprises and VAR Macro Evidence

Figure 17: The Gerko-Rey instrument for UK monetary policy shocks



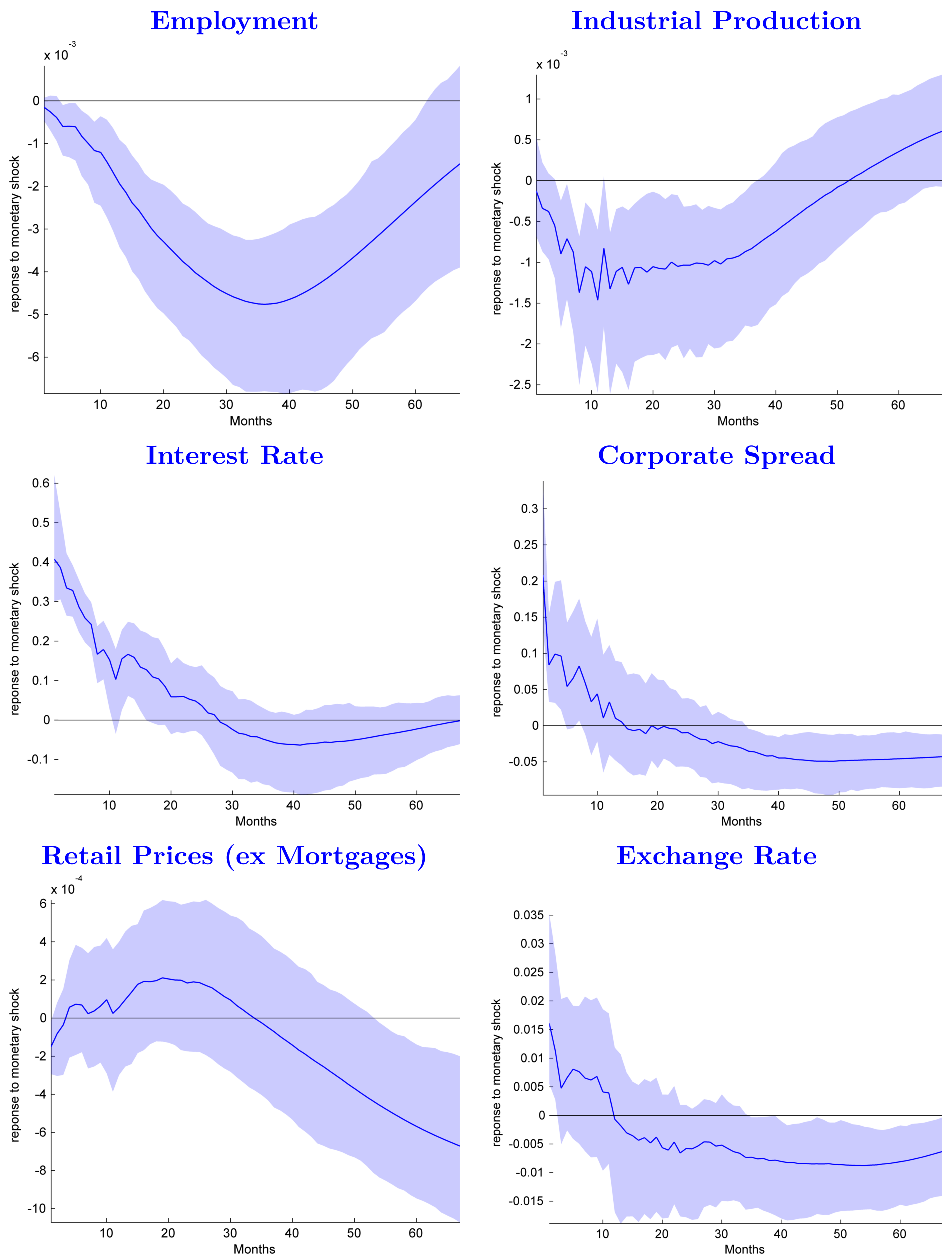
Notes: Instrument for monetary policy shocks from Gerko-Rey (January 2001 to March 2015). The time series is the raw market surprises to monetary policy announcements. The y-axis can be interpreted as changes in an interest rate.

Figure 18: 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 19: 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, this 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_tL^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 $b_t = max\{w_tN_{i,t} - W_t^i, 0\}$ 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 ($w_tN_t^i - W_t^i > 0$), creditors demand an additional spread $\lambda(b_t, q_tL^i) = \lambda_t^i \geq 0$.

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 (similar to the Auclert (2018) set up for households).

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

$$W_{t+1}^i = p_tA_t^i(N_t^i)^\alpha - (1 + r_t)\left(w_tN_t^i - W_t^i\right) - \lambda_t^i max\{w_tN_t^i - W_t^i, 0\} \tag{6}$$

Assume that the firm can commit not to default,[36] the firm's problem is to choose:

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

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

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

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

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:

$$\alpha p (N^i)^{\alpha-1} = \left(1 + r + \mathbf{1}\left[wN^i - W^i > 0\right](\lambda^i + \lambda_1^i w N^i)\right) w. \tag{7}$$

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

$$\underbrace{log(MPL^i) - log(w) - r}_{\text{unconstrained firm's foc}} = \underbrace{\lambda^i + \lambda_1^i w N^i}_{\text{wedge due to constraint}}, \tag{8}$$

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 8, we get:

$$\frac{dN^i}{dr} = -\frac{\frac{\partial MB^i}{\partial r} - \frac{\partial MS^i}{\partial r}}{\frac{(\alpha-1)}{N^i} - 2wcs_1^i - cs_{11}^i}. \tag{9}$$

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 in expectation cashflows 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:

$$\frac{dN^i}{dr} = -\frac{\frac{\partial MB}{\partial r} - \frac{\partial \lambda^i}{\partial r} - wN^i \frac{\partial \lambda_1^i}{\partial r} - \frac{\partial w}{\partial r} N^i \lambda_1^i}{\frac{(\alpha-1)}{N^i} - 2w\lambda_1^i - \lambda_{11}^i}. \tag{10}$$

Define $\Lambda^i = -\left(\frac{(\alpha-1)}{N^i} - 2w\lambda_1^i - \lambda_{11}^i\right)^{-1}$ and note the following regarding the denominator of 10: (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 with who 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:

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

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 11 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 11 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) $\Lambda^{uc} = \frac{N^{uc}}{(1-\alpha)}$; (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:

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

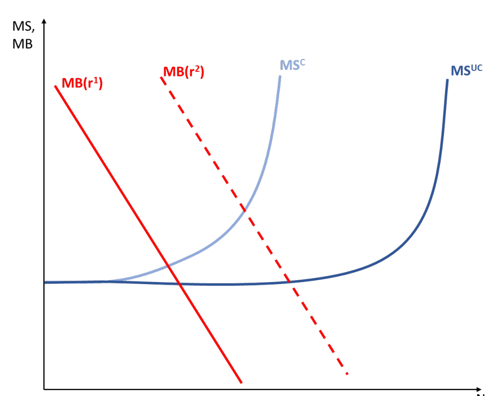
The above is a relative impulse response and hence is an analogue of our empirical analysis in Section 5.1. If the sources of firm level heterogeneity we are relying upon are proxying financial constraints our empirical evidence suggests that $\frac{dN}{dr}^{c} - \frac{dN}{dr}^{uc} < 0$. However, note that $(\Lambda^c - \Lambda^{uc}) < 0$ so the first term on the right-hand side of equation 12 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 12 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 19 in the Appendix, this is exactly what emerges from the aggregate data using our VAR in Section 4.1.

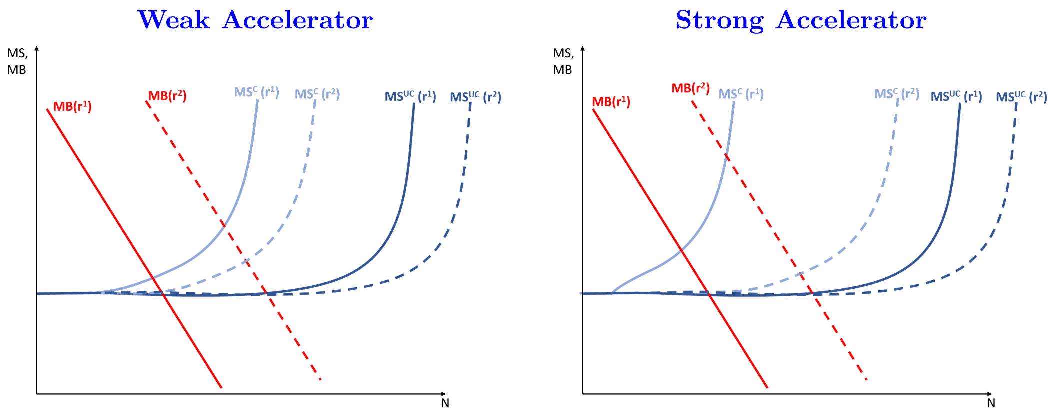
Curve Shifting Let us illustrate these effects graphically. Consider two interest rates r^1 and r^2 with $r^2 < r^1$. Assume that the two firms face two different marginal spread curves: $MS^{uc} \leq MS^c$ (e.g. because $W^c < W^{uc}$). In Figure 20 we assume that $\frac{\partial q}{\partial r} = 0$. 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 12 above).

Figure 20: Employment responses: no financial accelerator



In Figure 21 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.

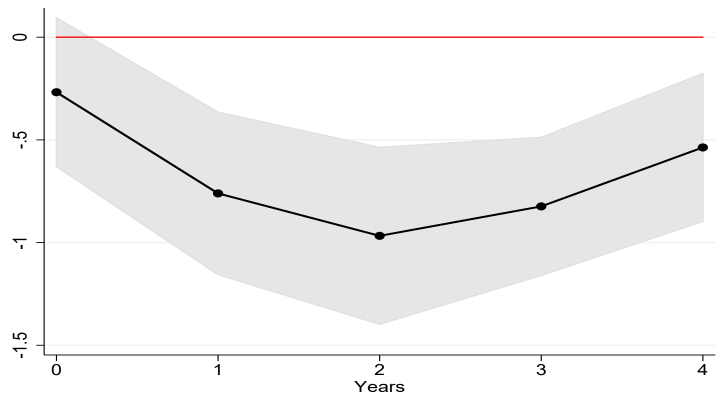
Figure 21: Employment responses: with financial accelerator



D Average Firm-Level Response: Robustness

D.1 Adding Firm Controls

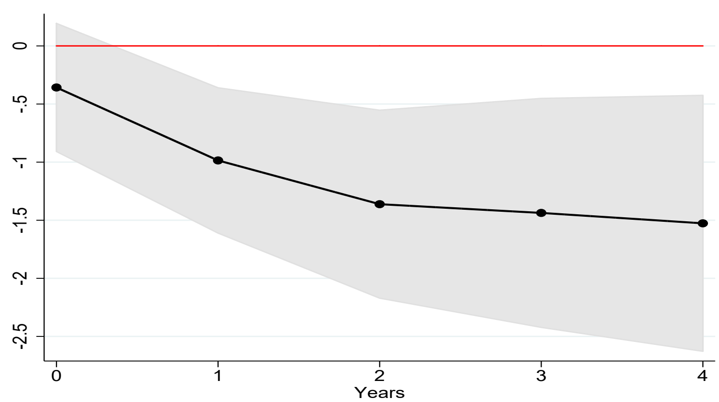
Figure 22: Linear Effect of Monetary Policy on Firms: Adding Firm Controls



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.2 Adding Firm Fixed Effects

