

MONETARY POLICY, CORPORATE FINANCE AND INVESTMENT

2019

James Cloyne, Clodomiro Ferreira,
Maren Froemel and Paolo Surico

Documentos de Trabajo
N.º 1911

BANCO DE ESPAÑA
Eurosistema



MONETARY POLICY, CORPORATE FINANCE AND INVESTMENT

MONETARY POLICY, CORPORATE FINANCE AND INVESTMENT (*)

James Cloyne

UNIVERSITY OF CALIFORNIA DAVIS, NBER AND CEPR

Clodomiro Ferreira

BANCO DE ESPAÑA

Maren Froemel

LONDON BUSINESS SCHOOL

Paolo Surico

LONDON BUSINESS SCHOOL, BANK OF ENGLAND AND CEPR

(*) First Draft: March 2018. We are grateful to Saleem Bahaj, Larry Christiano, Juan-Antolín Díaz, Thomas Drechsel, Martin Eichenbaum, Angus Foulis, Mark Gertler, Sebnem Kalemli-Ozcan, Yueran Ma, Elias Papaioannou, Gabor Pinter, Martin Schneider, Philip Vermeulen, Gianluca Violante and seminar participants at Banque de France, Banco de España, Northwestern University, University of Virginia, the Fed Board of Governors, University of Porto, the NBER Summer Institute 2018, CREI/UPF, LBS, the Federal Reserve Bank of San Francisco, the Science Po 2018 workshop on empirical monetary economics and LSE for very useful comments and suggestions. We also thank Diego Kaenzig and Ezgi Kurt for excellent research assistance. The views in this paper are those of the authors and do not necessarily reflect the views of the Banco de España, the Eurosystem or the Bank of England. Surico gratefully acknowledges financial support from the European Research Council (Consolidator Grant 771976). Address for correspondence: James Cloyne (University of California Davis, NBER and CEPR) jcloyne@ucdavis.edu; Clodomiro Ferreira (Banco de España) clodomiro.ferreira@bde.es; Maren Froemel (London Business School) mfroemel@london.edu; Paolo Surico (London Business School, Bank of England and CEPR) psurico@london.edu.

The Working Paper Series seeks to disseminate original research in economics and finance. All papers have been anonymously refereed. By publishing these papers, the Banco de España aims to contribute to economic analysis and, in particular, to knowledge of the Spanish economy and its international environment.

The opinions and analyses in the Working Paper Series are the responsibility of the authors and, therefore, do not necessarily coincide with those of the Banco de España or the Eurosystem.

The Banco de España disseminates its main reports and most of its publications via the Internet at the following website: <http://www.bde.es>.

Reproduction for educational and non-commercial purposes is permitted provided that the source is acknowledged.

© BANCO DE ESPAÑA, Madrid, 2019

ISSN: 1579-8666 (on line)

Abstract

We provide new evidence on how monetary policy affects investment and firm finance in the United States and the United Kingdom. Younger firms paying no dividends exhibit the largest and most significant change in capital expenditure – even after conditioning on size, asset growth, Tobin's Q, leverage or liquidity – and drive the response of aggregate investment. Older companies, in contrast, hardly react at all. After a monetary policy tightening, net worth falls considerably for all firms but borrowing declines only for younger non-dividend payers, as their external finance is mostly exposed to asset value fluctuations. Conversely, cash-flows change less markedly and more homogeneously across groups. Our findings highlight the role of firm finance and financial frictions in amplifying the effects of monetary policy on investment.

Keywords: monetary policy, financial frictions, firm finance, investment.

JEL classification: E22, E32, E52.

Resumen

En este trabajo se presenta nueva evidencia acerca del efecto que la política monetaria tiene sobre la inversión y la financiación de las empresas en Estados Unidos y en el Reino Unido. Las empresas más jóvenes y que no pagan dividendos son las que muestran la mayor, —y estadísticamente significativa—, reacción en términos de inversión en capital fijo, mientras que las empresas relativamente antiguas casi no presentan reacción alguna. Esto es así aun controlando por características tradicionales en esta literatura, como son el tamaño, el crecimiento en activos, la valuación, el apalancamiento y liquidez. La reacción de empresas jóvenes que no pagan dividendos explica el movimiento de la inversión agregada. Después de una contracción en la política monetaria, se observa una reacción de la valuación de todas las empresas, mientras que la deuda responde solo para aquellas empresas jóvenes que no pagan dividendos. Esto se debe a que estas últimas son las más expuestas a cambios en el valor del colateral a la hora de endeudarse. Por otro lado, se observa también una reacción en los flujos de caja, aunque dicha reacción es relativamente pequeña y homogénea entre empresas. Estos resultados resaltan la importancia de la estructura financiera, así como de las fricciones en la financiación externa de las empresas, en la amplificación de los efectos de la política monetaria sobre la inversión empresarial.

Palabras clave: política monetaria, fricciones financieras, financiación empresarial, inversión.

Códigos JEL: E22, E32, E52.

1 Introduction

Recent years have witnessed a resurgence of research about how monetary policy works. Motivated by the role of credit and housing in the Great Recession, much of this work has focused on households. But, financial frictions also play a central role in popular narratives around the dramatic fall in business investment during 2007-08. An equally pertinent question is, therefore, how interest rates affect firms and whether financial constraints and firm finance play an important role in how monetary policy affects investment.

A large empirical literature has provided clear evidence that aggregate investment and credit conditions are very sensitive to changes in monetary policy. On the theoretical side, capital formation and financial frictions play a key role in the transmission mechanism of a number of popular macro models. Despite this, evidence on the role of financial frictions in the propagation of monetary policy to firms remains limited. Part of the problem lies in measuring financial frictions and how these may constrain firm behaviour. The existing literature has proposed a number of proxies but with a variety of results; this is still an area of ongoing debate and it remains unclear what the best proxy might be.

To tackle this, we build on insights from a large body of work in corporate finance showing that many proxies of financial constraints are highly correlated, both with each other and with other (non-financial) factors. Common measures such as leverage, size, Tobin's Q or liquidity are endogenous variables. Furthermore, the empirical literature on employment at the firm-level has highlighted the crucial role of age in understanding financial frictions and firm dynamics (e.g. Haltiwanger et al. (2013), Fort et al. (2013) and Dinlersoz et al. (2018))). Until now, however, this proxy has gained little attention in the macro-monetary literature on investment, possibly reflecting limited data availability in commonly used datasets. We therefore introduce this new variable for studying firm-level investment and show why we interpret it as a measure of 'financial history' or 'corporate age'. We also document how firm age correlates with other common proxies for financial constraints and other firm characteristics.

Using nearly 30 years of detailed firm-level panel data for U.S. and U.K. public firms, together with state-of-the-art time-series identification of monetary policy shocks (Gurkaynak et al. (2005), Gertler and Karadi (2015))), we provide new evidence of how, and why, monetary policy affects firms. To the extent that financial frictions are important, we cannot understand why firms adjust capital expenditure when interest rates change without examining how different forms of corporate finance are affected. Our goal is, therefore, to systematically document the response of the firm balance sheet to monetary policy. On the asset side we ask: which firms adjust their capital expenditure the most when interest rates change? And how important are these firms for explaining

the aggregate response found in the macro literature? On the liabilities side, we document how different forms of corporate finance — e.g. debt, equity and cash-flows — are affected by monetary policy changes. Since theoretical models with financial frictions have important predictions for corporate finance variables — not just for investment — a main contribution of our paper is to show that the response of the firm balance sheet can shed light on the channels through which monetary policy affects investment.

We document five new findings. First, age is a robust predictor of significant heterogeneity in the response of investment. Younger firms make the largest and most significant adjustment in capital expenditure; older firms exhibit a small and insignificant response. Second, this heterogeneity is even more stark when we condition on younger firms paying no dividends and, importantly, holds true conditional on a wide range of other firm characteristics. For example, we show that smaller firms respond more but, within this group, it is the younger non-dividend payers that drive the result. We document a range of similar findings based on liquidity, leverage, firm growth and Tobin's Q. Third, younger/no-dividends firms account for more than 75% of the overall dynamic effects of monetary policy on aggregate investment. Fourth, turning to the sources of firm finance, we find that net worth falls considerably for all groups but borrowing only declines for the younger/no-dividends group. In contrast, earnings and sales decline less markedly and more homogeneously across groups. Fifth, the borrowing of young/no-dividends firms is highly correlated with collateral values but is far less correlated with earnings. Conversely, the borrowing of older dividend payers is mostly earnings-based.

These findings are consistent with a balance sheet channel of monetary policy for firms. For example, financial frictions may force younger companies to borrow against collateral, the value of which may be exposed to macroeconomic shocks. Alternatively, firms might be exposed to fluctuations in asset values because borrowing is tied to net worth as a result of agency problems (leading to an external finance premium). Higher interest rates generate a fall in asset prices which lowers the value of firms' assets. Tighter financial conditions lead to a fall in investment.¹ These predictions are very consistent with the balance sheet response of younger firms paying no dividends we find in the data. On the other hand, our evidence shows that older firms and dividend payers are less likely to be constrained by the value of their assets and seem less exposed to this type of amplification mechanism.

Our empirical strategy uses firm-level data from Worldscope for the U.K. and Compustat for the U.S.. These datasets have excellent coverage of balance sheet variables and are panel datasets with a long time dimension, which is necessary to examine the dynamic effects of monetary policy.

¹Bernanke et al. (1999) and Kiyotaki and Moore (1997) are classic references on these types of mechanisms.

Despite these benefits, one potential drawback is that these datasets focus on public firms. That said, public firms account for between 50% and 60% of aggregate business investment and the growth rates from the micro data and aggregate official statistics are highly correlated.² Our results are therefore informative about a large proportion of the aggregate effects of monetary policy. To the extent that financial constraints are likely to be tighter for private firms than for public firms, our findings might represent a lower bound for the role of firm finance and financial frictions in the transmission mechanism of monetary policy.

Our new proxy for financial constraints is based on firm age. This turns out to be an excellent sufficient statistic for a range of characteristics typically associated with credit constraints such as being smaller, having low credit scores and lower earnings. Importantly, however, age is pre-determined, does not respond to monetary policy and the assignment of firms to age groups is not sensitive to arbitrary decisions about what defines, for example, a small firm or a highly levered firm. Compustat only features a sparsely populated variable based on the Initial Public Offering (IPO) date. In contrast, Worldscope contains *incorporation* dates for the vast majority of public firms in both the United Kingdom and the United States.³

To study the dynamic effects of monetary policy we need a series of identified shocks. This ensures that our exogenous variation is not driven by other macro factors and also limits any potential reverse causality issues. We isolate a time series of monetary policy shocks by exploiting the high frequency surprises in interest rate futures contracts within a 30 minute window around policy announcements, following Gurkaynak et al. (2005), Gertler and Karadi (2015) and Nakamura and Steinsson (2018a). We then employ a local projection instrumental variable panel approach and estimate the dynamic effects of monetary policy shocks on firms. One flexible feature of the local projection technique is that we can estimate non-parametrically the dynamic effects across firms by interacting our monetary shock with bins of the age/size/leverage/liquidity/growth distribution. This allows us to estimate impulse response functions for different groups of firms and examine which group drives the aggregate response. The strategy also allows us to conduct multivariate heterogeneity analysis, flexibly defining our bins based on the outer product of various firm characteristics (for example younger and smaller vs. younger and larger, or younger and lower levered vs. older and lower levered). In this sense, we can study the response of different variables by age, conditioning on size, growth, leverage and liquidity in a non-parametric manner. By jointly study-

²The micro data can be aggregated and then compared to official business investment data from the Office for National Statistics and the Bureau of Economic Analysis, as in Appendix A.

³Our decision to focus on age since incorporation is driven by data availability. But, in the next section, we show suggestive evidence that both age since *incorporation* and age since *foundation* correlate similarly with other firms characteristics in a way that is consistent with both containing information about the length of a firms history or experience in the credit market.

ing key aspects of the firm balance sheet, we can shed light on whether the results for particular groups are consistent with the predictions of various financial frictions models.

Related literature. A selected review of the more theoretical contributions on financial frictions and firm dynamics will be covered in the next section, and this will serve as a motivation for our empirical strategy. Here, we summarize how our work relates to three independent, but related, branches of macro research using firm-level data.

A well-established empirical literature, exemplified by the studies of Davis et al. (1996), Haltiwanger et al. (2013), Kalemli-Ozcan et al. (2018) and Dinlersoz et al. (2018), has shown that corporate age is a key determinant of employment and leverage dynamics over the business cycle.⁴ Relative to these influential works, we focus on identified monetary policy shocks and investigate the dynamic responses of investment, borrowing, net worth and cash flows at the firm-level across different demographic groups.

Another important strand of research has looked at debt covenants and reports pervasive heterogeneity in asset-based versus earning-based lending (Chodorow-Reich and Falato (2017), Lian and Ma (2018), Drechsel (2018)). Covas and Den Haan (2011) and Begenau and Salomao (2018) study debt versus equity issuance by firm size over the business cycle. The significant role of collateral constraints for firms is the focus of Chaney et al. (2012), Liu et al. (2013) and Bahaj et al. (2018). Relative to these contributions, we look at heterogeneity in borrowing and other sources of funds by age and, more importantly, we associate it with heterogeneity in the investment responses to monetary policy shocks.

A large empirical literature on investment has proposed various proxies for financial constraints, including cash flows (Fazzari et al. (1988), Oliner and Rudebusch (1992)), size (Gertler and Gilchrist (1994), Crouzet and Mehrotra (2017)), paying dividends (Fazzari et al. (1988), Farre-Mensa and Ljungqvist (2016)), bank debt (Ippolito and Ozdagli (2018)), leverage (Ottonello and Winberry (2018)) and liquidity (Jeenas (2018)).⁵ Relative to these proxies, we find that age has stronger predictive power for the effects on investment. More importantly, we explore heterogeneity in the effects of monetary policy on net worth, debt and cash flows, and show that looking at how different forms of firm finance respond is crucial to shed light on the monetary transmission to investment.