Figure 23: Linear Effect of Monetary Policy on Firms: Firm Fixed Effect

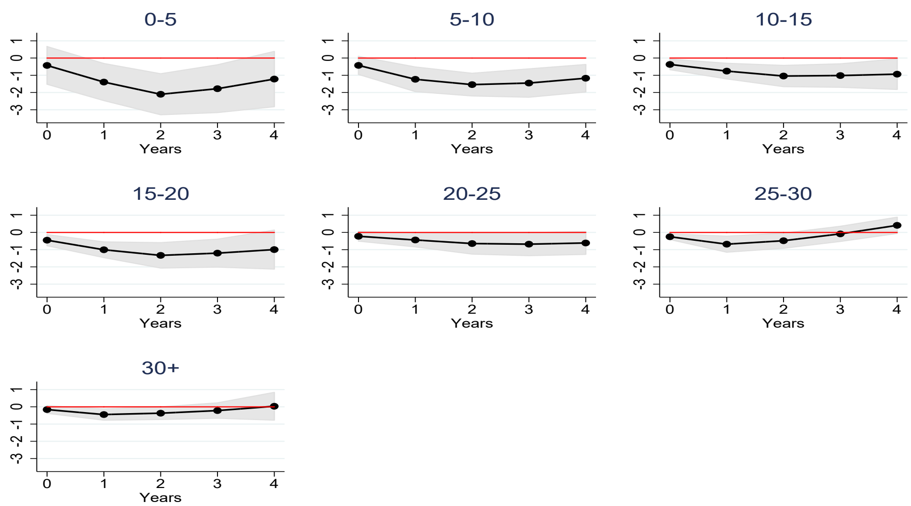


Notes: Firm level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock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

E Further Results on Firm-Level Heterogeneity

E.1 Alternative Firm Age Cuts

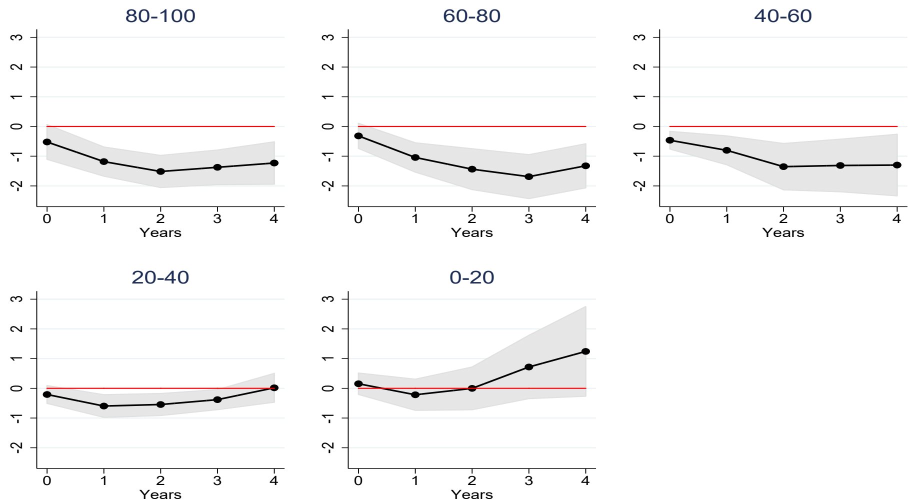
Figure 24: Level Effects on Employment by Firm Age Groups



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

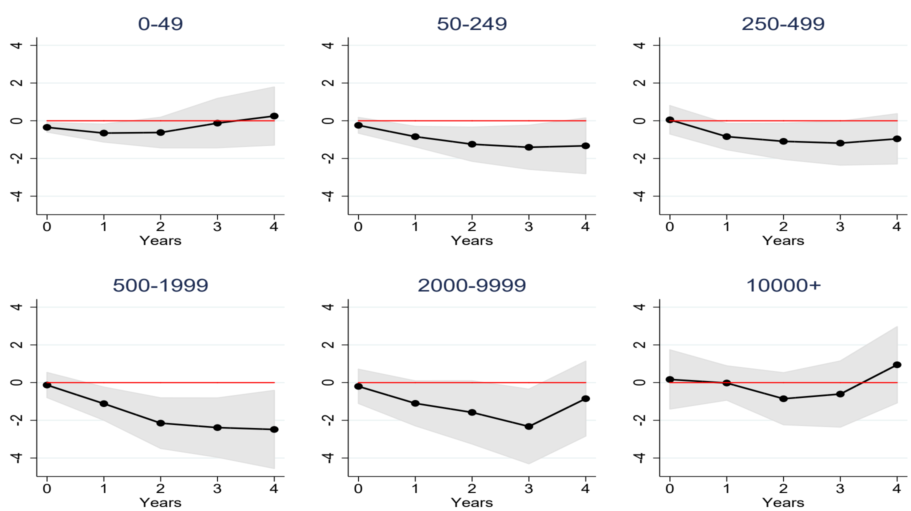
Figure 25: Level Effects on Employment by Firm Leverage Groups



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 26: Level Effects on Employment by Firm Size Groups

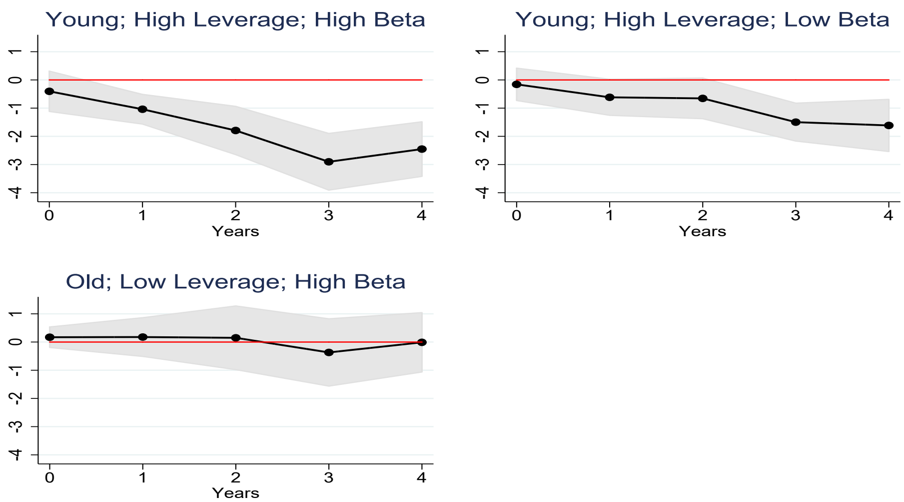


Notes: Firm level responses to a 25bp contractionary monetary policy shock for different firm size groups. Firm size is measured as the "Number of Employees". Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points 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.

F Robustness: Identification

F.1 Adding Region-Year Fixed Effects

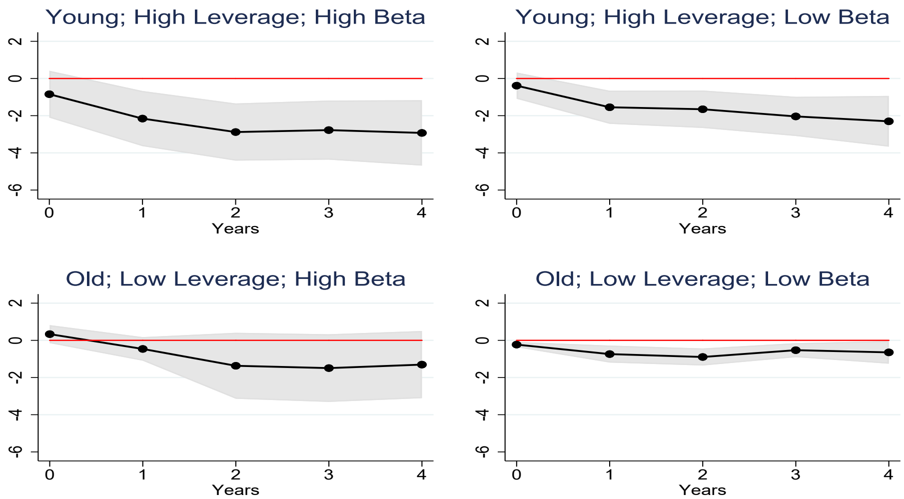
Figure 27: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



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).

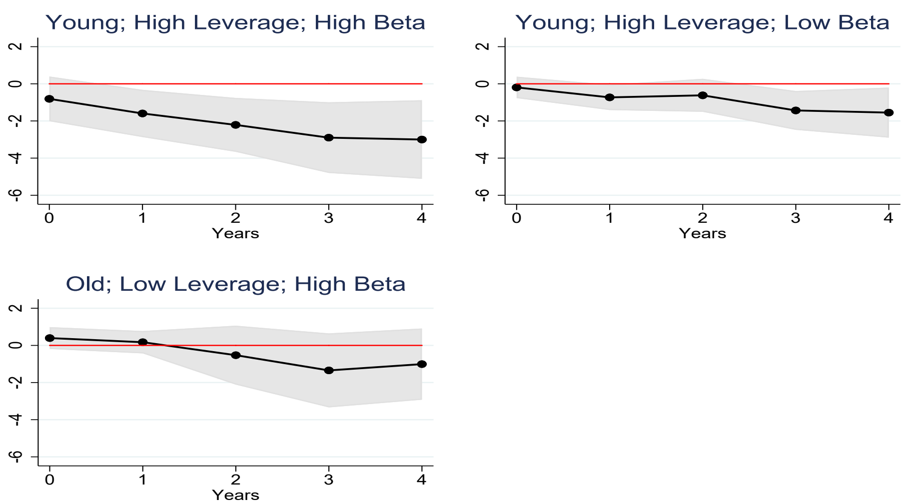
F.2 Controlling for Firm's Beta Interacted With Age and Leverage

Figure 28: 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 29: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted

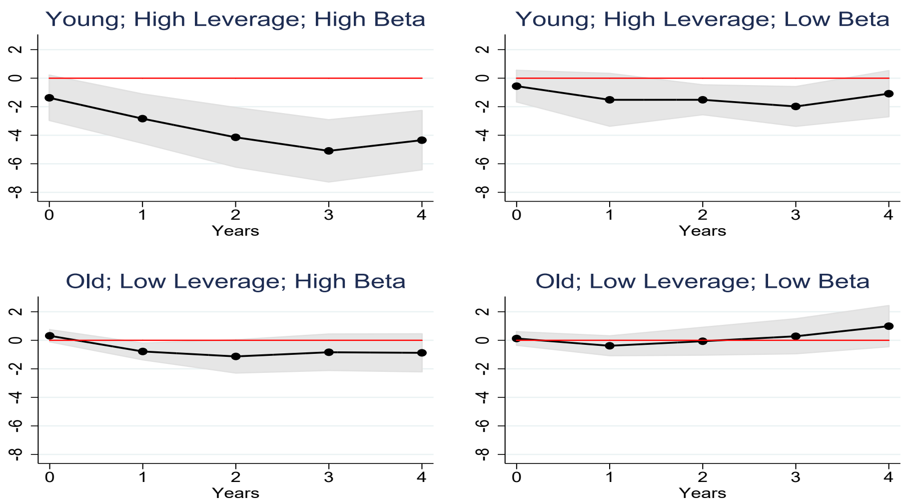


Notes: Firm level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock 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.3 Directors Who Live 30 Miles Away

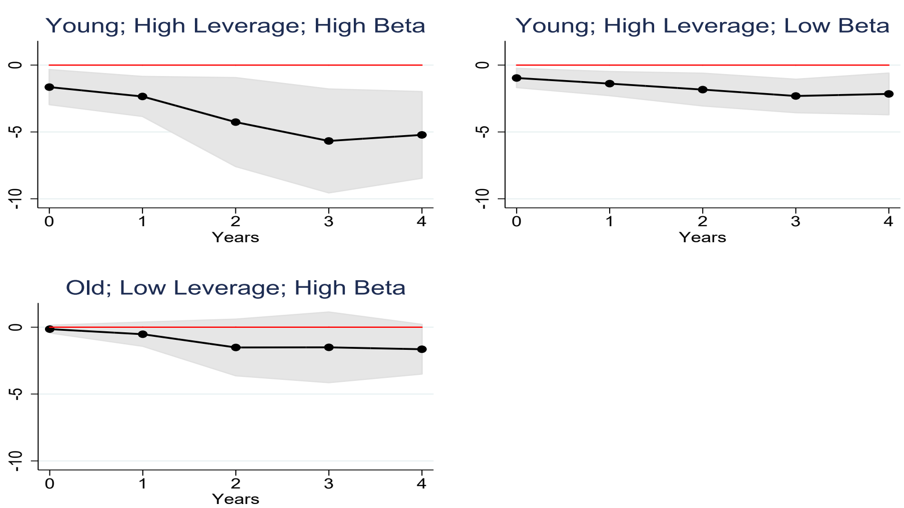
F.3.1 All Directors

Figure 30: 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.