⁴Similarly, a long standing tradition in the empirical analysis of household expenditure survey data has advocated age as a proxy for access to financial markets and an important driver of consumption dynamics (see for instance, Attanasio and Browning (1995) for a classical reference and Wong (2018) for a more recent contribution).

⁵Several later studies have warned that the investment sensitivity to cash flows should not be interpreted as evidence in favour of financial frictions as cash flows can be shown to be a determinant of investment in both theoretical models with and without financial frictions (see for instance Kaplan and Zingales (1997) and Gomes (2001a)).

Structure of the paper. In Section 2, we discuss selected theoretical contributions that help frame and guide our empirical analysis. This also formalizes the link between firm finance and investment. In Section 3, we present the data, the construction of our proxy for age and how firms' balance sheet variables and other characteristics vary over a firm's life-cycle. In Section 4, we lay out our empirical framework and identification strategy before presenting the average effect in our firm-level panel data. The heterogeneous adjustment in capital expenditure following an unanticipated interest rate change is the focus of Section 5, where we emphasize that our newly constructed measure of age is a stronger predictor of a larger capital expenditure response than size, asset growth, Tobin's Q, leverage or liquidity. In Section 6, we report the responses of several balance sheet variables and find that while net worth declines for all firms after a monetary tightening, borrowing declines only for younger firms. We also show that younger firms' debt is more exposed to asset values fluctuations, against the backdrop of an increase in interest payments. Finally, we document that the response of cash-flows is more homogeneous across firms. In the on-line Appendices, we conduct an extensive set of further, complementary analyses and robustness checks along many possible dimensions of heterogeneity.

2 Financial frictions and firm dynamics in theory

To guide and organize our empirical analysis, we first summarize key aspects of the theoretical literature. Several frameworks emphasize the role of financial frictions in the transmission of macroeconomic shocks. Broadly, we group these contributions into three sets: studies that examine asset value/net worth channels in representative agent models; theories that emphasize age and growth prospects in the presence of firm heterogeneity; and, studies that link firm dynamics with different corporate finance decisions.

In the first set of contributions, more grounded in the traditions of the macro literature, constraints on a firm's ability to finance its operations have been typically captured by introducing asymmetric information and imperfect contract enforceability in models with a representative firm.⁶ Classic references include Bernanke and Gertler (1989), Kiyotaki and Moore (1997), and Bernanke et al. (1999). In these models, asset values and net worth play a key role in propagating and amplifying shocks. This is either because assets have to be used as collateral for borrowing or because the value of net worth reflects the probability of default leading to an external finance premium (the so-called "financial accelerator" as in, for example, Bernanke et al. (1999)). As argued by Catherine et al. (2018), the main robust prediction of these mechanisms is that movements in net

⁶Although the distribution of leverage in these models is degenerate, this simplification comes with the advantage of being able to analyse the feedback between investment and endogenous asset prices.

worth/collateral values can heavily influence borrowing and investment dynamics. Our joint empirical analysis of both capital expenditure and different forms of corporate finance will shed light on the role of this type of mechanism.

The second literature models heterogeneity along multiple dimensions to study how these affect firm dynamics. Life cycle aspects can be important. Generating such multidimensional heterogeneity in a firm dynamic model is challenging but a number of important contributions by Cooley and Quadrini (2001), Gomes (2001b), Cooper and Haltiwanger (2006) and Khan and Thomas (2013) have successfully incorporated financial constraints (implicitly or explicitly modelling the underlying friction) as well as non-convexities/irreversibilities in investment into the standard firm dynamic model with decreasing returns to scale technology.⁷ In these models age is important. Younger firms, reflecting their higher growth prospects and/or risk, are more financially constrained and change their borrowing and investment more significantly following a shock. These frameworks match several moments of the dynamics of growth and investment rates by age (conditional on size) and by size (conditional on age) in the data (mainly on manufacturing firms).⁸ In these models, it is usually the case that firms start with debt-financed investment and then, as they approach their efficient level, invest less and so tend to pay off their debts. These models predict that leverage should decrease with age.⁹

The third strand of work focuses on firm finance and highlights that a firm's leverage is not necessarily the best predictor of how that firm responds to shocks: the relationship between leverage and age/size depends on how frictions are modelled. Lian and Ma (2018) document pervasive heterogeneity in how loan contracts are specified for different U.S. companies. Although many firms use assets as collateral, a sizable share of them have debt covenants drawn on their earnings. Following a shock, this may generate heterogeneous investment responses, even if all firms experience the same fall in asset values.¹⁰ In Begenau and Salomao (2018), entrepreneurs can finance their investment with both internal accumulated liquidity or external funds, such as debt and equity.

⁷It is technically difficult to model such multidimensional heterogeneity in a firm dynamic model in a frictionless environment with constant return to scale production technologies, or in models where firms face the same financial friction and productivity shock (see Bayer (2006)).

⁸Most of the early literature on firm dynamics focused heterogeneity in growth and investment rates by age and size, matching the *unconditional* dynamics in the data, either across the age dimension (through a learning mechanism as in Jovanovic (1982)) or across the size dimension (through the persistence of technology innovations as in Hopenhayn (1992)). Conditional on size/age, all firms are identical and therefore make the same decisions.

⁹In the firm dynamics literature, corporate age has also been associated with experience and the possibility of learning about features that affect how a firm reacts to shocks: earning uncertainty, managing customers and suppliers, etc. For instance, Atkeson and Kehoe (2005) consider a model with heterogeneity in productivity and age across plants, which they refer to as *organizational* capital. This type of intangibility captures how much knowledge a plant has accumulated in order to operate a given technology. Rampini and Viswanathan (2010) and Rampini et al. (2014) focus, instead, on how firms of different experience engage in risk management so as to avoid being exposed to future unwanted fluctuations. Younger/more constrained firms might very well be less able/willing to engage in such management practices, therefore being more vulnerable to future shocks.

¹⁰Asset-versus-earnings based constraints have been recently studied in general equilibrium by Drechsel (2018).

Firms face an external finance premium because they can default on their debt, although this also has a tax-advantage over equity. On the other hand, there is a cost of issuing equity and all firms face a fixed operating cost. Conditional on a given degree of leverage, smaller/younger firms are riskier than larger firms. This is because the fixed operating cost makes smaller/younger firms more exposed to bad earnings shocks and they therefore default. In equilibrium, younger firms face a higher external finance premium and end up relatively less levered.

In summary, several key points are relevant for our empirical strategy. First, to understand the transmission of monetary policy to investment, we need to look at a broad range of firm characteristics, including age. Whether a particular firm characteristic predicts financial frictions will often depend on the specific model. Consequently, we need to look at the responses of all the different forms of firm finance, including borrowing. All these theories have different implications for how a firm's financial variables will respond to shocks. By examining all these variables in the data, our findings can be used to understand which theoretical mechanism(s) might account for the response of investment. Without considering (all these dimensions of) corporate finance, it is hard to evaluate why investment responds in a particular way to changes in monetary policy.

3 A new 'age' for firms

In this section, we briefly describe the micro data from firm-level balance sheet and income statements and the main variables of interest for our empirical analysis. Most of the variables used are standard in the literature, so we relegate a detailed description of sources, definitions and sample selection to Appendix A. Here we propose and focus on a simple proxy for a firm's track record in the credit market, which we loosely refer to as 'age', and show how this demographic measure correlates with a number of firms' characteristics. The age dimension has been so far overlooked in the empirical analysis on firms' investment decisions, but it will play an important role in our analysis.

Detailed and high quality balance sheet and income statement data for publicly listed companies are available on a quarterly basis from Compustat for the United States and on a fiscal year basis from Thomson Reuters' WorldScope for the United Kingdom. In WorldScope, British firms report in different months throughout the year but each firm tends to report always in the same month across years. This allows us to exploit monthly variation in annual changes for the U.K.. Consistent information for a sufficiently large number of firms in both dataset only begins in 1986, when our sample starts. The sample ends in 2016, when the data were collected for this project. Turning to our main variables of interest, the investment *rate* is defined as capital expenditures in period t relative to the level of physical capital, as measured by net plant, property and equipment at the

beginning of the period. For the U.K., this information refers to activity throughout the reporting period (the fiscal year); for the U.S., these data are based on calendar quarters.¹¹ In addition to being a widely-used measure in the empirical literature on investment (see for example Chaney et al. (2012)), it allows us to compare the investment decision of firms with different levels of capital. The main corporate finance variables of interest are cash-flows, which we proxy with EBITDA (earnings before interest, tax, depreciation and allowances) as is common in the literature, total and long term debt, net worth/market value of equity (the product of common shares outstanding multiplied by the price), share prices and interest expenditure. We therefore jointly examine the response of internal funds, debt and equity. In our analysis we will also use information on cash dividends paid, firm size (book value of total assets), leverage (total debt divided by the book value of total assets), liquidity (short term cash and investments divided by the book value of total assets), growth (growth in total assets), Tobin's (average) Q (the ratio of market value of assets to book value).¹² More detailed information on data sources, variable definitions and sample selection are provided in Appendix A.

A long-standing literature using micro-data on firm-level employment has strongly advocated an important role for age (since foundation) as a driver of aggregate employment growth as well as a source of heterogeneity across firms over the business cycle (e.g. Haltiwanger et al. (2013) and Fort et al. (2013)) but this 'demographic' dimension has been typically overlooked in the empirical literature on firm-level investment.¹³ A possible reason for this is that most of the research on investment has focused on U.S. Compustat data where age is based on IPO date and is sparsely populated.¹⁴ Interestingly, however, the incorporation year is available for the vast majority of publicly listed companies in the United States and the United Kingdom from WorldScope. Hence, we merge these datasets to provide a consistent measure of firm age in both countries: the number of years since incorporation.¹⁵ Importantly, age is an exogenous characteristic and is a function of predetermined decisions about incorporation. The identification of firms by age is also not sensitive to decisions about what defines, for example, a small firm or a highly leveraged firm. These endogenous characteristics vary over a firm's life, vary at high frequency and, as we shall see, respond to monetary policy.

¹¹Although data are assigned to calendar quarters in Compustat, some variables are cumulative within the fiscal year. In line with the literature, we difference these variables within the fiscal year to reconstruct the quarterly series.

¹²We proxy size using total assets rather than employment because the employment variable is less well populated.

¹³Analogously, a large empirical literature using micro data on household expenditure has advocated a very significant role for age in driving consumption dynamics over the life-cycle and over the business cycle (see for instance Attanasio and Browning (1995) and Gourinchas and Parker (2002)).

¹⁴The age variable in Centre for Research in Security Prices database, which can be easily merged into Compustat, is based on the start of the stock market data.

¹⁵In the minority of cases where this is missing, we use the number of years since IPO from the Centre for Research in Security Prices database.

Our goal is to construct a proxy for a firm's track record or financial history in credit markets and use this variable — together with size, leverage, liquidity and other characteristics — to explore the heterogeneous response of capital expenditure to interest rate changes. For this purpose, the number of years since incorporation compares well with the number of years since foundation. Furthermore, while it is possible to exploit information on the founding years, these are only available for a limited number of companies in either dataset.¹⁶ Years since incorporation will therefore be our proxy for firm age. Importantly, however, the descriptive statistics reported in this section are very similar to the correlations reported by Dinlersoz et al. (2018), who measure age as years since foundation among all publicly listed companies using the U.S. Census Bureaus Longitudinal Business Database from 2005-2012.

A simple but formal way of assessing the association between our new measure of financial age and other firm characteristics is to regress each of the characteristics of interest against a polynomial on age together with a measure of firm size (for all firms' characteristics regressions but the one for size) and the interaction between sector and year fixed effects to clean for common trends at the sectoral level. This specification is similar to the one used by Dinlersoz et al. (2018) and this facilitates a comparison with their results based on administrative data.¹⁷ Our dependent variables in Figure 1a are (i) size in the first row (ii) asset growth in the second row, (iii) Tobin's Q in the third row and (iv) EBITDA (as a share of past assets) in the fourth row. In Figure 1b, we report the relationship between age and selected firms' financial variables such as: (v) leverage in the first row, (vi) the probability of having paid dividends or buy backs in the previous year or having issued bonds ever in the second row, (vii) credit performance — measured by credit ratings in the small sample of U.S. bond issuers and credit scores in the full sample of U.K. listed firms — in the third row and (viii) liquidity in the last row.¹⁸

The top row of Figure 1a reveals that firm size is monotonically increasing with age for both the U.S. (left column) and the U.K. (right column), independent of whether we use the full sample

¹⁶This can be done in the United States using Jay Ritter's database and we have verified that our main findings are robust to exploiting years since foundation as a measure of age in this more selected sample of firms.

¹⁷As a robustness check, we use instead a set of dummies that capture the position of each firm in any given year within the distribution of age. In practice, we categorize each firm-year observation into an age quintile so that the corresponding dummy takes value of one if a firm-year belongs to that quintile and zero otherwise. Results using this semi-parametric approach are similar. It is also worth noting that while we focus on age rather than birth cohorts, the empirical specifications behind the charts in Figures 1a and 1b include time fixed effects (interacted with industry fixed effects). This implies that the evidence in this section can be interpreted as evidence on firm dynamics over their life-cycle.

¹⁸The chart on credit scores for the U.K. (made available to us by Bahaj et al. (2018)) refers to the universe of listed companies based on the Companies House information recorded in the Bureau van Dijk database. The chart on credit ratings for the U.S. comes from the Centre for Research in Security Prices and is only available for the small group of bond issuers. More specifically, on average, every year less than 7% of U.S. traded firms issue bonds and only one fifth have ever done so over their entire life. While credit ratings are, in principle, an appealing — albeit endogenous — metric, the lack of coverage is one reason why finding a good proxy for financial conditions is necessary.

of firms that record assets or the smaller sample of firms that report the number of employees. In line with Davis et al. (1996), the second row confirms a sharp negative association between growth and years since incorporation; the third row shows that older companies tend to experience lower Tobin's Q values, while the fourth row reveals that younger firms tend to have smaller or even negative operating profits early in their corporate cycle.