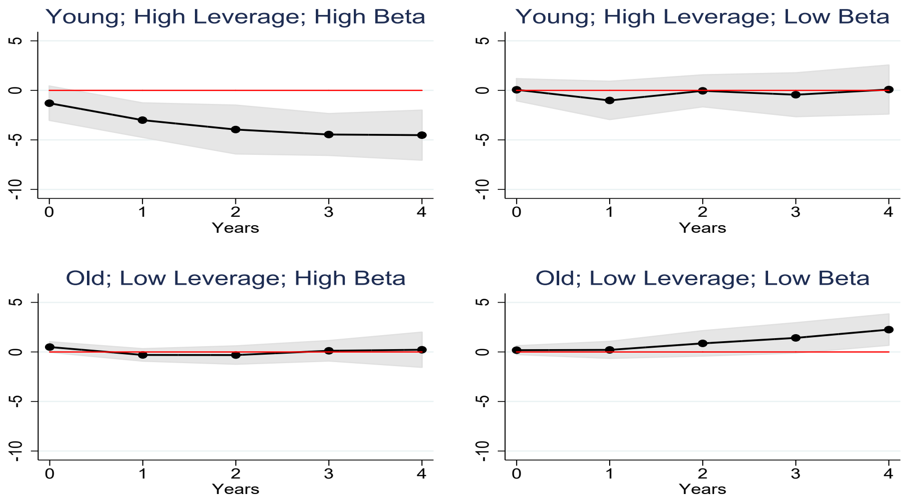
Figure 31: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



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).

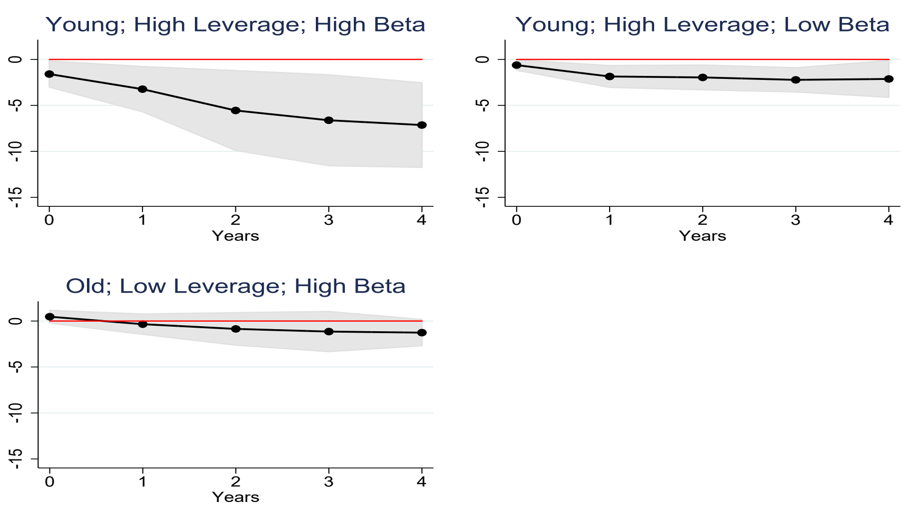
F.3.2 Shareholder Directors

Figure 32: 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.

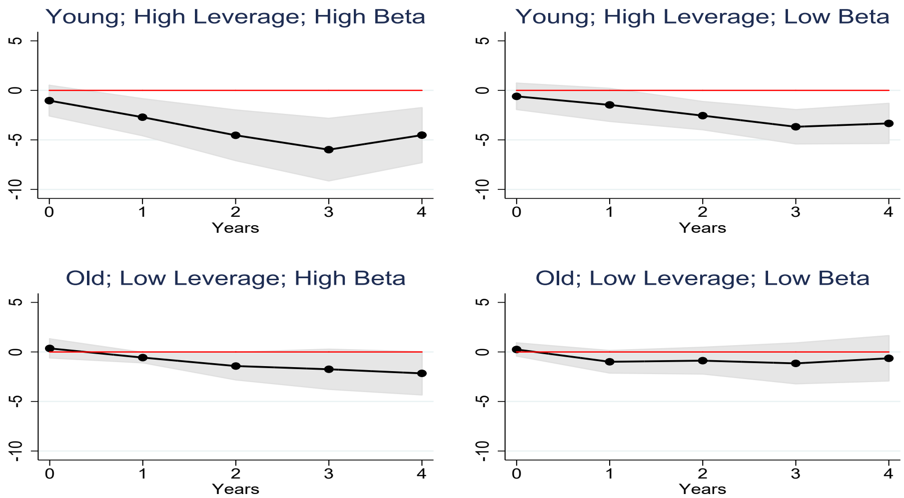
Figure 33: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



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).

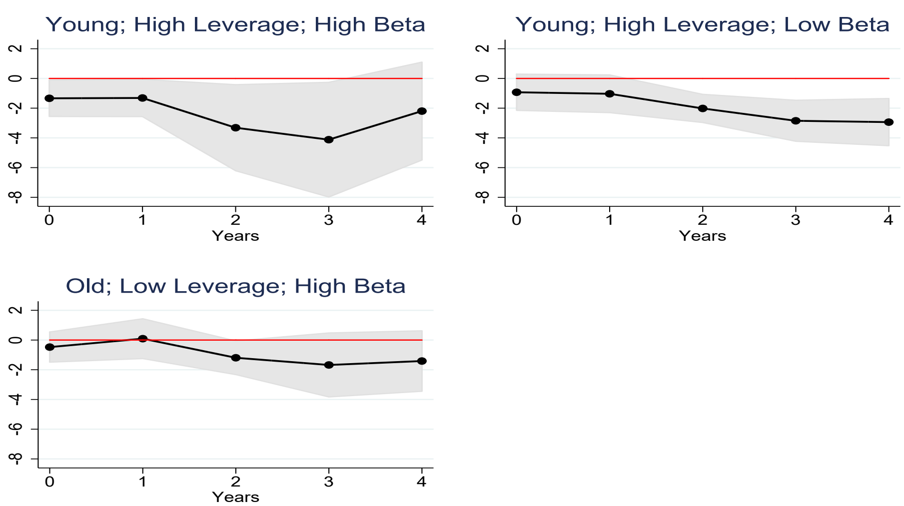
F.3.3 Non-Shareholder Directors

Figure 34: 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.

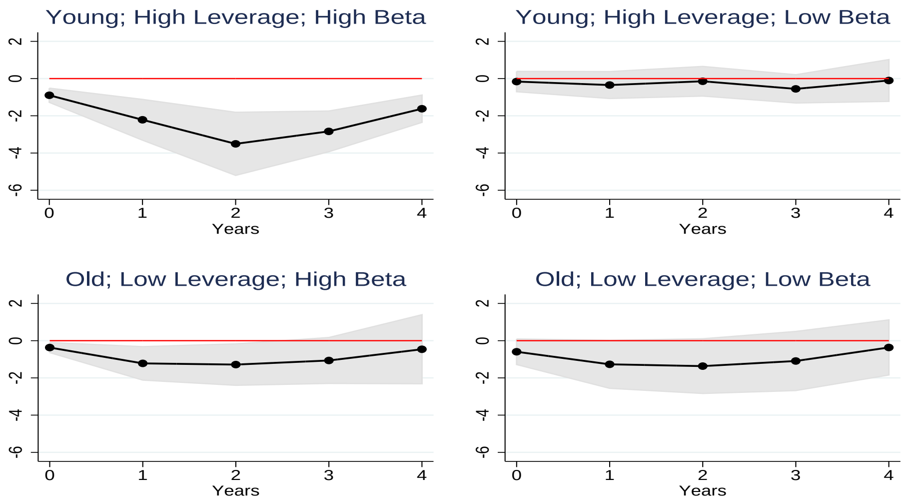
Figure 35: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



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).

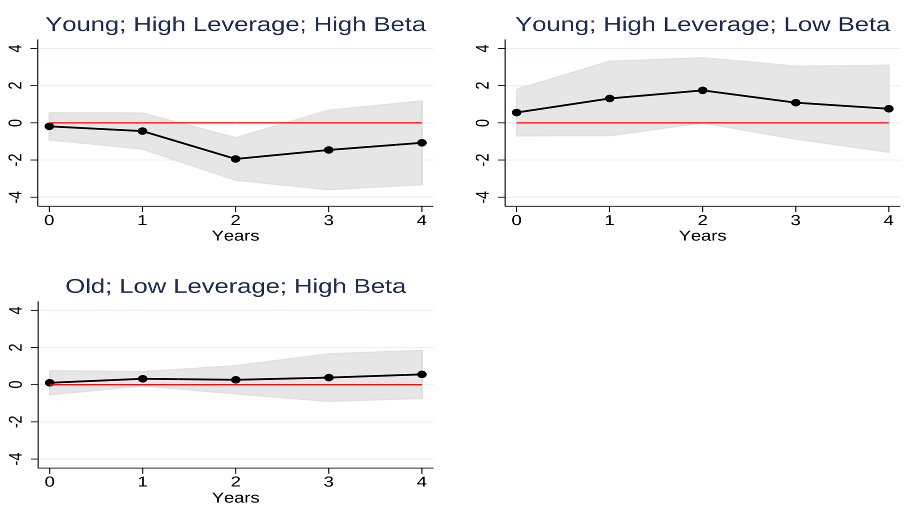
F.4 Excluding Non-Tradeable Sectors

Figure 36: 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.

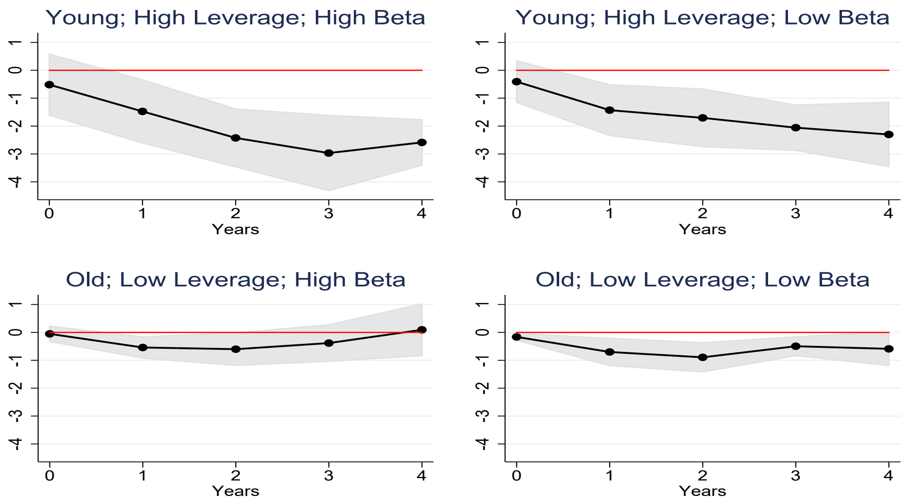
Figure 37: Relative Effects on Employment on by Age, Leverage and Director Beta, Triple Sorted



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.