Figure 1b examines the financial variables. Less experienced companies appear less leveraged (first row),¹⁹ are less likely to pay dividends,²⁰ or issue bonds (second row), have worse credit scores (third row) and tend to hold a higher share of liquid assets (last row).²¹ In particular, the results on the relation between leverage and age is consistent with the results based on years since foundation for publicly listed companies in Dinlersoz et al. (2018). The statistical association of age with the probability of paying dividends and Tobin's Q is consistent with the predictions of the theoretical model by Cooley and Quadrini (2001).

In summary, our descriptive analysis reveals that, on average, younger firms are smaller, have lower cash-flows/earnings, worse credit scores and a lower probability of paying dividends. On average, they also grow faster, have a higher Tobin's Q, have lower leverage and more liquidity. Furthermore, a comparison with the results in Dinlersoz et al. (2018) suggests that years since incorporation (used in this paper) and years since foundation (used in their paper) correlate similarly with other firm characteristics.

Finally, as a first step toward a macro analysis with micro data, we are interested in understanding how much of the aggregate investment dynamics is captured by publicly traded firms.²² To do so, we aggregate the investment reported by each firm for a given period of time into a measure of investment at calendar frequency. The comparison with the growth rates of the aggregate series from the BEA and ONS national statistics, which include investment by both public and private firms, is shown in Appendix A Figure A.1. The left column refers to the U.S. and the right column to the U.K.. While publicly listed companies account for between 50% and 60% of the level of investment in both countries, the dynamics of the capital expenditure series aggregated from micro data are very similar to the dynamics of the official investment data. More specifically, the correlation of the growth rate of capital expenditure from the micro data and the growth rate of of-

¹⁹As shown by Dinlersoz et al. (2018) for the U.S. and by Bahaj et al. (2018) for the U.K., the regression curve between leverage and age is negatively sloped among private firms.

²⁰The proportion of firms paying dividends in the US is systematically lower than in the U.K. but this may partly reflect the (historic) tax advantage given to buying back stock. We therefore also report this probability for the U.S. and the U.K.. As expected the probability of engaging in buy back is much larger for the U.S.. We will return to the issue of buy backs later.

²¹The larger liquidity holding observed among younger firms chimes with the evidence in Bates et al. (2009), who identify a precautionary motive (in anticipation of possible financial constraints in the future) as a main driver of larger cash holdings among U.S. traded firms, especially non-dividend payers (which are likely to be younger firms).

²²Unlike survey data where we would use sampling weights to evaluate the representativeness relative to the population, here we are not dealing with a sampling issue as we observe the universe of publicly listed companies.

ficial aggregate business investment is above 0.7. Understanding the dynamic behaviour of publicly listed companies can therefore provide important information about a sizable part of transmission of monetary policy (and other shocks) to the aggregate economy. To the extent that private firms face similar, or even tighter, financial conditions, our findings could be interpreted as a lower bound on the relevance of financial constraints for the transmission of monetary policy to investment. In the next section, we lay out our strategy for identifying monetary policy shocks and the empirical design for the micro-data analysis.

4 Empirical framework

In this section, we describe our identification and empirical strategy. In particular, we first discuss the way we construct the series of monetary policy shocks. We move then to our main empirical specifications. In the final part of this section, we present the estimates of the average effect of interest rate changes on investment in our micro-data and show this compares well with standard results from the macro time series literature.

4.1 Identification

Identifying the dynamic causal effects of monetary policy on investment requires tackling the potential reverse causality: interest rates respond to the economy and also affect it. This is a standard problem in the empirical macro literature (see Nakamura and Steinsson (2018b)) but it poses a further specific problem in our panel micro data setting. We need our estimated effects to be driven by exogenous changes in monetary policy, not some other macro factor that drives interest rate changes. Furthermore, some of the firm groups we consider may account for sizeable movements in aggregate variables and thus trigger a monetary policy responses that are correlated with conditions in that particular group. As in the macro literature, we need some exogenous variation in policy rates.

Our identification strategy is based on the proxy-VAR/external instrument approach of Mertens and Ravn (2013) and Stock and Watson (2018), applied to monetary policy in the U.S. by Gertler and Karadi (2015) and in the U.K. by Gerko and Rey (2017). The idea is to isolate interest rate surprises using the movements in financial markets data in a short window around central bank policy announcements. Building on Gurkaynak et al. (2005), Gertler and Karadi (2015) and Gerko and Rey (2017) measure financial market surprises from Fed Funds Futures and Short-Sterling Future contracts respectively, using a very short time window around the Federal Reserve and the Bank of England policy announcements. The plausible identifying assumption is that nothing else occurs within this time window (which could drive both private sector behavior and monetary policy decisions). The technical innovation in Gertler and Karadi (2015), and also employed in Gerko and

Rey (2017), is to use these high frequency surprises as proxies for the true structural monetary policy shocks in a Vector Autoregression.

Data on Fed Funds Futures and on Short-Sterling Futures are available since 1991 and 2000 respectively while the firm-level data span the period 1986-2016. One advantage of the Mertens and Ravn (2013) and Stock and Watson (2018) proxy-VAR used by Gertler and Karadi (2015) and Gerko and Rey (2017) is that even if the identification of the contemporaneous causal relationships is based on the sample for which the proxy/instrument is available, the VAR can be estimated on a longer sample. This identifies a sequence of monetary policy shocks for a longer sample. We therefore use the implied monetary policy shocks from the Gertler and Karadi (2015) and Gerko and Rey (2017) VAR as our measure of monetary policy shocks in the micro data. This allows us to obtain a time series of monetary policy innovations for the full micro-data sample: 1986-2016.²³ The approach also only requires the high frequency surprises to be contemporaneously exogenous and the VAR will purge any remaining predictability. Finally, by directly following Gertler and Karadi (2015) and Gerko and Rey (2017), our micro results will be more directly comparable to the macro literature (as we show in Appendix C). For all these reasons this method is preferable to using the financial surprises directly in our panel estimation.²⁴

First, we estimate the Gertler and Karadi (2015) and Gerko and Rey (2017) reduced-form VAR for our sample period 1986-2016, keeping as close as possible to their specification. Our goal is to take these monetary policy shocks “off the shelf”. The VAR includes a measure of interest rates, log industrial production, the employment rate, the log of the consumer prices index for the U.S. and the log of the retail prices index (excluding mortgage interest payments for the U.K.), a measure of corporate interest spreads and, for the U.K. only, the dollar-sterling exchange rate.²⁵ The monetary policy shocks used for estimation are shown in Appendix B, together with the high-frequency monetary policy surprises.

We then use these monetary policy shocks in our micro panel regressions. Since these are exogenous disturbances, there is no need to include further macro controls. To estimate the dynamic causal effects from the micro data, we use a panel local projection instrumental variable technique, following Jordà et al. (2017). This is a very flexible specification that allows us to estimate impulse

²³These can simply be obtained by inverting the structural VAR impact matrix in Gertler and Karadi (2015) and Gerko and Rey (2017).

²⁴This approach does not, therefore, require that the high frequency surprises are the true monetary policy shocks (as in Ottonello and Winberry (2018) and Jeenas (2018)).

²⁵Following Gertler and Karadi (2015) and Gerko and Rey (2017), the interest rate is the one-year government bond yield for the U.S. and the five year gilt yields for the U.K. (as those rates maximize the instrument strength in the first stage regressions) while the credit spread is the excess bond premium compiled by Gilchrist and Zakrajsek (2012) for the U.S. and the difference between the mortgage rate and the 3-month sterling bill rate used by Gerko and Rey (2017) for the U.K.. We are grateful to Peter Karadi who has kindly provided us with an updated set of financial market surprises to 2016. The updated Gilchrist and Zakrajsek (2012) spreads data are available from the authors' websites.

response functions on firm-level panel data using the identified monetary shocks as instruments for interest rate changes. With this technique, it will then be straightforward to conduct multivariate heterogeneity analysis in a dynamic setting.

Before turning to the precise micro-econometric specification, it is first useful to study whether monetary policy has an effect on business investment in the data from national accounts. Official business investment data are available at quarterly frequency. As is common in the macro literature, we therefore sum our monetary policy shocks to quarterly frequency. A simple regression will then allow us to uncover the impulse response functions for business investment and any other variable of interest. To keep the specification close to the micro regressions below, we estimate the following sequence of local projections for any horizon h :

$$y_{t+h} - y_{t-1} = \alpha^h + \beta^h R_t + \nu_{t+h} \quad (1)$$

where R_t is the end-of-quarter interest rate used in the VAR above, which is instrumented using our extracted series of monetary policy shocks summed to quarterly frequency.²⁶ The variable y_{t+h} represents log real quarterly business investment and the β^h refers to the impulse response function at period h .²⁷

In Appendix C, we show that an initial 25bp rise in the interest rate leads to a fall in business investment of around 0.6-0.8% after two years. We also report the results for industrial production, employment and credit spreads to show that this method produces results that are qualitatively and quantitatively consistent with results in Gertler and Karadi (2015) and Gerko and Rey (2017). Higher interest rates contract economic activity and investment in the aggregate. In the micro analysis below, we will also find a similar time profile for the firm-level impulse responses but we will depart significantly from the macro analysis in this section by studying various dimensions of heterogeneity.

4.2 Baseline specification

In order to capture the heterogeneous effects of monetary policy, in our benchmark empirical specification, we estimate impulse response functions using an instrumental variable (IV) variation of the local projection (LP) approach (LP-IV) proposed by Jorda (2005).

$$\Delta_h X_{i,t+h} = \gamma_i^h + \sum_{g=1}^G \beta_g^h \cdot \mathbb{I}[Z_{i,t-1} \in g] \cdot R_t + \sum_{g=1}^G \alpha_g^h \cdot \mathbb{I}[Z_{i,t-1} \in g] + \epsilon_{i,t+h} \quad (2)$$

²⁶It is possible to estimate these macro responses in one step using the proxy-VAR, although this requires summing the instruments to quarterly frequency. We prefer to instrument interest rates at a monthly frequency (which is closer to the frequency of monetary policy decisions) and estimate the quarterly IRFs ex-post. This two-step approach is also more consistent with the way we estimate the effects on investment using the micro data but we have verified that it has a negligible impact on the estimated effects using aggregate data.

²⁷Generally, the error terms exhibit serial correlation, so these are corrected using the Newey-West method.

In the U.S., t refers to quarters and we have a standard quarterly panel. We also include quarter dummies to handle seasonality. In the U.K., different firms report in different months throughout the year and we observe (or can construct) variables that refer to changes over the twelve months running up to the reporting month. The subscript t refers to years but the data have a monthly dimension. For each firm observation, the interest rate is recorded at the end of the reporting month m in year t and we include month dummies.

The dependent variable X will be the variable of interest: the investment rate in Section 5 and net worth, borrowing and cash flows in Section 6.²⁸ Z_{t-1} is a set of firm characteristics and the indicator function takes a value of 1 if the firm characteristic falls in a particular “bin” of the distribution, which we will refer to as the firm’s group. Importantly, Z can be multidimensional and we can have separate slopes for finer groups, for example young/small/low leverage, old/large/high leverage, etc. In essence, this is a non-parametric way of estimating the heterogeneous effects of monetary policy by different (and possibly multivariate) firm characteristics. We are not, therefore, imposing linearity in the interaction. This is something that turns out to be important and also distinguishes us from virtually all earlier contributions working on investment heterogeneity at the firm-level. We also do not include other time or sector-time fixed effects as we want to interpret these coefficients as group specific impulse response functions, including any general equilibrium effects. This allows us to estimate conditional impulse response function as flexibly as possible. But we do add firm fixed effects, which not only absorb any sector fixed effect but also allows us to exploit within-firm variation. The interest rate (interacted with the dummies) will be instrumented by the monetary policy shock (also interacted with the dummies).²⁹ Standard errors are clustered by firm and time, although the error bands are not particularly sensitive to clustering by other cross-sectional units.³⁰ Finally, we will be estimating IRFs over five years, so we restrict the sample to only include firms we observe for at least five years.

4.3 The average effect

Before presenting the IRFs across the various groups, it is useful to report the average effect in our firm-level panel data. This serves two purposes. First, it will shed light on the contribution of the average publicly traded firm to the dynamics of the impulse response based on aggregate national accounts data, where the latter (but not the former) is an object that has been thoroughly analysed

²⁸Our results for investment are also robust to only including changes in the investment rate of more than $\pm 1\%$.

²⁹The advantage of using the monetary shocks as instruments is that the scale of the shocks extracted from the VAR are not pinned down. This approach allows us to interpret our impulse response functions in whatever units of R_t we choose, rather than units of the shock.

³⁰For the U.S. where the time dimension is sizable, we use the approach of Driscoll and Kraay (1998) which deals with possible serial correlation in the forecast errors $\epsilon_{i,t+h}$ which is a feature of the local projections technique. We set the number of lags to 12.

in the macro literature. Second, the average effect will provide a benchmark against which we can evaluate the contribution of the response of each group. To estimate the average effect, we drop the group dummies from equation 2 and replace the group-specific coefficients on the interest rate with a single parameter β_h for the full-sample and for each horizon h . We interpret β_h as the average effect of interest rates on investment at horizon h .