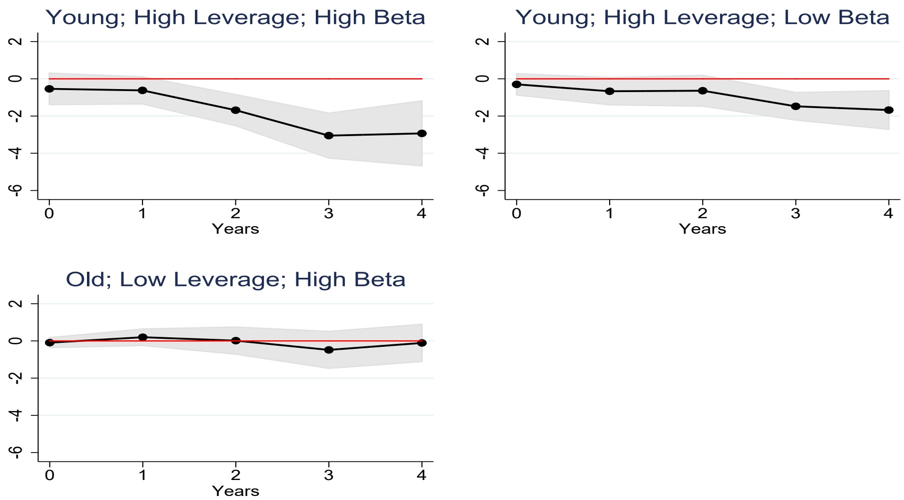
F.5 Excluding Directors Living In London

Figure 38: 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.

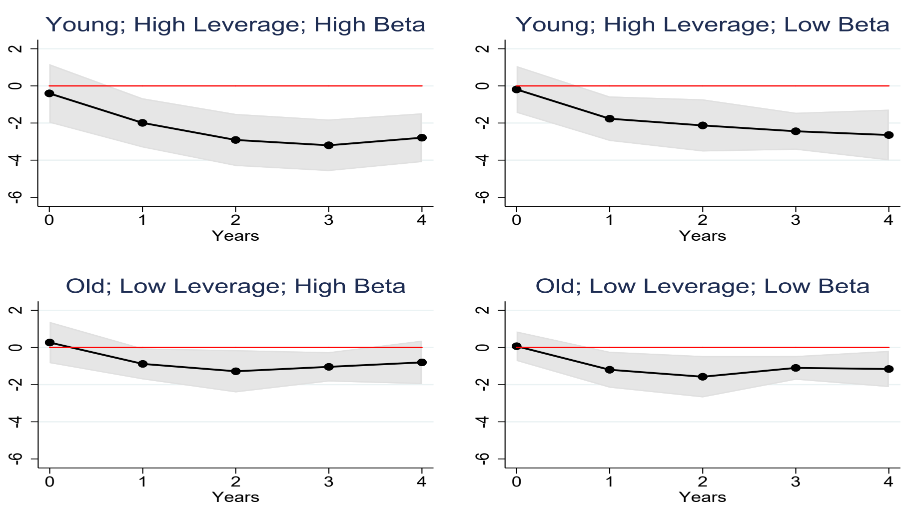
Figure 39: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



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.

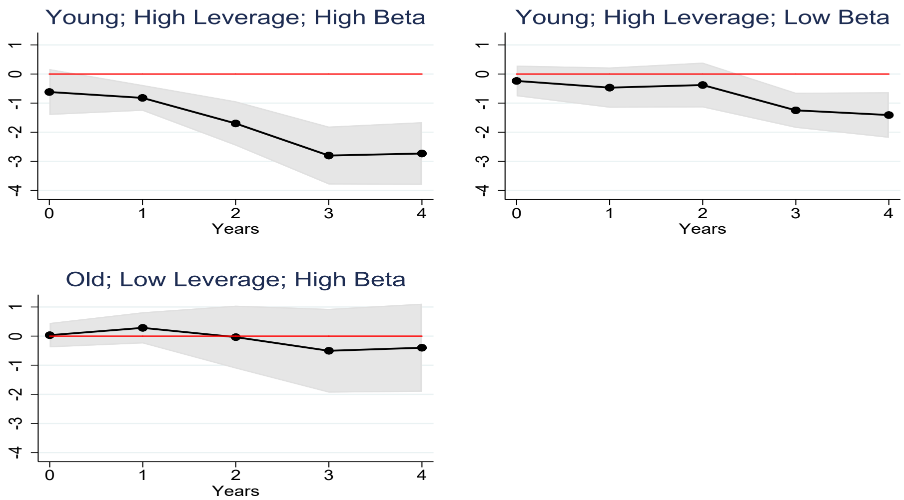
F.6 Including Director Characteristics

Figure 40: 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.

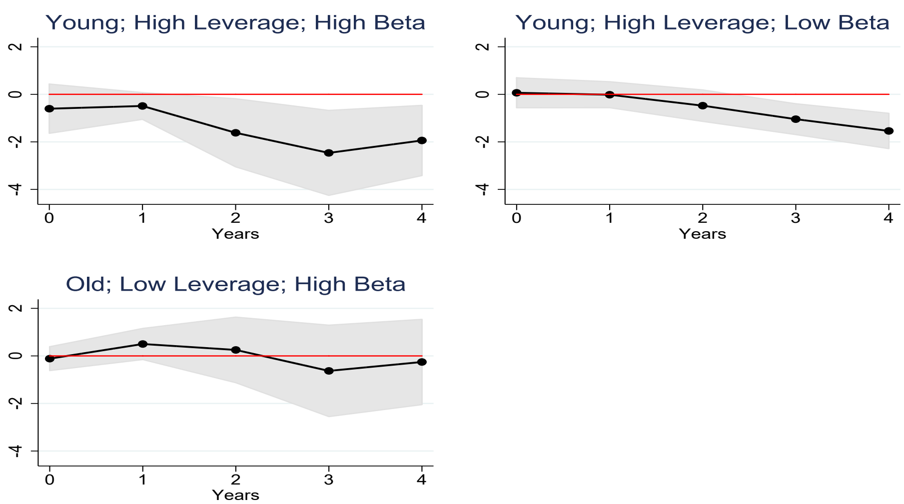
Figure 41: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



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.7 Adding Bank-Combination x Year Fixed Effects

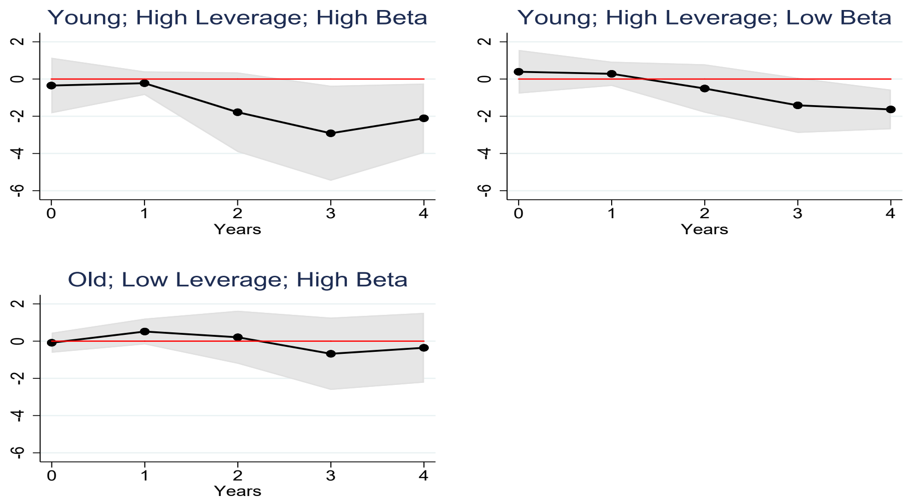
Figure 42: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



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.8 Adding Firm Age x Bank-Combination x Year Fixed Effects

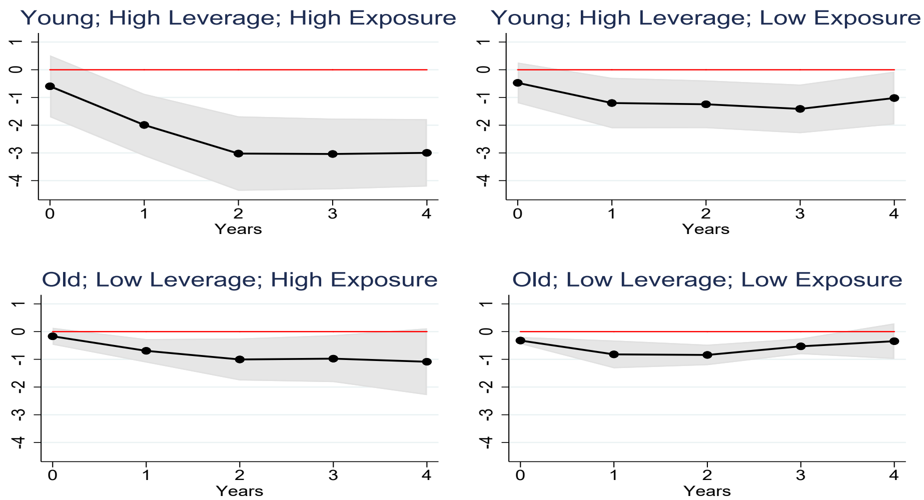
Figure 43: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



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).

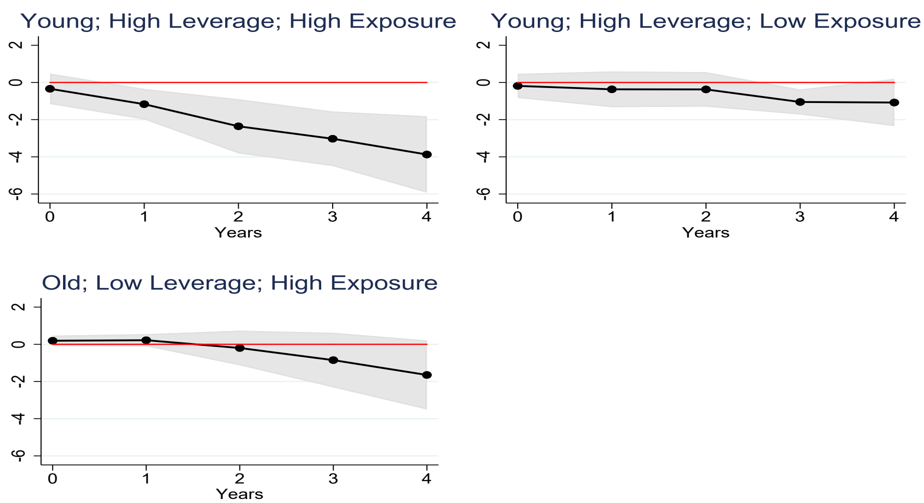
F.9 Exposure

Figure 44: Level Effects on Employment by Age, Leverage and Director Housing Exposure, 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.

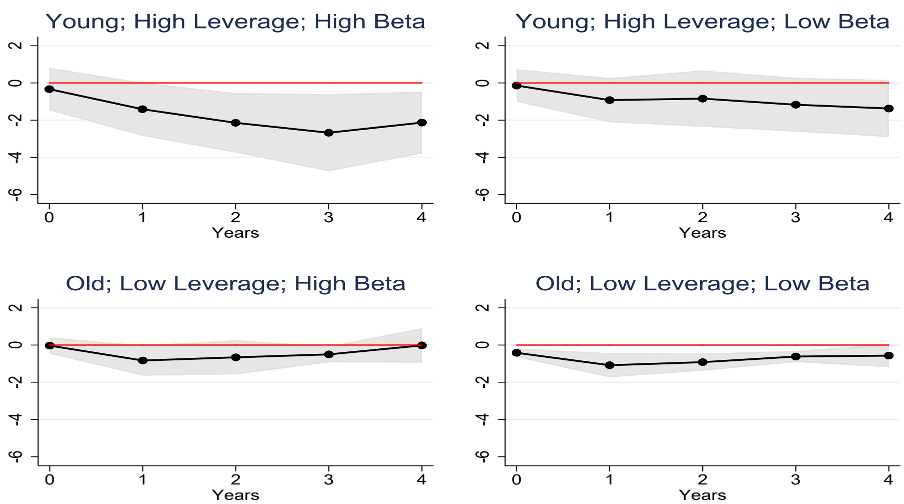
Figure 45: Relative Effects on Employment by Age, Leverage and Director Housing Exposure, Triple Sorted



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).

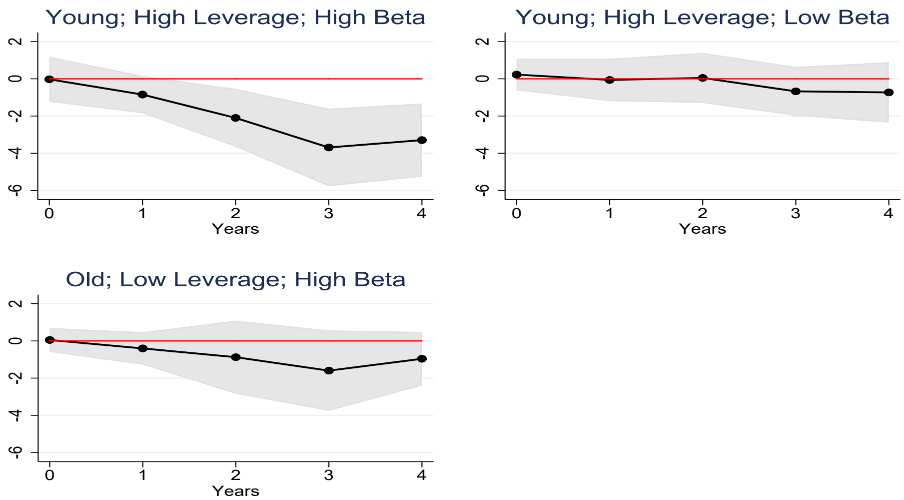
F.10 Director Cash-Flow Proxy: Controlling for Average Mortgage Size

Figure 46: 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.

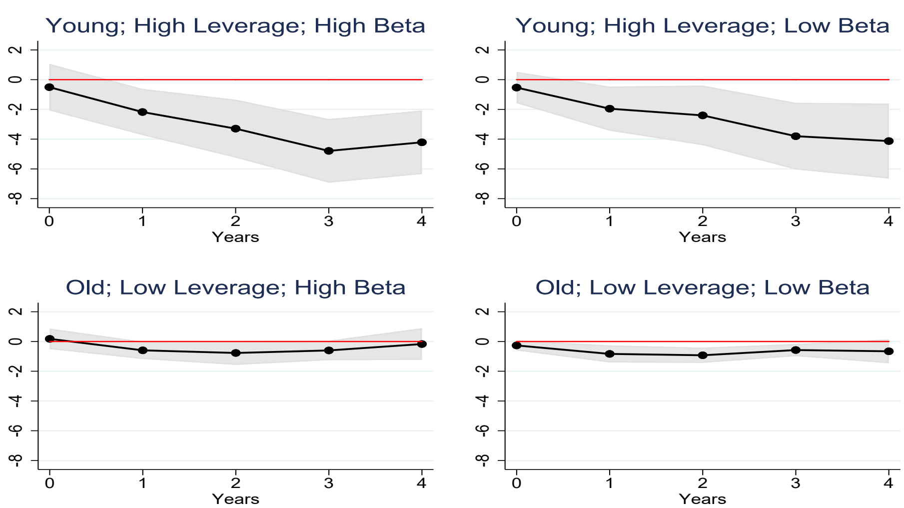
Figure 47: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



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).

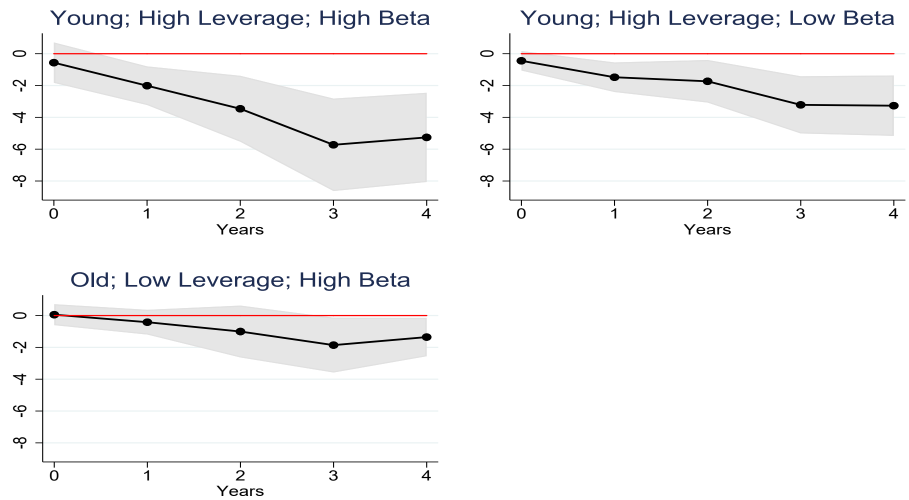
F.11 Director Cash-Flow Proxy: Controlling for Average Mortgage Size to Average Income

Figure 48: 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.

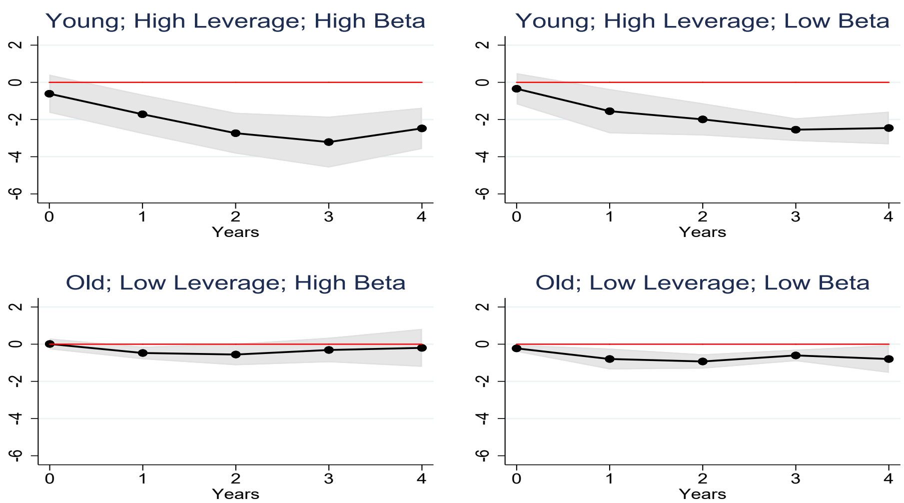
Figure 49: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



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).

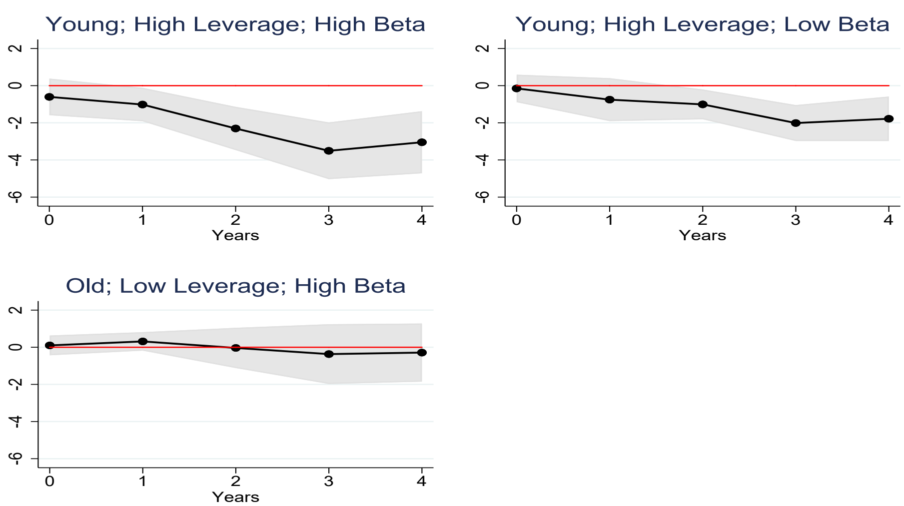
F.12 Director Cash-Flow Proxy: Controlling for Share of Purchases in Director's Region With Mortgage

Figure 50: 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 51: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted

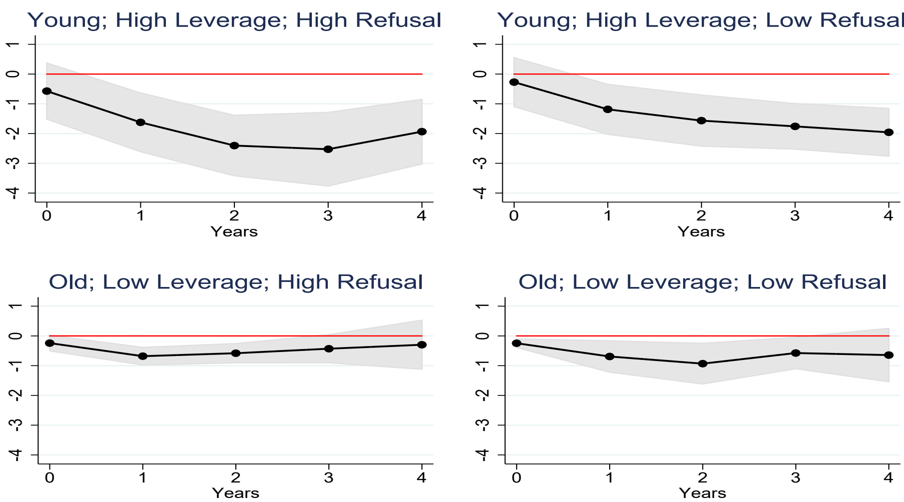


Notes: Firm level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock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

G Further Robustness

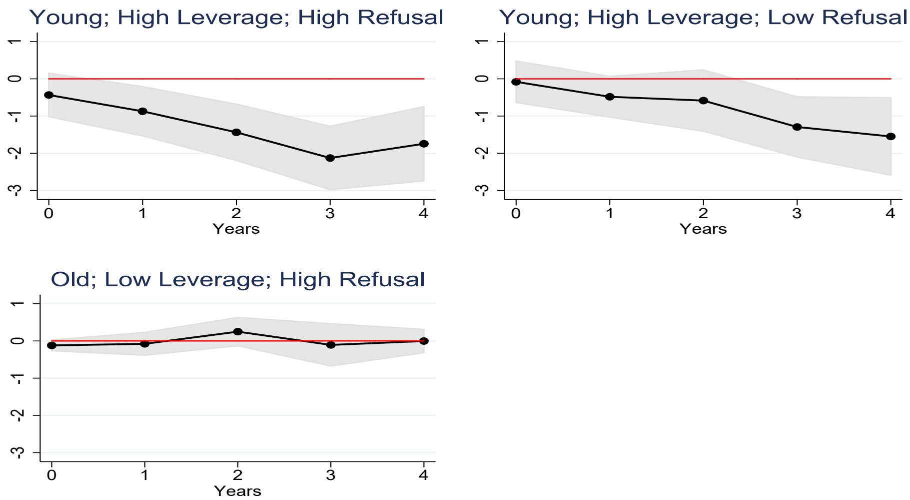
G.1 Using Refusal Rates

Figure 52: 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.

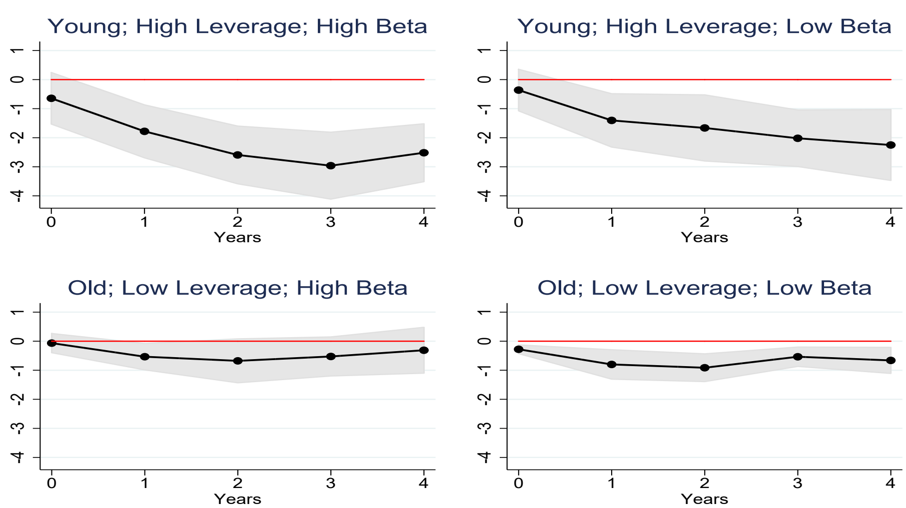
Figure 53: Relative Employment Effects by Age, Leverage and Director Region Refusal Rate, Triple Sorted



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).