The left column of Figure 2 reports the impulse response function at quarterly frequency for the U.S. while the right column refers to the yearly impulse responses for the U.K.. Both sets of estimates cover a period of up to five years (β_h for each horizon h and so twenty point estimates for the U.S. and five point estimates for the U.K.). The investment rate declines significantly following a 25bp rise in the interest rate in both countries. The quarterly frequency of the U.S. estimates reveal that effect becomes significant towards the end of the first year and in both countries the peak effect is reached between the second and third year after the shock, at a value around -0.5 .³¹ The dynamic effects dissipate after the peak and become statistically negligible by the forecast horizon. These dynamics are consistent with the impulse response functions using aggregate data presented in Appendix C. This result is reassuring as it suggests that the average impulse response for the investment rate estimated from the micro data lines up with the macro response of business investment conventionally estimated using official national statistics. The firms in our sample are therefore responsible for a significant share of aggregate investment dynamics following a monetary policy shock. Furthermore, this average result gives us a meaningful benchmark against which to study the heterogeneous responses of capital expenditure across different groups of firms. In the next section our goal is therefore to “disaggregate” this average effect and see which groups drive the response and why. We will do this in two steps. First we look at the asset side of the balance sheet and examine heterogeneity in the investment adjustment by age (and other common proxies). We then explore the responses of the source of funds, namely equity, debt and cash flows, and ask how consistent is the behaviour of *both* financing variables *and* capital expenditure with a firm balance sheet channel of monetary policy.

5 The response of investment across firms

In this section, we look at the asset side of the corporate balance sheet and focus specifically on capital expenditure, given its importance in the macro-monetary literature. Our goal is to establish which firms are most sensitive to monetary policy, how important are these firms for the aggregate

³¹In the U.K. yearly impulse responses, the estimated value ‘on impact’ refers to the effect of capital expenditure within the first year after the shock. So the significant response within the first year for the U.K. impulse responses is consistent with the significant estimate in the fourth quarter after the shock for the U.S. quarterly impulse responses. In Appendix D, we report the U.S. average effect both at quarterly and yearly frequency so as to make visually easier for the readers to appreciate the similarities of the capital expenditure dynamics in the two countries.

response, and how well our new proxy of financial experience predicts heterogeneity in the response of investment.

We begin by focusing on the response of investment by ‘corporate age’, namely the number of years since incorporation. We examine how these results compare to more traditional proxies based on size, asset growth, leverage and liquidity. Age is a far more robust predictor of heterogeneity in the response of investment. We then consider a refinement of this demographic grouping strategy which splits the sample further according to whether a company has paid dividends or not in the past. We present three main results: (i) when grouping by age, heterogeneity in the investment response is far more pronounced than the differences found when grouping firms by any other characteristic; (ii) relative to any single dimension, the heterogeneity is even sharper when considering age and dividend status; (iii) this heterogeneity by age and dividend status is robust to controlling for size, asset growth, leverage and liquidity using a triple sorting strategy. In particular, for the most monetary-policy-sensitive group of firms by size, asset growth, leverage and liquidity, the response is always driven by the younger non-dividend payers. This highlights the risks of conditioning only on one of these other (endogenous) characteristics. For instance, some highly levered firms might be riskier. But highly levered companies may also be safer, as established firms may take on larger projects financed more with debt than equity (as noted by Lian and Ma (2018)).

5.1 Results based on corporate age (and other characteristics)

A long standing tradition in the micro-econometric analysis of expenditure survey data uses age of the household head as a proxy for access to credit markets. The rationale for such an interpretation is that younger households are typically less experienced, have a shorter credit history and a lower credit score, earn a lower income and therefore are more likely to face tighter financial conditions. On the firms’ side, the demographic dimension has been extensively investigated in the empirical literature on employment at the firm-level, especially using census data. But, although age is a proxy for a firm’s growth prospects in models where these firms face financial constraints (e.g. Cooley and Quadrini (2001)), we are unaware of studies using firm age in the context of capital expenditure.

Our goal is to measure the experience of a firm in financial markets or the length of corporate credit history. As argued in Section 3, and in a parallel to the consumption literature, years since incorporation is likely to be correlated with this credit history. We refer to our newly constructed variable as ‘corporate age’ or simply ‘age’ for short. More specifically, as explained in Section 4.1, we allow the effects of monetary policy to vary across the age distribution. We split the distribution into three bins/groups depending on whether, at the time of the monetary shock, they were incorporated less than fifteen years ago (‘younger’), between fifteen and fifty years (‘middle-aged’) or more than

fifty years ('older'). While there is no conceptual reason to prefer one specific age cutoff over another the results are not sensitive to the precise cut-off.³²

The capital expenditure responses by age are reported in Figure 3: the top row refers to younger firms, the middle row to middle-aged firms and the bottom row to older firms. The left column presents estimates for the United States while the right column for the United Kingdom. Three results are clear. First, there are considerable differences across groups. Second, the investment of younger firms is by far the most responsive: following a 25 basis points unanticipated increase in the interest rate, the investment rate falls by around 1% two-three years after the shock, before returning to zero. The effect is insignificant by the fourth year. Second, middle-aged firms and especially older firms reduce their capital expenditure by a far smaller amount, around 0.25%. The effect is also often insignificant for most — if not all — of the period. Third, despite the differences in productivity and capital market structures between the U.S. and the U.K., the behaviour of firms along the age dimension, especially younger companies, is very similar across the two countries. The main difference is that the response of middle-aged firms is slightly more pronounced in the U.S.. Given the average effects reported in Figure 2, and given the high correlation between aggregated micro data and national statistics in Figure A.1, the estimates in Figure 3 already suggest that younger firms account for most of the dynamic response of investment in the aggregate economy. We will quantify this more precisely below.

Results based on other (endogenous) firm characteristics. An important advantage of using incorporation date to sort firms into different demographic groups is that a firm's incorporation date is fully pre-determined and thus invariant to changes in monetary policy or the business cycle. Splitting the sample along other dimensions which *endogenously* respond to the shock or change frequently over the business cycle is, in contrast, problematic.

Policy changes, and business cycle fluctuations in general, could change the ranking of firms in the distribution of the variable used to create the bins/groups. This blurs the distinction between lower and higher groups, which are defined according to the *ex-ante* distribution. As a result, it is harder to interpret any (ex-post) heterogeneity as being driven exclusively (or even partially) by ex-ante differences in that particular firm characteristics. Heterogeneity in the capital expenditure response suggests total assets might respond heterogeneously. Bahaj et al. (2018) show that a firm's number of employees (another commonly used measure of size) responds to monetary policy, especially among younger firms. In Section 6.1, we find heterogeneity in the response of debt,

³²Further, when we do double- and triple-sorted later we will collapse this to younger and older firms based on the fifteen year threshold. This leaves the two groups evenly populated. Of course, these "younger" firms are not young in an absolute sense, so we avoid the term young vs. old.

implying that leverage endogenously responds. In Section 6.4 we show that cash flows and liquidity vary significantly in response to monetary policy.

Despite all these caveats, for the purposes of completeness and for comparison with other papers in the literature, we now examine heterogeneity in the response of capital expenditure allowing the impulse response functions to vary across the size, asset growth, leverage and liquidity distributions.³³ For each of these alternative characteristics, we assign firms to groups based upon their position in the distribution during the previous year. This is akin to non-parametrically estimating the effects of monetary policy by the variable of interest. For presentational reasons we report responses for lowest quartile, the middle two quartiles and the highest quartile of the variable of interest (e.g. size/leverage/growth etc.)

The full set of estimates are reported in Appendix E. Here, we summarize three main results. First, there seems to be little heterogeneity when splitting the sample by asset growth and Tobin's Q. This is important because younger companies may simply face better growth opportunities than older firms. The results in Figures E.4 and E.5, however, suggest that this interpretation is unlikely to account for the heterogeneity in capital expenditure by age reported in Figure 3.³⁴ Second, firms that are smaller size, have lower leverage or have higher liquidity tend to adjust investment more than firms in the rest of the distribution.³⁵ Third, the heterogeneity by size, leverage and liquidity in Appendix E appears less pronounced than the heterogeneity by age presented in Figure 3.³⁶ For

³³In Appendix E, we look at heterogeneity by Tobin's Q as an alternative proxy (relative to asset growth) for heterogeneity in growth prospects.

³⁴By definition, older companies have lived for longer and therefore, one may be concerned about survivorship rates among younger firms. Two main considerations, however, make this issue empirically less relevant in the present context. First, among younger firms, we find no heterogeneity when we further divide them according to their productivity or profitability, as measured for instance by high and low asset growth or high and low Tobins Q. To the extent that asset growth and Tobins Q are correlated with the unobserved characteristics driving survivorship, then the lack of heterogeneity across these high and low groups suggests that this concern is unlikely to affect our estimates. Second, any survivorship issue would most likely bias downward our estimates for the younger firms and thus the extent of heterogeneity we uncover would be, if anything, a lower bound. The reason is that the exiting firms would be more sensitive to business cycle fluctuations and monetary policy, which is why they stop capital expenditure and terminate their business in the face of an adverse shock. In other words, either monetary policy shocks have little impact on firms exit (and thus our estimates are unaffected) or if they do, their correlation with investment would be far more negative than for surviving firms and therefore the true extent of heterogeneity in the micro data would be even larger than what we report.

³⁵Lower levered and higher liquidity firms tend also to be younger, smaller, have lower credit rating, little earnings and are less likely to pay out dividends or issue bonds. This is consistent with the evidence in Opler et al. (1999), Han and Qiu (2007) and Bates et al. (2009), who document that firms with lower debt and higher cash holdings are more likely financially constrained.

³⁶As noted by Ottonello and Winberry (2018), the evidence based on grouping firms by leverage is not robust and one may find that the investment of lower or higher levered companies responds most depending on whether the firms grouping is based on leverage in the last period (as in Ottonello and Winberry (2018)) or is based on an average of leverage over the last few periods (as in Jeenas (2018)). While there is no substantive reason to prefer one definition to the other, the lack of robustness of the findings by leverage groups is consistent with the view that leverage is an endogenous variable and its distribution is not rank-invariant to the business cycle or the monetary policy shocks. This makes leverage an unattractive dimension along which to group firms. Age, in contrast, is fully predictable (independently of business cycle fluctuations) as the incorporation date has been set at least several years before the shock hits. Indeed, this is a main reason why age has proved such a popular grouping strategy in the empirical literature on firm-level employment and household-level expenditure.

example, both low and high leverage firms respond more than firms in the middle of the leverage distribution, but these differences are not sizable. We find some evidence that smaller firms respond more than larger firms, but again the heterogeneity is less pronounced than the heterogeneity by age. Older firms do tend to be larger, but not all older firms are large and not all larger firms are old. We will come back to this last set of results in Section 5.4 where we show that the heterogeneity in the investment responses by age is robust to conditioning on size, asset growth, Tobin's Q, leverage and liquidity, whereas the heterogeneity in the other characteristics becomes far less pronounced once we control for age (see Appendix F).

5.2 A refinement based on paying dividends status

A number of earlier contributions have argued that not paying dividends or not buying back shares could signal a different capital structure and thus a different access to financial markets.³⁷ To the extent that age does not fully capture the presence or, possibly, the severity of credit constraints, splitting our sample also along the dividends/buyback dimension (over and above demographics) may sharpen the identification of firms facing financial frictions.

Of course, as noted above, a potential drawback of this further sample split is that paying dividends or buying back shares may also be a firm's endogenous response to changes in monetary policy. To formally assess this hypothesis, we run a set of panel regressions in which the left hand side variable takes the value of one if a firm at time $t - 1$ paid dividends/bought back shares and zero otherwise. The regressors are firm fixed effects and two years of monetary policy shocks interacted with dummies for each age group.³⁸ We run separate panel regressions for firms paying dividends and for firms buying back shares to assess the cyclicity of each of these financial choices in isolation. In both countries, we find that the monetary policy shocks are significant predictors of whether a firm buys back shares whereas the probability of paying dividends in any given period is not statistically affected by changes in the interest rate.³⁹ Accordingly, we exclude buybacks from the sub-grouping strategy of this section and focus exclusively on further splitting the age groups between firms that have and have not paid dividends in the previous year.

To minimize the number of groups, we collapse middle-aged and older firms into one group (motivated by the results in Figure 3 and to maximize observations per group) and interact these

³⁷Farre-Mensa and Ljungqvist (2016) provide suggestive evidence that being young or not paying dividends may also proxy for a firm's position in its life cycle rather than for financial constraints only. In Section 5.4, however, we will show that in our data there is little heterogeneity among younger non-dividend payers when we further divide this group into faster-growing and slower-growing firms or into companies with higher and lower Tobin's Q.

³⁸Similar results are obtained using linear probability models, logit or probit specifications, with the latter however subject to the incidental parameter problem.

³⁹This is consistent with the finding that paying dividends seems an almost 'absorbing' state in the data: once firms begin to pay dividends, they rarely stop do so in normal times. In contrast, a firm's decision to engage in buy backs appears far more cyclical, possibly because of their uncertain future returns or their different tax treatment.

two age groups with a binary indicator of whether the firm paid dividends in the previous year. This produces four groups. The first row of Figure 4 shows the impulse response functions for younger firms (less than fifteen years since incorporation) and the second row reports the results for older firms (more than fifteen years since incorporation). The first column in each block refers to non-dividend payers and the second column refers to dividend payers. The two blocks reports results for the U.S. and the U.K.. Comparing the two rows reveals the marginal contribution of age, controlling for dividend status. Comparing the columns reveals the marginal contribution of paying dividends, controlling for age.

There are three main results from Figure 4. First, for younger firms, the investment of younger non-dividend payers accounts for the bulk of the effect in the left panel of Figure 3. On average the response of younger non-dividend payers is twice as large (at the peak) as for those paying dividends. Second, for non-dividend payers, younger firms (top row, columns 1 and 3) have the largest and most significant response, with the peak effect exceeding 1% in the U.S. and around 1.5% in the U.K.. Third, the adjustment of capital expenditure for older dividend payers (bottom row, columns 2 and 4) is both statistically and economically insignificant, being on average only one fifth than the response of younger firms who paid no dividends.⁴⁰

In summary, we have further refined the estimates in Figure 3 by showing that younger firms paying no dividends largely account for the average response documented in Section 4.3.