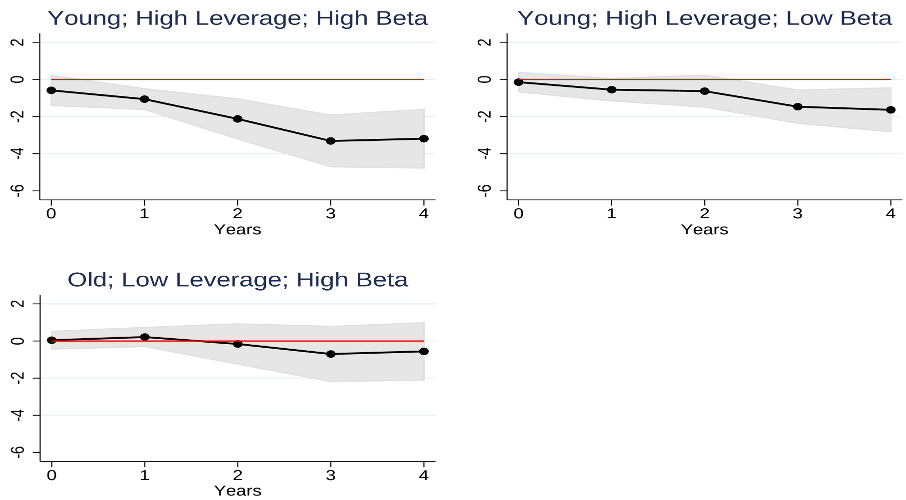
G.2 Adding Firm Controls

Figure 54: 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.

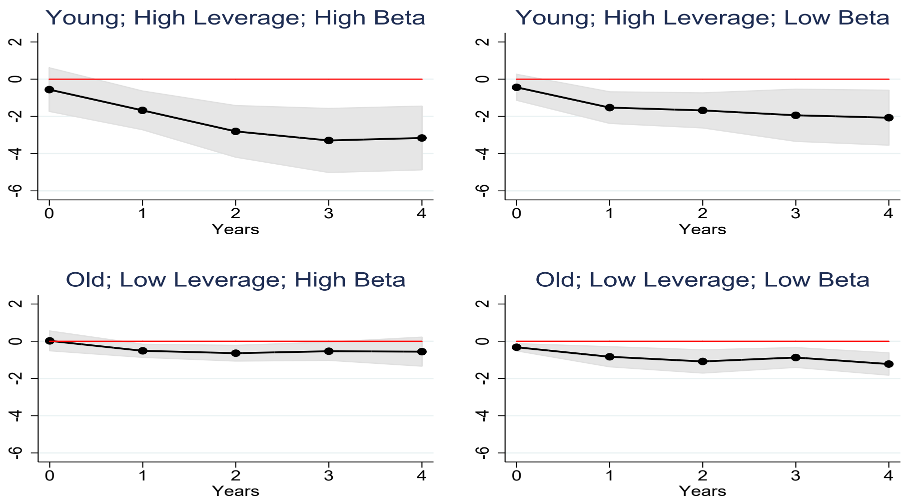
Figure 55: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



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.

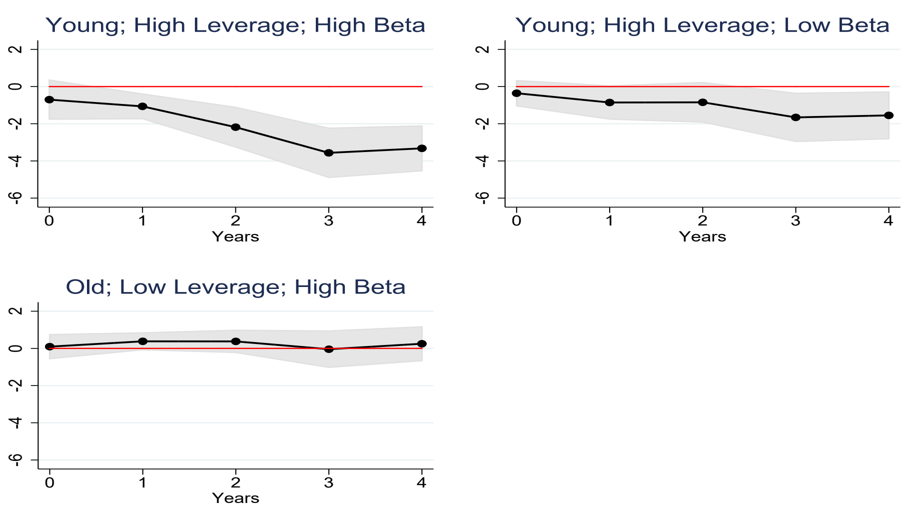
G.3 Adding Firm Fixed Effects

Figure 56: 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*.

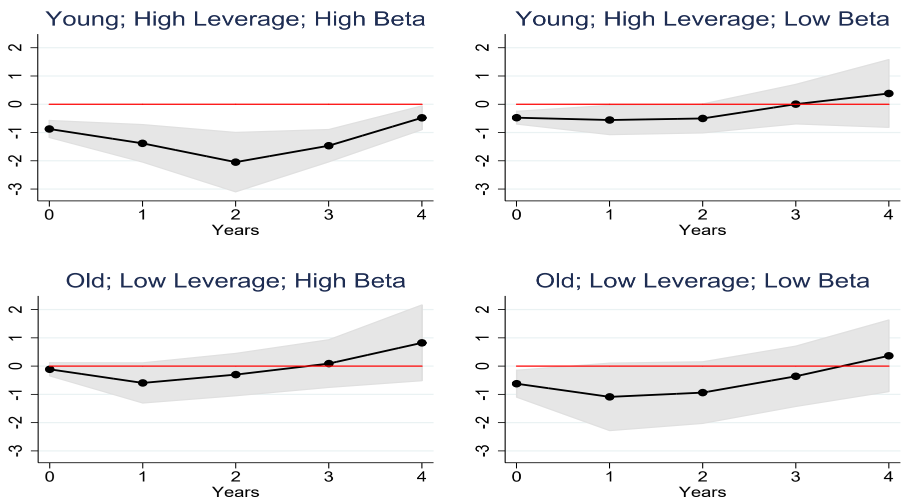
Figure 57: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



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*.

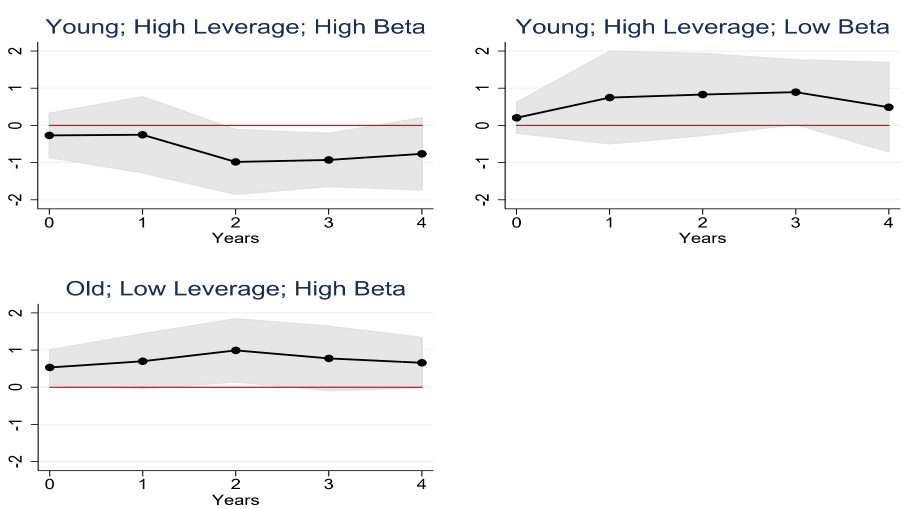
G.4 Firm Region Responsiveness: Tradable Firms

Figure 58: 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.

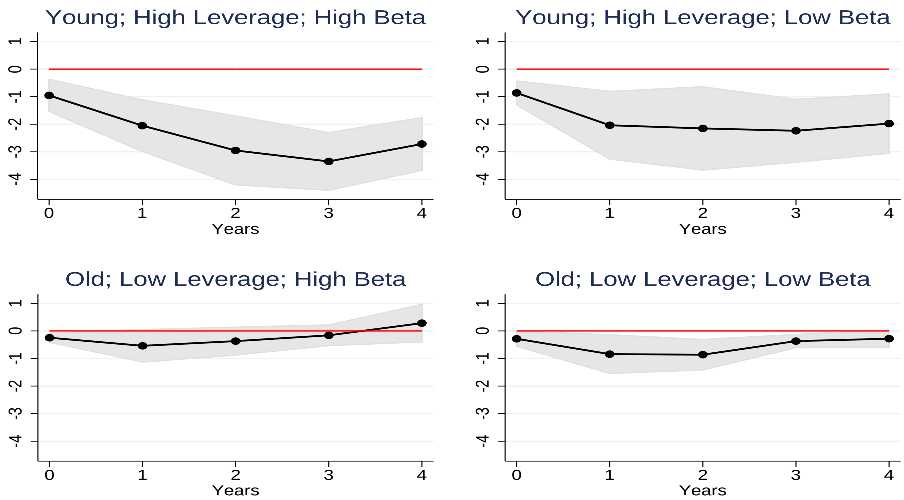
Figure 59: Relative Effects on Employment by Age, Leverage and Firm Beta, Triple Sorted



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 and NUTS1-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).

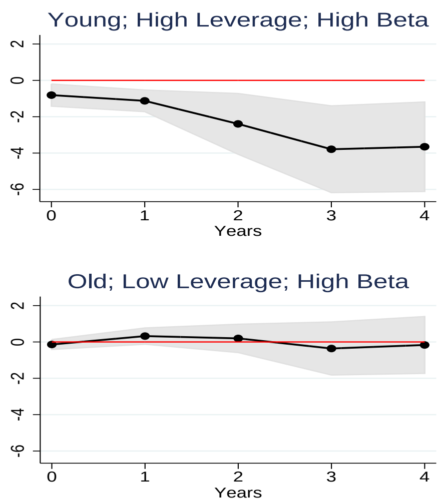
G.5 Excluding Zero Lower Bound Period

Figure 60: 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.

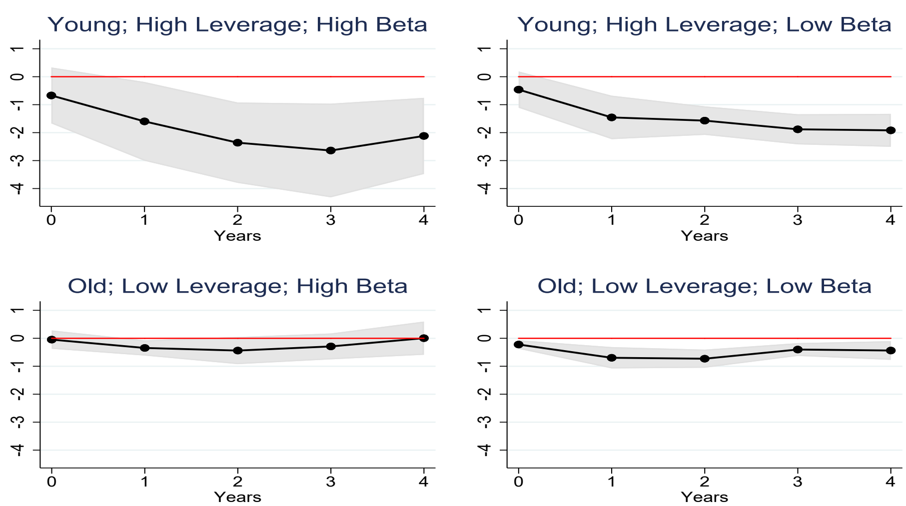
Figure 61: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



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.