5.3 Contribution to the aggregate investment response

The evidence in Figure 4 suggests that younger non-dividend payers are likely to drive the average effect estimated in Figure 2 and are, therefore, also likely to make a very significant contribution to the aggregate response of investment to monetary policy shocks.⁴¹ To show this more formally, we compute the share of the average investment response accounted for by each of the four age/dividend groups. For each set of firms in Figure 4, we first compute the (discounted) cumulated percent change of capital expenditure over the forecast horizon and then multiply this by the average investment share of each group (relative to the total investment in the sample). Dividing this object by the sum of the same statistics for all groups provides an estimate of the contribution of that group to the

⁴⁰For completeness, in Appendix E, we also report the impulse response functions based only on past dividend status (Figure E.6) or based only on whether the firm has issued bonds in the past (Figure E.7). On average, only 20% of companies ever issue bonds in the U.S. and only 10% in the U.K.. The vast majority of non-bond issuers does not pay dividends. The results in Figures E.6 and E.7 reveal that the aggregate response of investment is driven by neither dividend payers nor bond issuers as we never record a larger (and in most cases not even significant) response for these groups.

⁴¹Older and larger firms paying dividends typically make a significantly larger contribution to the aggregate *level* of investment whereas younger firms account for about 30%. It is worth to emphasize, however, than in this paper we focus on *changes* in investment (induced by a monetary policy shock) rather than its level and therefore, as we shall see, the contribution of younger firms to that could be, and indeed is, much larger.

average response of investment.⁴² Table 1 shows the findings. The estimates are striking: younger firms paying no dividends account for around three quarters of the average effect of monetary policy on capital expenditure in both countries.

While the estimates in Table 1 refer to the contribution of each group to the average effect, it is straightforward to generalize these findings to the contribution of each group to the (whole-economy) response of aggregate investment to a monetary policy shock. These back-of-the-envelope calculations depends on an assumption about the investment elasticity of private firms, which we do not observe in our data. But, to fix ideas and provide a range of estimated contributions, we consider three cases. First assume that private firms are fully insensitive to monetary policy shocks. As listed firms account for about 50% to 60% of the gross fixed capital formation in the national statistics, this scenario implies that younger/no-dividends public firms would account for between 40% and 50% of the aggregate response. We find this scenario the least likely, nonetheless the contribution of younger firms paying no dividends would still be very significant. Second, in the intermediate scenario, assume that the distribution of investment responses to interest rate changes by age and dividend status is identical for private and public firms. The estimates in Table 1 would then represent the contribution of each group to the aggregate response. In the final scenario, the investment sensitivity of younger non-listed companies (paying no-dividends) to monetary policy changes is larger than the sensitivity of their listed counterparts and therefore the estimates in Table 1 would be a lower bound for the contribution of younger non-dividend payers in the whole economy to the response of aggregate investment to monetary policy changes.

5.4 Conditioning on other firm characteristics

The evidence in the previous section reveals that being younger and paying no dividends is a strong predictor of a larger response of investment to monetary policy changes. In Section 3, we have shown that younger firms tend to be smaller, have worse credit ratings, are less levered and hold more cash relative to older firms. We have also uncovered that younger firms exhibit higher asset growth, have a higher Tobin's Q but are far less likely to issue bonds. Above, we showed that each of these characteristics on their own generate far less heterogeneity (if any) than age but, in this section, we ask whether the heterogeneous responses by age/dividends grouping are robust to *controlling* for size, firms' growth, leverage and liquidity. It could be, for instance, that the heterogeneity by age disappears once we condition on size.

Unlike traditional panel regression analyses in which the identification exploits exogenous variation in the cross section, our identification strategy is based on exogenous changes (in monetary

⁴²While this strategy ensures that the shares of all groups sum up to 100%, we have verified that similar findings are obtained using as denominator the cumulated percentage change of the average effect in Figure 2 instead.

policy) that vary over time but are common across firms, while allowing for heterogeneous slopes along a variety of dimensions. Accordingly, the notion of controlling for other characteristics requires a different approach than simply adding further regressors to our baseline empirical specification. To examine the marginal contribution of age conditional on other characteristics, we interact the four age/dividends groups with quartiles of the size/leverage/liquidity/growth distribution. This is essentially controlling for the third variable in a fully non-parameter manner, a strategy that we refer to as triple-cutting the data or triple sorting.

By looking at the differences between the response of smaller-younger-paying no dividends firms and smaller-older-paying dividends companies, for instance, one can infer the marginal contribution of age and paying dividends status for a given (smaller) size. Similarly, by comparing smaller-younger-paying no dividends firms to larger-younger-paying no dividends companies, we will be able to assess the marginal contribution of size for a given (younger) age and (paying no) dividends status. As triple sorting is very demanding on the data, we maximize the number of observations per sub-groups of companies by using only two categories for age and two categories for the other characteristics. We maintain the same two age groups from above (based on fifteen years since incorporation). Dividend status is already binary. In terms of the third dimension of interest, we use the most responsive quartile from the analysis above vs. the rest of the distribution. To stick with the size example, this means comparing the bottom quartile of size (smaller) with the rest of the size distribution. This outer product generates eight bins. As a result, the full set of impulse response functions for all groups are reported in Appendix F. Here, for simplicity, we focus on younger firms paying no dividends vs. older firms paying dividends, conditional on the most responsive group according to the third dimension.

Considering size and growth first, we report the results conditional on being smaller or having faster growth. Figure 5 shows that among the smaller and faster-growing companies, only the younger non-dividend payers adjust their capital expenditure significantly after a monetary policy shock. In contrast, the investment of small and fast-growing older dividend payers is not affected by the change in the interest rate. In other words, the larger response of smaller and faster-growing companies in Appendix E is mostly driven by younger non-dividend payers.⁴³ Figure 6 for liquidity and leverage paints a very similar picture. Among the firms with lower leverage or with more liquidity, younger non-dividend payers is always the group that responds the most and drives the results in Appendix E. Another way to interrogate the figures in the Appendix is to ask: conditional

⁴³In Appendix Figures F.9 and F.10, we show that this finding is robust to using Tobin's Q instead of asset growth to proxy a firm's growth opportunities. This is interesting because a further concern is that older firms may be subject to a survival bias due to being firms with higher profitability or growth prospects. This interpretation, however, is inconsistent with the evidence in Appendix F which shows that younger firms with lower asset growth or lower Tobin's Q do not respond significantly less than younger firms with higher asset growth or higher Tobin's Q.

on being younger, do the effects vary by size, leverage, liquidity or growth? The answer is no. Once we condition on being young/paying no dividends, the responses across firms grouped along the third dimension are relatively homogeneous.

In summary, age and dividend status are strong predictors of significant heterogeneity in the response of capital expenditure to changes in monetary policy. This holds true over and above any possible heterogeneity by size, asset growth or Tobin's Q, leverage and liquidity. Heterogeneity along these more traditional (and arguably endogenous) firm characteristics seems weaker than the heterogeneity based on age and dividend status. It also tends to become marginally insignificant after controlling for age and paying dividends status.

6 Monetary policy and firm finance

In the previous section, we saw that age is a robust predictor of heterogeneity in the response of investment to monetary policy: younger firms, especially non-dividend payers, respond considerably but other companies react far less or hardly at all. Earlier empirical studies on consumption using household-level data (see for instance Attanasio and Browning (1995) and more recently Wong (2018)) and on employment using firm-level data (see for instance Davis et al. (1996) and Haltiwanger et al. (2013)) provide evidence consistent with the notion that being young is correlated with unobserved characteristics driving experience and access to credit markets. Earlier studies on investment using firm-level data (see for instance Fazzari et al. (1988) and more recently Farre-Mensa and Ljungqvist (2016)) have shown evidence consistent with the notion that non-dividend payers face a relatively larger wedge between internal and external funding costs and thus possibly tighter financial conditions. While this is suggestive of a possible correlation between age and financial constraints, at this stage it is only an educated conjecture. Theoretical models of financial frictions, however, also have predictions for the responses of different forms of corporate finance. Understanding why capital expenditure at the firm-level is sensitive to movements in interest rates therefore requires a detailed analysis of how monetary policy affects firm finance. This is the goal of this section.

On the theoretical side, several studies in the firm balance sheet channel tradition of Kiyotaki and Moore (1997) and Bernanke et al. (1999) emphasize that financial frictions could amplify the transmission of monetary policy. Higher interest rates lower asset prices and push down equity values. This may lead to a rise in the external finance premium and generate a further decline in investment.⁴⁴ Higher interest rates can also trigger falling collateral values, and lead to a tightening of borrowing constraints whenever a significant portion of debt is secured against collateral (as in

⁴⁴This is the classic financial accelerator in Bernanke et al. (1999)

Kiyotaki and Moore (1997)). These asset-based channels have important implications for firms' financing decisions and their balance sheets. In this section, we look at how firms' net worth, share prices, borrowing, interest payments and cash flows/earnings respond to evaluate whether the response of these variables is supportive of the view that younger non-dividend payers may face more severe credit frictions.

6.1 Borrowing and interest payments

To examine the role of a firm balance sheet channel, a natural place to start is with the response of borrowing. These theories would predict that the borrowing of financially constrained firms should respond more. Figure 7 therefore shows the response of real debt growth, which we take as a measure of new issuance. The chart is structured using the same format of Figure 4: the two columns on the left (right) refer to U.S (U.K.) younger firms not paying dividends and paying dividends respectively. The two rows refer to younger and older firms, defined as before. Figure 7 shows that in both countries younger non-dividend payers change borrowing the most, following the monetary policy shock.⁴⁵

For this decline in borrowing to be consistent with a deterioration of credit conditions, younger non-dividend payers should also be facing a higher marginal interest rate following a contractionary monetary policy shock. While we do not observe the (marginal) interest rate at the firm-level, we can infer its response by looking at the movement in interest payments. This is shown in Figure 8. Interest expenditure tends to rise on impact and this is often significant. This effect is typically reversed during the second year. At face value, the response of interest expenditure is hard to interpret because this is a function of both interest rates and debt decisions. These negative estimates, however, are insignificant and are consistent with the decline in borrowing documented in Figure 7. In Figure 7, we showed that younger/no dividend companies borrow less when interest rates rise. The relatively homogeneous rise in interest payments, together with a more significant fall in borrowing for the younger/no dividend group, is consistent with a sharper rise in the marginal interest rate for these latter firms. Ideally, one would like to test this using actual interest rate data, but marginal interest rates are not available in our dataset. Finally, the findings in Figure 8 rules out that the heterogeneity in capital expenditure of Figure 4 is driven by heterogeneity in cash flows from interest payments.

This inference on the interest rate increases for younger non-dividend payers chimes with two additional pieces of evidence. First, using data on corporate bond yields, Anderson and Cesa-Bianchi (2018) show that the corporate spread only increases significantly for firms with a lower

⁴⁵The decline for younger non-dividend payers applies to both short-term and long-term borrowing.

credit rating (younger firms in our sample) following a tightening in monetary policy. Second, the aggregate evidence from national statistics in Appendix C reveals that, on average, corporate spreads and the policy rate are positively correlated after a monetary policy shock. The positive correlation between interest rates and corporate spreads is also consistent with the evidence in Gertler and Karadi (2015) and Caldara and Herbst (2018). The first finding is consistent with younger firms facing more severe financial frictions; the second result is consistent with financial frictions amplifying the effects of monetary policy.

6.2 Asset value exposure

In the previous subsection, we showed that borrowing only responds significantly for the younger/no-dividend firms. Another prediction of models where borrowing constraints are related to asset values is, naturally, that the borrowing of more constrained firms should be more exposed to fluctuations in asset prices and collateral values. A growing literature, however, has noted that different firms may face different types of financial constraints (see, for example, Lian and Ma (2018)). Some firms' borrowing may be more tied to their assets but others may face earnings/cash-flow based constraints. The fall in borrowing documented above might, therefore, be more correlated with changes in earnings than asset values.

To examine this question, in this section, we follow a very recent and promising literature on debt covenants (covering a sample of U.S. public firms) and project changes in long-term debt on lagged collateral values and lagged cash flows, controlling for firm fixed effects and other characteristics, including size, leverage, liquidity and Tobin's Q (see Lian and Ma (2018) and Drechsel (2018)). Relative to this literature, our focus is on heterogeneity in the correlation of borrowing with asset values and cash-flows by age/dividend status. Standard errors are clustered by firm and time.

Table 2 reports the results for both countries. In each panel, the first row displays the coefficient on collateral values (plant, property and equipment, plus accounts receivable and inventories scaled by total assets at the start of period t) while the second row shows the coefficient on lagged cash flows (EBITDA scaled by lagged total assets). The two columns on the left report estimates for younger firms (not paying dividends and paying dividends respectively) and the two columns on the right refer to older firms.

The estimates in Table 2 offer two main insights. First, the borrowing of younger non-dividend payers is significantly correlated only with collateral values. The coefficient on cash flows is insignificant and has the wrong sign. Second, for all dividend paying groups, the coefficient on earnings is not only very significant but also it is typically at least 50% larger than the coefficient on collateral values. These two findings reveal that the borrowing of younger non-dividend payers is far more correlated with asset values than is the case for older or dividend paying firms. This chimes with

independent evidence on debt covenants by Lian and Ma (2018) who, following our demographic classification (but using the number of years since Initial Public Offering as proxy for age), show that among U.S. traded companies, only the borrowing of younger firms is predominantly secured against assets whereas the vast majority of older firms debt is secured against cash flows.

6.3 Asset values and net worth

Borrowing declines the most for younger/no-dividend firms and their debt seems more highly correlated with asset values. If a firm balance sheet channel is at play via asset values, we should also see a decline net worth and/or asset prices following a monetary contraction. This is what we show in this section. In particular, equity values and share prices decline for all firms, consistent with the general equilibrium effects of monetary policy. As noted above, a key part of the asset-value-based financial constraints story is that falling net worth or collateral values then leads to a tightening of credit constraints. This is consistent with our evidence: net worth and share prices fall across the economy, but only the constrained firms experience a fall in borrowing, and these are the firms for whom investment responds the most.

Figure 9, shows the response of common stocks at market value.⁴⁶ In keeping with the format of the previous charts, the top (bottom) row displays the estimated impulse responses for younger (older) firms while in the odd (even) columns we further split the sample according to whether companies have not paid (paid) dividends in the previous year. The figure has one panel for the U.S. and one panel for the U.K.. Figure 9 reveals a significant, sizable and persistent decline in net worth for all groups following a contractionary monetary policy shock. The peak effect is around -4% for younger/no dividend firms. The peak effect for the other groups is also sizable (between -2% and -3%), somewhat less negative but not significantly so.

Another way to evaluate the response of asset values, is to look at how firms' share prices respond to monetary policy. This is shown in Figure 10. Similar to Figure 9, all groups witness a large and significant drop in share prices after an interest rate hike. The effects are persistent with a peak effect around -4% after two-three years for younger/no-dividend firms. The degree of heterogeneity in Figure 10 appears more pronounced than in Figure 9, especially for the U.K, although the differences do not seem significant.⁴⁷

In summary, for all age/dividend groups of companies, equity at market value and share prices decline persistently and sizably in response to an unanticipated interest rate increase.

⁴⁶Similar results are obtained using the log of assets at market values, whose interpretation, however, is confounded by the fact that assets increase mechanically with an expansion in capital expenditure, as estimated in Section 5.

⁴⁷The estimates of the dynamic effects of monetary policy on firm-level share prices are consistent with the aggregate response estimated using data use an aggregate stock market index.

6.4 Cash flows

Another channel through which financial frictions may amplify the effects of monetary policy on investment is the response of cash flows (a term we use in an economic sense rather than in strictly accounting sense). For instance, a fall in earnings following an interest rate increase could further accelerate the decline in capital expenditure if a significant fraction of firm debt is secured against earnings. While we have already shown in Section 6.2 that the debt of younger non-dividend payers is secured mostly against assets, a decline in cash flows could also trigger a shortage of internal funds, which may result in a further contraction of investment for firms struggling to attract external funds.

This earning-based amplification hypothesis is explored in Figures 11 and 12. Figure 11 reports the results for sales growth and Figure 12 reports the results for the growth of EBITDA (essentially sales net of costs). Again, we show the response of cash flows by age and dividend status. We maintain the usual 2x2 format. The responses of cash flows are not particularly sizable (especially in comparison to the response of net worth in Section 6.3) and are also relatively homogeneous across the four age/dividends groups. This is true in both countries using sales or EBITDA, although there is a slightly more pronounced effect on EBITDA for younger non-dividend payers in the U.K.. Together with the evidence in Section 6.2, we interpret the relatively smaller and more uniform estimates for earnings across groups as evidence that a cash flow channel, on its own, seems unlikely to play a quantitatively major role in accounting for the heterogeneity in the response of capital expenditure that we document in Figure 4. That said, although an earnings-based channel may be less important than an asset-based channel for younger firms, both channels imply that financial frictions amplify the dynamic effects of monetary policy.⁴⁸

6.5 Summary

In this section, we have provided a detailed and comprehensive analysis of how monetary policy influences different sources of firm finance. Corporate age appears an intuitive proxy for financial constraints, but it is hard to interpret heterogeneity in the investment responses without also looking at how a firm's financing behaviour changes with monetary policy.

Our findings are: (i) only the borrowing of younger firms paying no dividends declines when interest rates increase, despite interest payments increasing for all groups (Section 6.1); (ii) younger non-dividend payers are far more exposed to fluctuations in asset values (Section 6.2); (iii) net worth falls considerably for all companies (Section 6.3); (iv) the drop in cash flows is smaller and more

⁴⁸Figure 11 also shows that sales exhibit an even more homogeneous response to monetary policy shocks across demographic/dividend status groups. This also suggests that heterogeneity in demand is unlikely to be a main driver of the heterogeneity in capital expenditure responses. Furthermore, we emphasize that even a significant demand channel for all groups would still require the presence of some forms of financial frictions to rationalize the finding that younger non-dividend payers adjust their capital expenditure far more following a monetary policy shock.

homogeneous across firms (Section 6.4). In the previous section, we have shown that investment declines far more for younger non-dividend payers.

All these findings are consistent with theoretical frameworks in which the firm's ability to borrow is related to the value of their assets. That said, we do not find much heterogeneity by leverage after conditioning on age. Consequently, although our evidence appears consistent with a balance sheet channel of monetary policy, many of the models featuring an amplification mechanism based on asset values (such as Kiyotaki and Moore (1997) and Bernanke et al. (1999)) do not consider age. On the other hand, financial friction models that do consider age (such as Cooley and Quadrini (2001)) typically abstract from an explicit role for asset values.

7 Conclusions

In this paper, we have combined high-frequency identified monetary policy shocks with panel econometric techniques for micro data to explore how, and why, different firms respond to changes in interest rates. Our main contribution is to provide a systematic evaluation of the balance sheet channel of monetary policy for firms. On the one hand, we have investigated which group of firms change their investment the most. On the other hand, we have documented how different forms of corporate finance respond. Our goal is to analyse jointly these two sets of new findings to shed light on the relevance of financial constraints and firm finance in the transmission mechanism of monetary policy to investment. Our approach also allows us to quantify the aggregate importance of the firms most likely facing financial constraints.

Across all the dimensions considered, firm age is the strongest predictor of having a significantly higher sensitivity to monetary policy, with the response of capital expenditure being particularly pronounced among younger non-dividend payers. This pervasive heterogeneity by age is robust to controlling for other firm characteristics including size, growth, Tobin's Q, leverage and liquidity.

Our evidence on the heterogeneous response of investment and different forms of corporate finance is also informative about the underlying transmission channels. Following a monetary policy tightening, we find that borrowing declines significantly only for younger non-dividend payers, against the backdrop of a sizable fall in net worth and a rise in interest payments for all groups of firms. Younger firms paying no dividends are more exposed to asset price fluctuations because their borrowing is highly correlated with asset values but not with earnings, both in absolute terms and relative to the debt sensitivity of the other groups. In contrast, the response of cash flows is less pronounced and more homogeneous.

One interpretation of all our new firm-level findings is that the capital expenditure of younger non-dividend payers is constrained by their asset values and/or net worth. As monetary policy

changes affect asset prices, this magnifies the investment response. Older companies, in contrast, rely on a more diverse set of funding sources and their investment decisions are, therefore, less vulnerable to fluctuations in asset prices. Younger firms paying no dividends account for over 75% of the response of aggregate investment. As a result, our findings suggest that this balance sheet channel plays an important role in the transmission of monetary policy to firms.

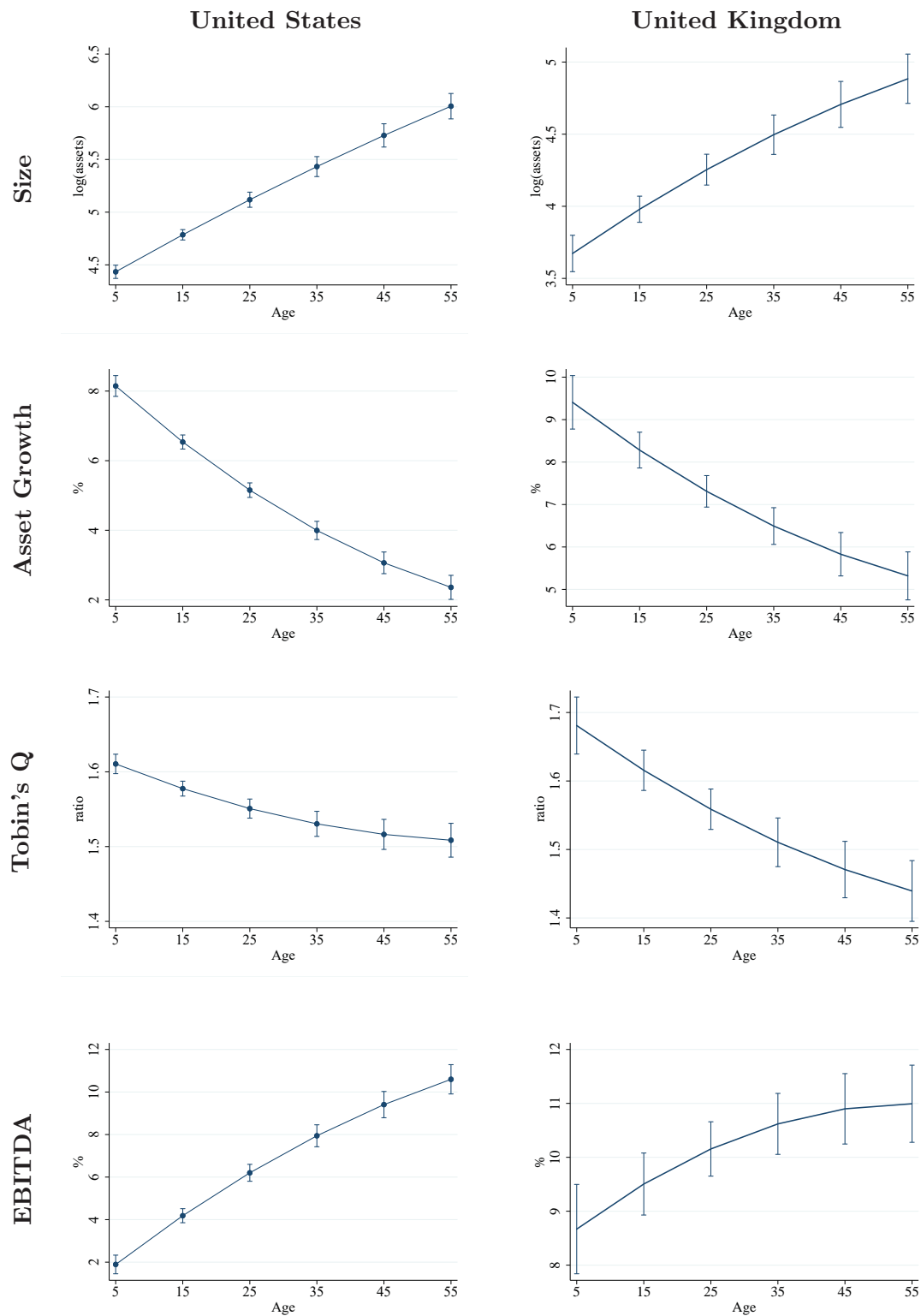
References

- Andreson, G. and A. Cesa-Bianchi (2018). Firm heterogeneity, credit spreads and monetary policy. *Mimeo, Bank of England and Oxford University*.
- Atkeson, A. and P. J. Kehoe (2005). Modeling and measuring organization capital. *Journal of Political Economy* 113(5), 1026–1053.
- Attanasio, O. and M. Browning (1995). Consumption over the life cycle and over the business cycle. *American Economic Review* 85(5), 1118–1137.
- Bahaj, S., A. Foulis, and G. Pinter (2018). Home values and firm behaviour. *CFM Discussion Paper 2018*.
- Bahaj, S., A. Foulis, G. Pinter, and P. Surico (2018). The employment effects of monetary policy: Macro evidence from firm-level data. *mimeo, Bank of England and London Business School*.
- Bates, T., K. Kahle, and R. Stulz (2009). Why do u.s. firms hold so much more cash than they used to? *Journal of Finance* LXIV(5), 1985–2021.
- Bayer, C. (2006). Investment dynamics with fixed capital adjustment cost and capital market imperfections. *Journal of Monetary Economics* 53(8), 1909–1947.
- Begenau, J. and J. Salomao (2018). Firm financing over the business cycle. *Review of Financial Studies forthcoming*.
- Bernanke, B. and M. Gertler (1989). Agency costs, net worth, and business fluctuations. *The American Economic Review* 79(1), 14–31.
- Bernanke, B., M. Gertler, and S. Gilchrist (1999). The financial accelerator in a quantitative business cycle framework. *Handbook of Macroeconomics* 1, 1341–1393.
- Caldara, D. and E. Herbst (2018). Monetary policy, real activity, and credit spreads: Evidence from bayesian proxy svars. *American Economic Journal: Macroeconomics Forthcoming*.
- Catherine, S., T. Chaney, Z. Huang, D. Sraer, and D. Thesmar (2018, May). Quantifying reduced-form evidence on collateral constraints.
- Chaney, T., D. Sraer, and D. Thesmar (2012). The collateral channel: How real estate shocks affect corporate investment. *American Economic Review* 102(6), 2381–2409.
- Chodorow-Reich, G. and A. Falato (2017). The loan covenant channel: How bank health transmits to the real economy. *Mimeo Harvard University*.
- Cooley, T. F. and V. Quadrini (2001). Financial markets and firm dynamics. *American Economic Review* 91(5), 1286–1310.
- Cooper, R. W. and J. C. Haltiwanger (2006). On the nature of capital adjustment costs. *The Review of Economic Studies* 73(3), 611–633.
- Covas, F. and W. J. Den Haan (2011). The cyclical behavior of debt and equity finance. *American Economic Review* 101(2), 877–99.
- Crouzet, N. and N. Mehrotra (2017). Small and large firms over the business cycle. *mimeo, Northwestern University and Brown University*.
- Davis, S., J. C. Haltiwanger, and S. Schuh (1996). Job creation and destruction. *MIT Press*.
- Dinlersoz, E., S. Kalemli-Ozcan, H. Hyatt, and V. Penciakova (2018). Leverage over the life cycle and implications for firm growth and shock responsiveness. *NBER Working Paper 25226*.
- Drechsel, T. (2018). Earning-based borrowing constraints and macroeconomic fluctuations. *Mimeo, London School of Economics*.
- Driscoll, J. C. and A. C. Kraay (1998). Consistent covariance matrix estimation with spatially dependent panel data. *The Review of Economics and Statistics* 80(4), 549–560.
- Farre-Mensa, J. and A. Ljungqvist (2016). Do measures of financial constraints measure financial constraints? *Review of Financial Studies* 29(2), 271–308.