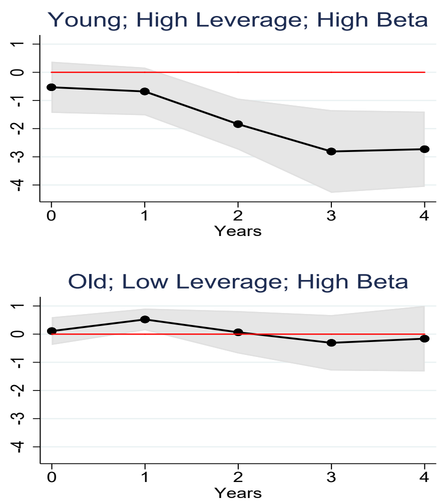
G.6 Controlling for Inflation and GDP Forecast Surprises

Figure 62: 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.

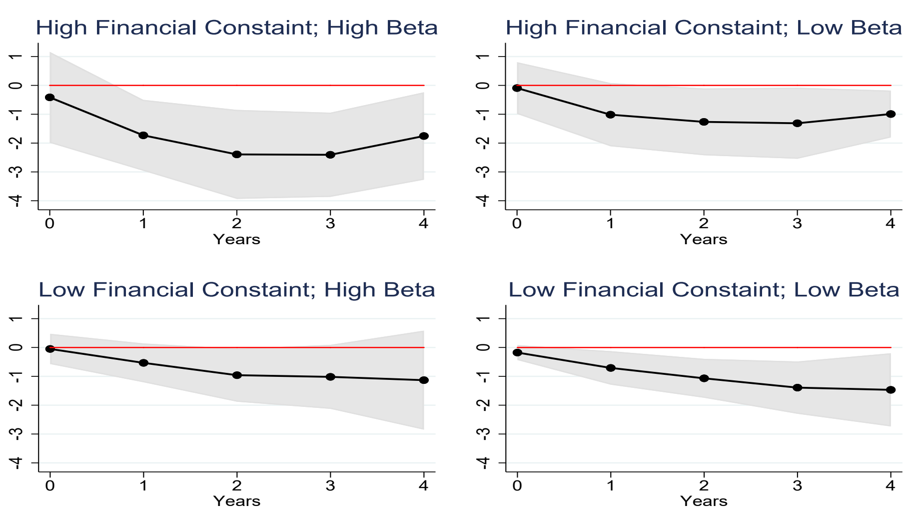
Figure 63: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



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).

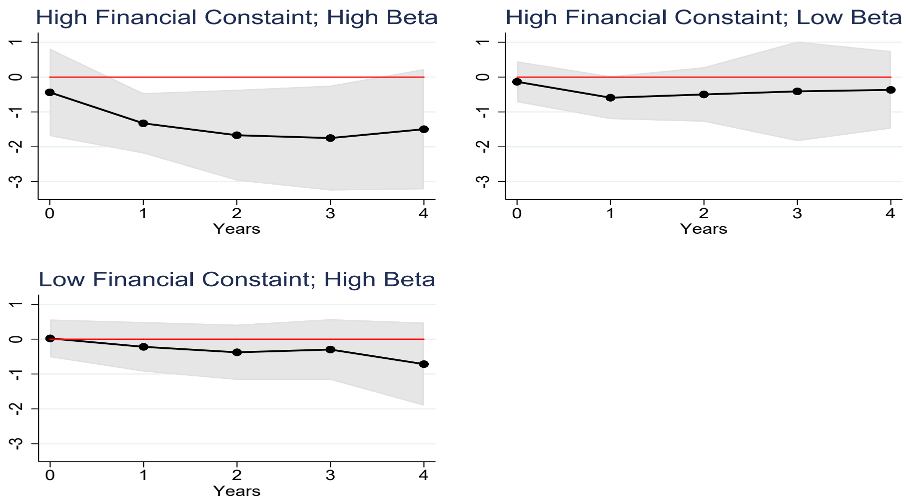
G.7 Using A Financial Constraint Index

Figure 64: 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.

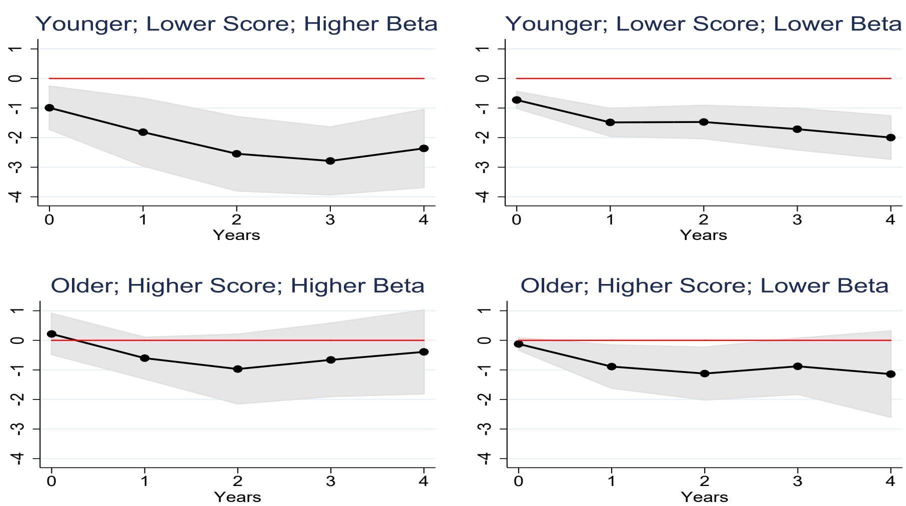
Figure 65: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



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).

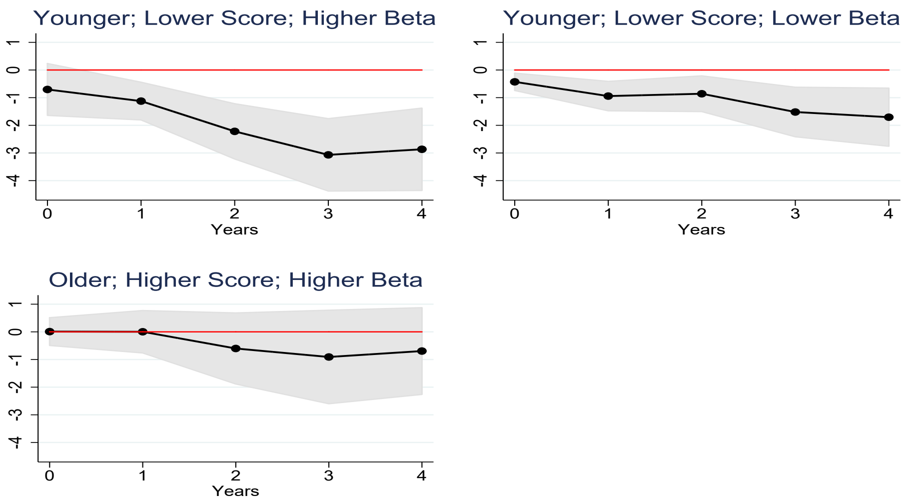
G.8 Using Credit Score As Alternative To Leverage

Figure 66: 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.

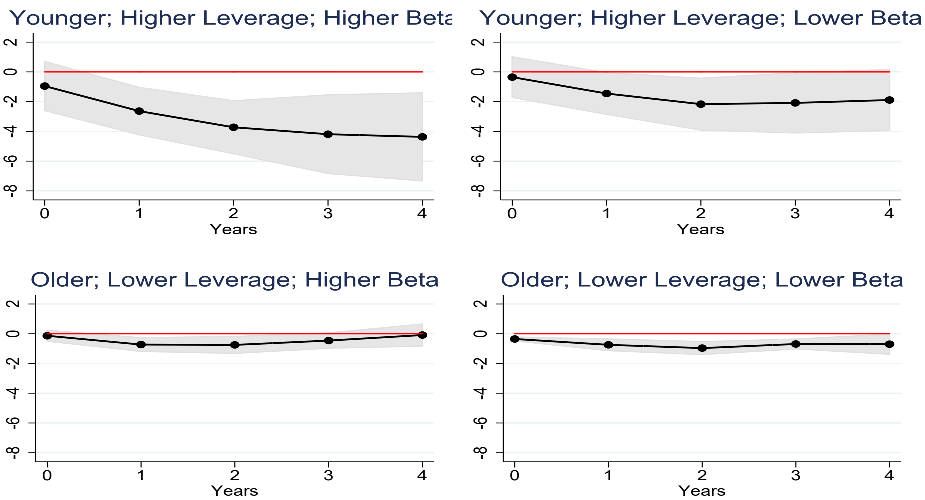
Figure 67: Relative Effects on Employment by Age, Credit Score and Director Beta, Triple Sorted



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.

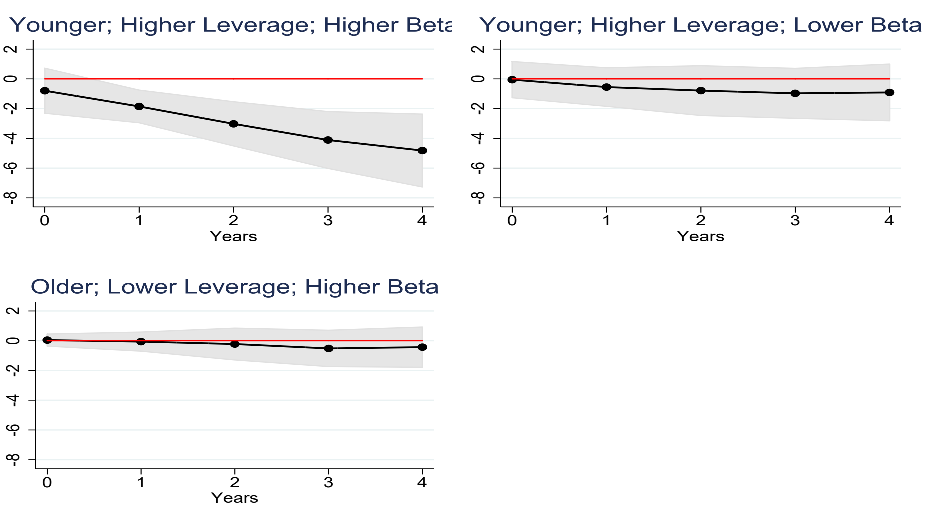
G.9 Alternative Firm Age Cut at 5 Years Old

Figure 68: 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.

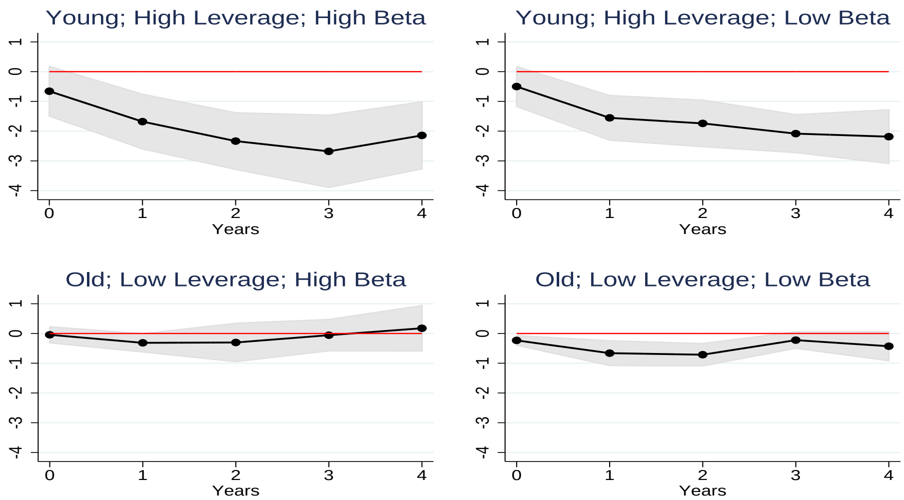
Figure 69: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



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.

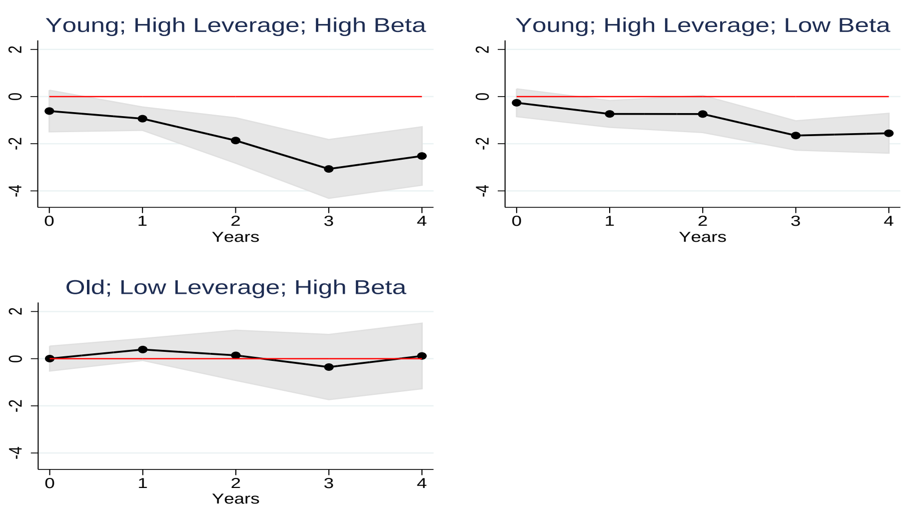
G.10 Restricting to SMEs

Figure 70: 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.

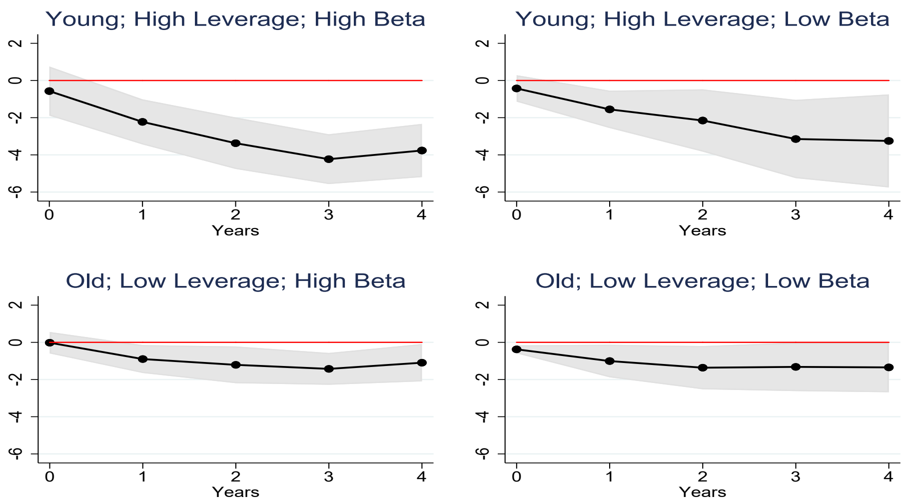
Figure 71: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted



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.

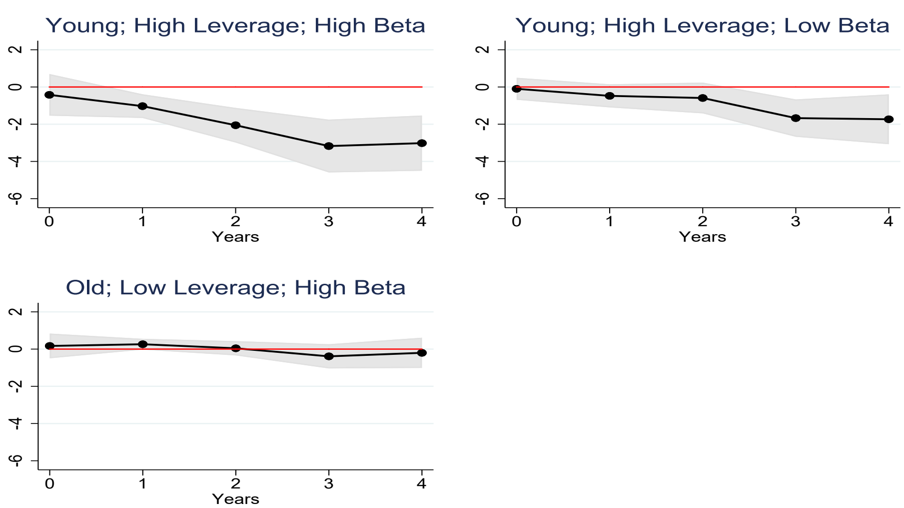
G.11 Controlling for Firm Size x Director Beta

Figure 72: 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 73: Relative Effects on Employment by Age, Leverage and Director Beta, Triple Sorted

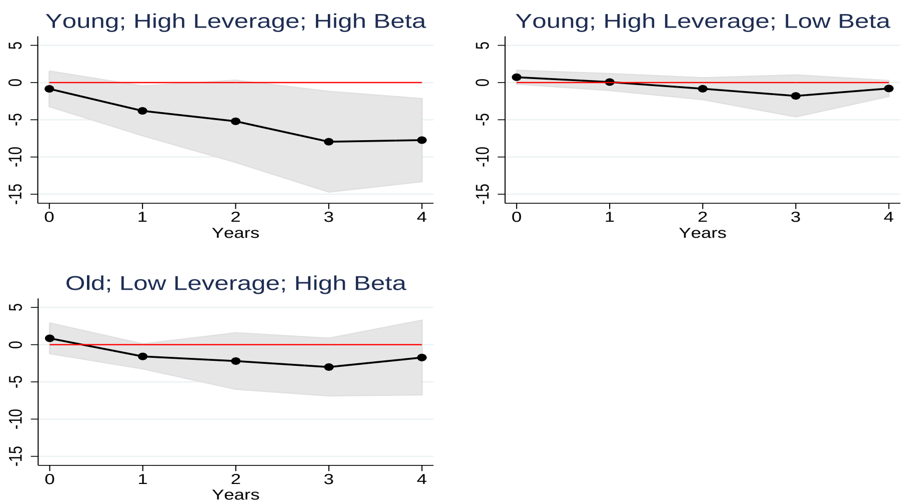


Notes: Firm level responses to a 25bp contractionary monetary policy shock. Black lines are point estimates. Grey shaded area is 90% confidence interval. The dependent variable is the cumulative growth rate in log points of Employment from $t-1$ to $t+h$ where t is the date of the monetary policy shock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

H Alternative Dependent Variables

H.1 Total Debt

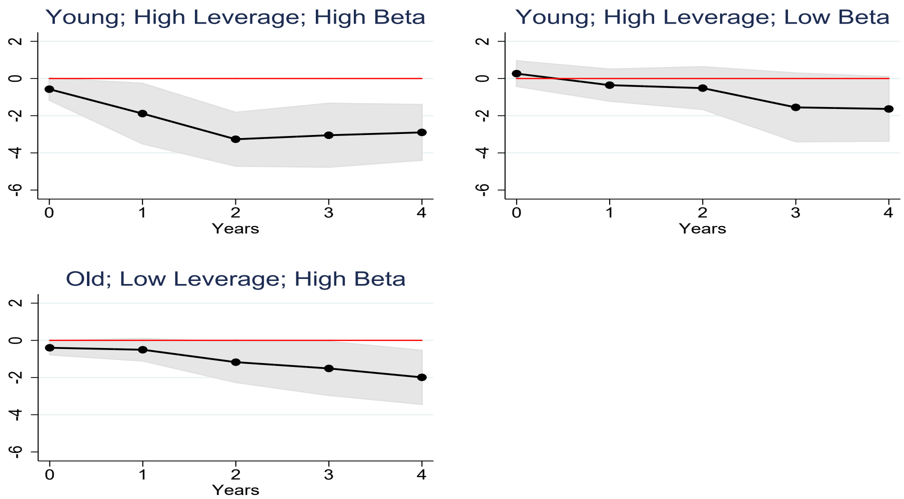
Figure 74: Relative Effect on Total Debt by Age, Leverage and Director Beta, Triple Sorted



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).

H.2 Current Assets

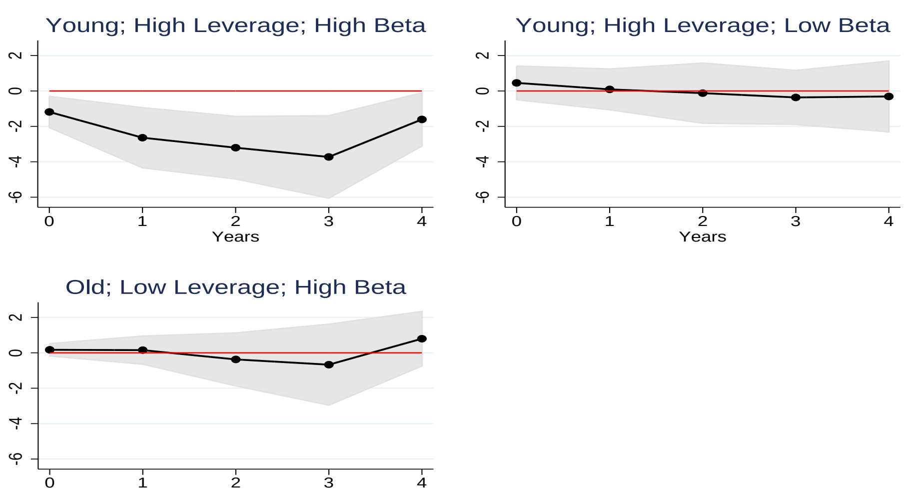
Figure 75: Relative Effect on Current Assets by Age, Leverage and Director Beta, Triple Sorted



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 Current 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).

H.3 Fixed Assets

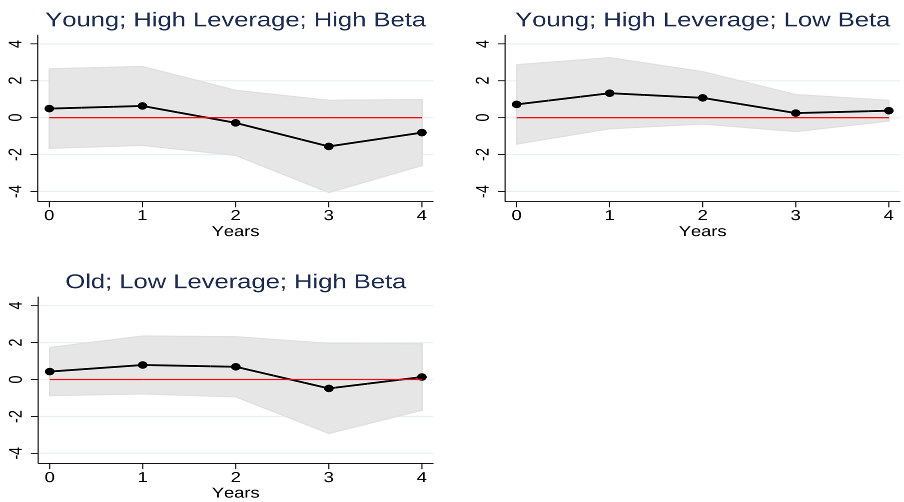
Figure 76: Relative Effect on Fixed Assets by Age, Leverage and Director Beta, Triple Sorted



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).

H.4 Turnover

Figure 77: 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).