- Fazzari, S., G. Hubbard, and B. Petersen (1988). Financing constraints and corporate investment. *Brookings Papers on Economic Activity* (1), 141–206.
- Fort, T., J. Haltiwanger, R. Jarmin, and J. Miranda (2013). How firms respond to business cycles: The role of the firm age and firm size. *IMF Economic Review* 95(3), 520–559.
- Gerko, E. and H. Rey (2017). Monetary policy in the capitals of capital. *Journal of the European Economic Association* 15(4), 721–745.
- Gertler, M. and S. Gilchrist (1994). Monetary policy, business cycles, and the behavior of small manufacturing firms. *Quarterly Journal of Economics* 109(2), 309–340.
- Gertler, M. and P. Karadi (2015). Monetary policy surprises, credit costs, and economic activity. *American Economic Journal: Macroeconomics* 7(1), 44–76.
- Gilchrist, S. and E. Zakrajsek (2012). Credit spreads and business cycle fluctuations. *American Economic Review* 102(4), 1692–1720.
- Gomes, J. (2001a). Financing investment. *American Economic Review* 91, 1263–1285.
- Gomes, J. F. (2001b). Financing investment. *The American Economic Review* 91(5), 1263–1285.
- Gourinchas, P.-O. and J. Parker (2002). Consumption over the life cycle. *Econometrica* 70(1), 47–89.
- Gurkaynak, R., B. Sack, and E. Swanson (2005). Do actions speak louder than words? the response of asset prices to monetary policy actions and statements. *International Journal of Central Banking* 1(1).
- Haltiwanger, J., R. Jarmin, and J. Miranda (2013). Who creates jobs? small versus large versus young. *Review of Economics and Statistics* 95(2), 347–361.
- Han, S. and J. Qiu (2007). Corporate precautionary cash holdings. *Journal of Corporate Finance* 13, 43–57.
- Hopenhayn, H. A. (1992). Entry, exit, and firm dynamics in long run equilibrium. *Econometrica* 60(5), 1127–1150.
- Ippolito, F. and A. Ozdagli (2018). Bank loans and the transmission of monetary policy: the floating rate channel. *Journal of Monetary Economics* 95(C), 49–71.
- Jeenas, P. (2018). Monetary policy shocks, financial structure, and firm activity: A panel approach. *mimeo, New York University*.
- Jorda, O. (2005, March). Estimation and inference of impulse responses by local projections. *American Economic Review* 95(1), 161–182.
- Jorda, O., M. Schularick, and A. Taylor (2017). The effects of quasi-random monetary experiments. *Federal Reserve Bank of San Francisco Working Paper* (2017-02).
- Jovanovic, B. (1982). Selection and the evolution of industry. *Econometrica* 50(3), 649–670.
- Kalemli-Ozcan, S., L. Laeven, and D. Moreno (2018). Debt overhang, rollover risk, and corporate investment: Evidence from the European crisis. *NBER Working Paper* 24555.
- Kaplan, S. and L. Zingales (1997). Do investment-cash flow sensitivities provide useful measures of financing constraints? *Quarterly Journal of Economics* 112, 169–215.
- Khan, A. and J. K. Thomas (2013). Credit shocks and aggregate fluctuations in an economy with production heterogeneity. *Journal of Political Economy* 121(6), 1055–1107.
- Kiyotaki, N. and J. Moore (1997). Credit cycles. *Journal of Political Economy* 105(2).
- Lian, C. and Y. Ma (2018). Anatomy of corporate borrowing constraints. *mimeo, MIT and Chicago Booth*.
- Liu, Z., P. Wang, and T. Zha (2013). Land-price dynamics and macroeconomic fluctuations. *Econometrica* 81(3), 1147–1184.
- Mertens, K. and M. O. Ravn (2013). The dynamic effects of personal and corporate income tax changes in the United States. *American Economic Review* 103(4), 1212–47.

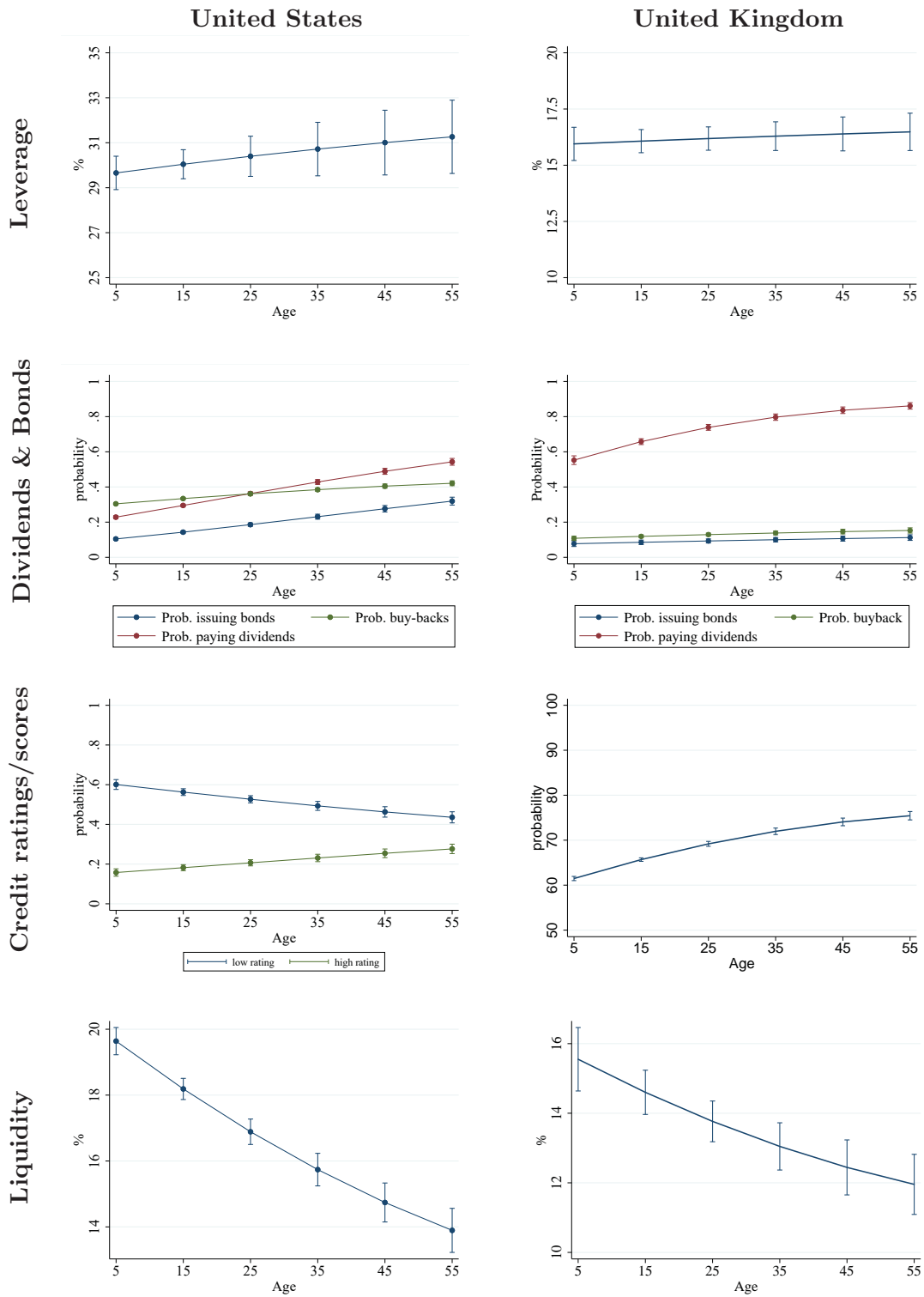
- Nakamura, E. and J. Steinsson (2018a). High frequency identification of monetary non-neutrality: The information effect. *Quarterly Journal of Economics* 133(3), 1283–1330.
- Nakamura, E. and J. Steinsson (2018b). Identification in macroeconomics. *Journal of Economic Perspectives* 32(3), 59–86.
- Oliner, S. D. and G. D. Rudebusch (1992). Sources of the financing hierarchy for business investment. *Review of Economics and Statistics* 74(4), 643–654.
- Opler, T., L. Pinkowitz, R. Stulz, and R. Williamson (1999). The determinants and implications of corporate cash holdings. *Journal of Financial Economics* 52, 3–46.
- Ottonello, P. and T. Winberry (2018). Financial heterogeneity and the investment channel of monetary policy. *NBER Working Paper* (24221).
- Rampini, A., A. Sufi, and S. Viswanathan (2014). Dynamic risk management. *Journal of Financial Economics* 111(2), 271–296.
- Rampini, A. and S. Viswanathan (2010). Collateral, risk management, and the distribution of debt capacity. *The Journal of Finance* 65(6), 2293–2322.
- Stock, J. and M. Watson (2018). Identification and estimation of dynamic causal effects in macroeconomics using external instruments. *NBER WP* 24216.
- Wong, A. (2018). Transmission of monetary policy to consumption and population aging. *Mimeo, Princeton University*.

Figure 1a: Descriptive statistics on firm characteristics by age



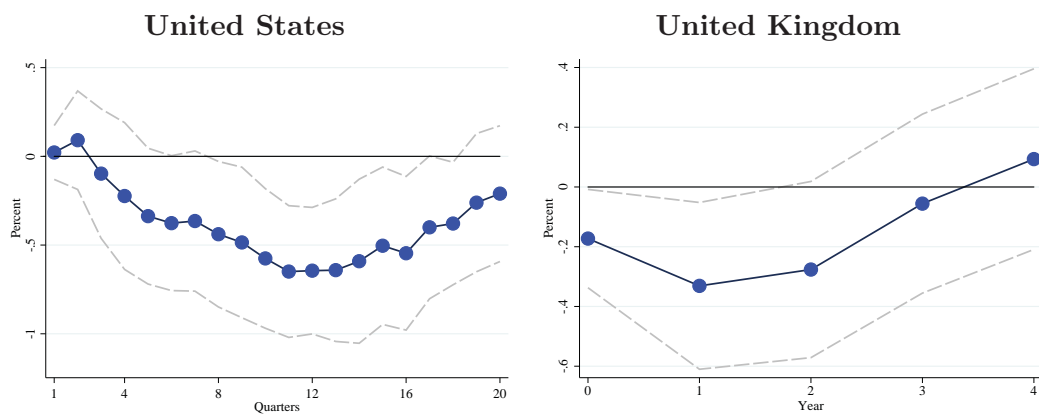
Notes: Each panel reports the predicted values based on age and its squares from a regression of the variable of interest on age and age squared conditional on sector-time fixed effects and firms' controls as detailed in Section 3. Standard errors are clustered by firm and time.

Figure 1b: Descriptive statistics on firm characteristics by age cont'd



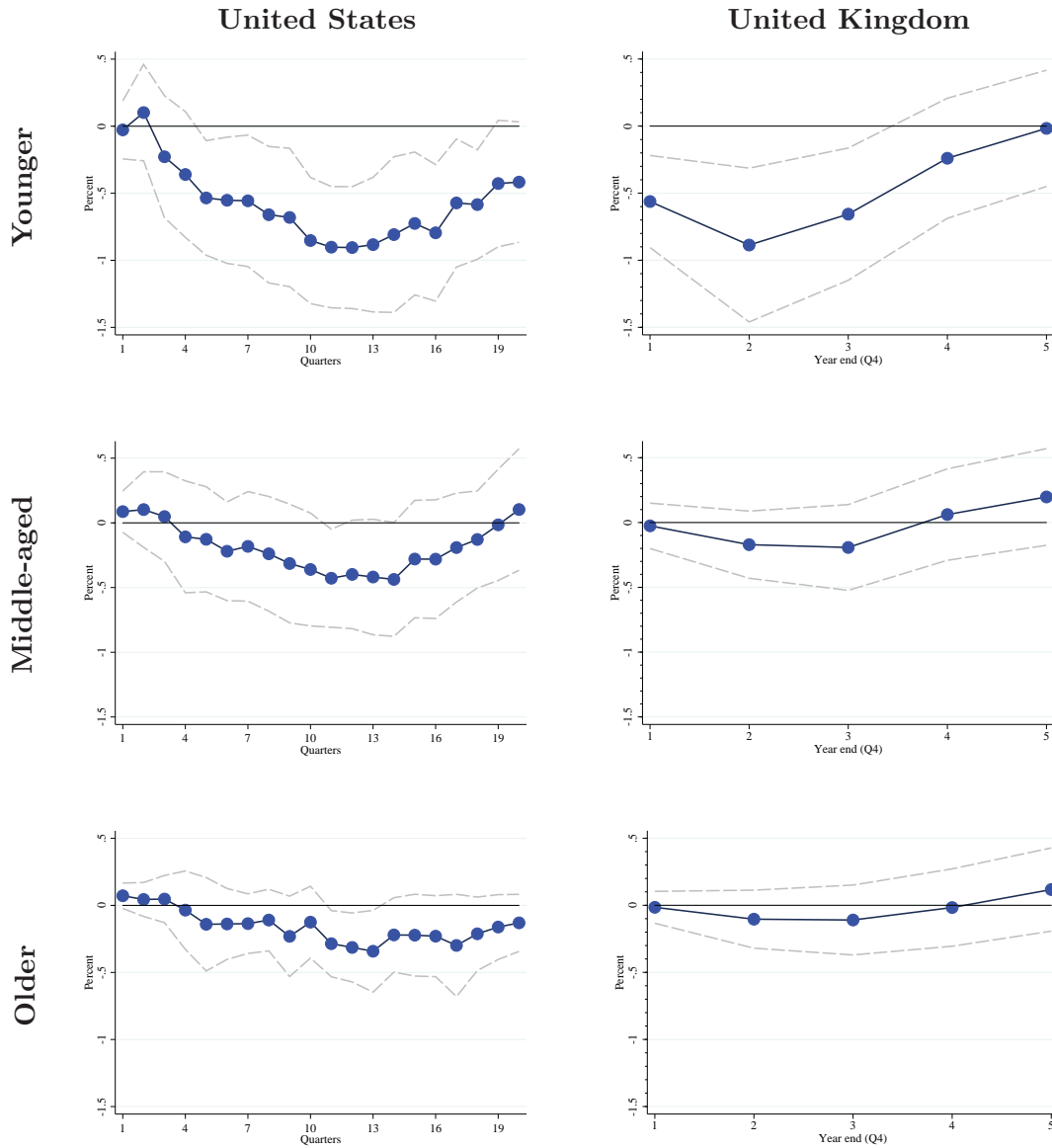
Notes: Each panel reports the predicted values based on age and its squares from a regression of the variable of interest on age and age squared conditional on sectors-time fixed effects and firms' controls as detailed in Section 3. Standard errors are clustered by firm and time.

Figure 2: Average Effect of Monetary Policy on Investment



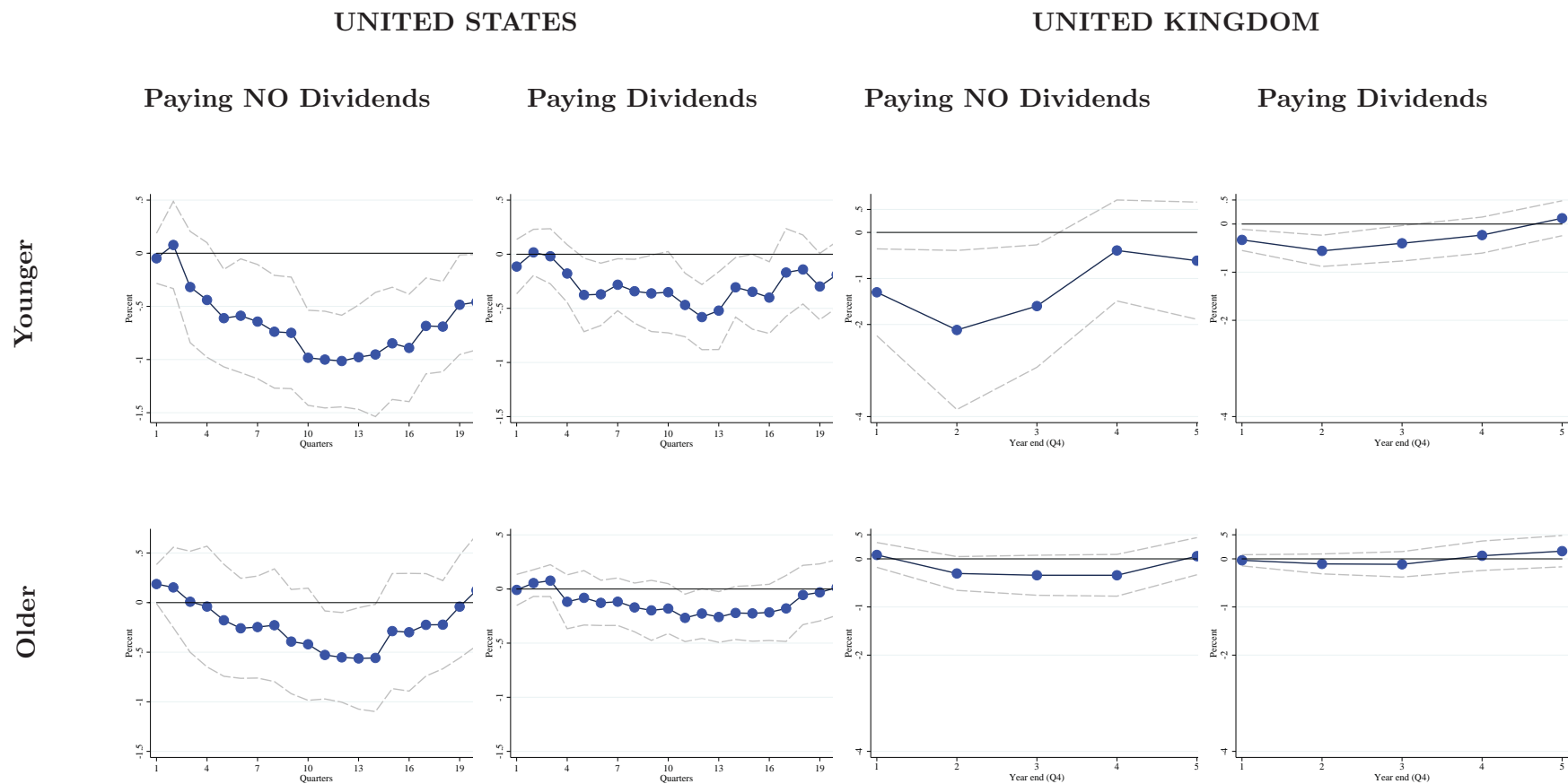
Notes: This figure shows the impulse response functions following a 25bps increase in the interest rates. The IRFs are estimated using the local projection IV approach described in the text. Standard errors are clustered by firm and time. For the US the Driscoll-Kraay adjustment is used to correct for potential serial correlation.

Figure 3: Dynamic Effects of Monetary Policy on Investment by Age



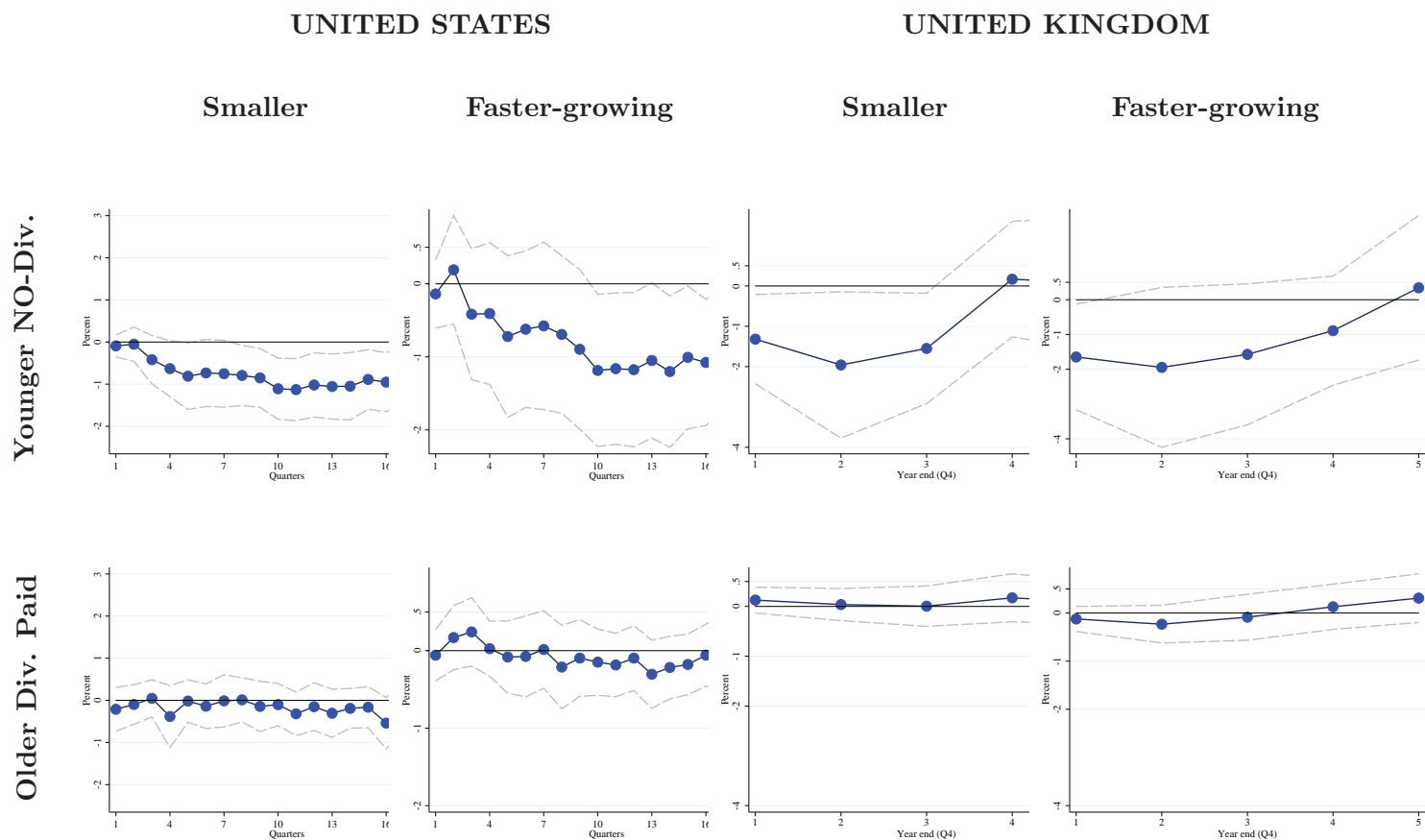
Notes: This figure shows the impulse response functions following a 25bps increase in the interest rates. The interest rate is interacted with binary indicators for younger (< 15 years since incorporation), middle-aged (15 – 50 years since incorporation) and older firms (> 50 years since incorporation). The IRFs are estimated using the local projection IV approach described in the text. Standard errors are clustered by firm and time. For the US the Driscoll-Kraay adjustment is used to correct for potential serial correlation.

Figure 4: Dynamic Effects of Monetary Policy on Investment by Age and Dividends Paid



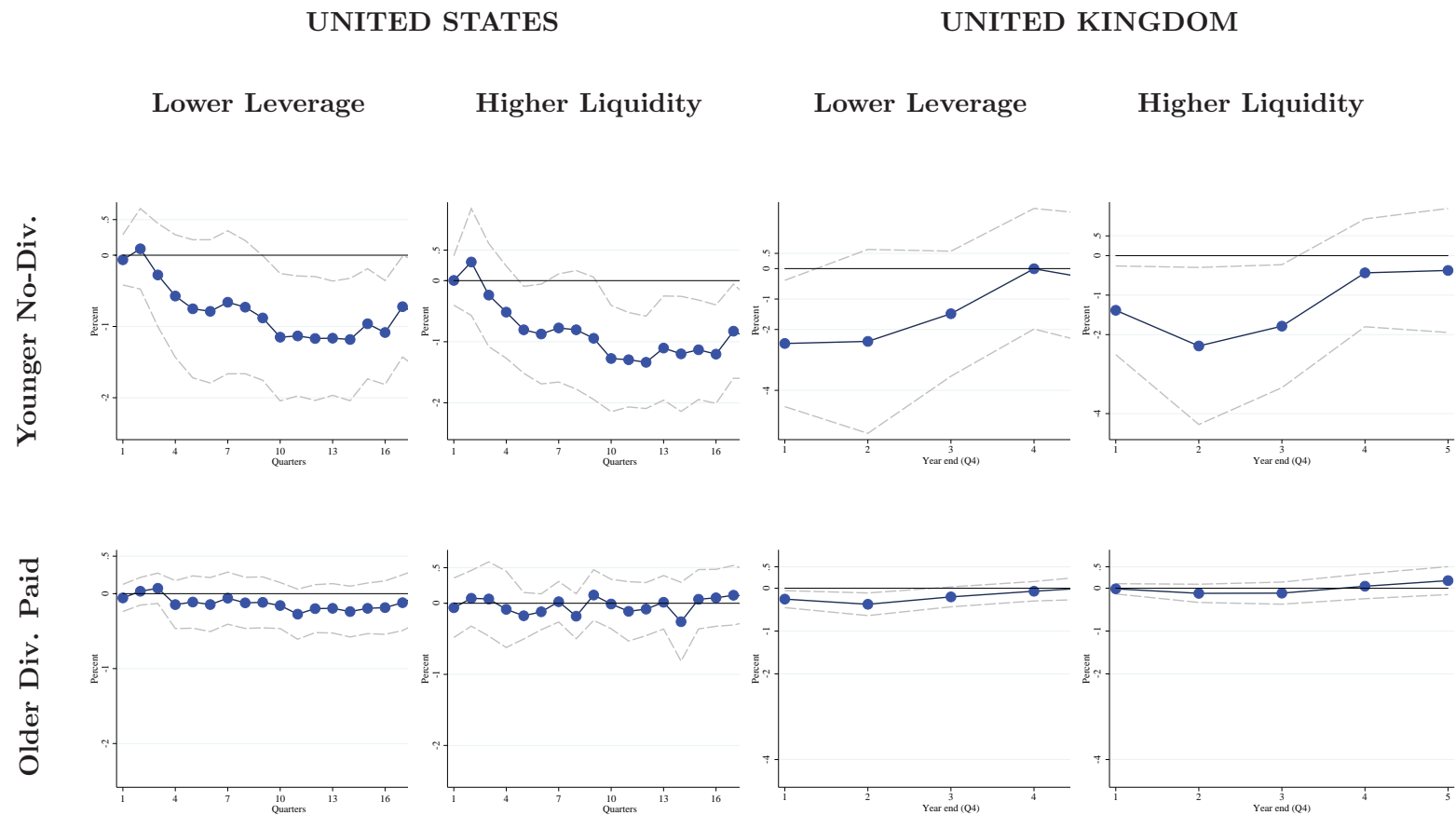
Notes: This figure shows the impulse response functions following a 25bps increase in the interest rates. The interest rate is interacted with binary indicators based on age and dividend status. Younger refers to < 15 years since incorporation and older refers to > 15 years since incorporation. No dividends means the firm did not pay cash dividends in the previous year. The IRFs are estimated using the local projection IV approach described in the text. Standard errors are clustered by firm and time. For the US the Driscoll-Kraay adjustment is used to correct for potential serial correlation.

Figure 5: Dynamic Effects of Monetary Policy on Investment by Age, Dividends Paid and Size/Growth



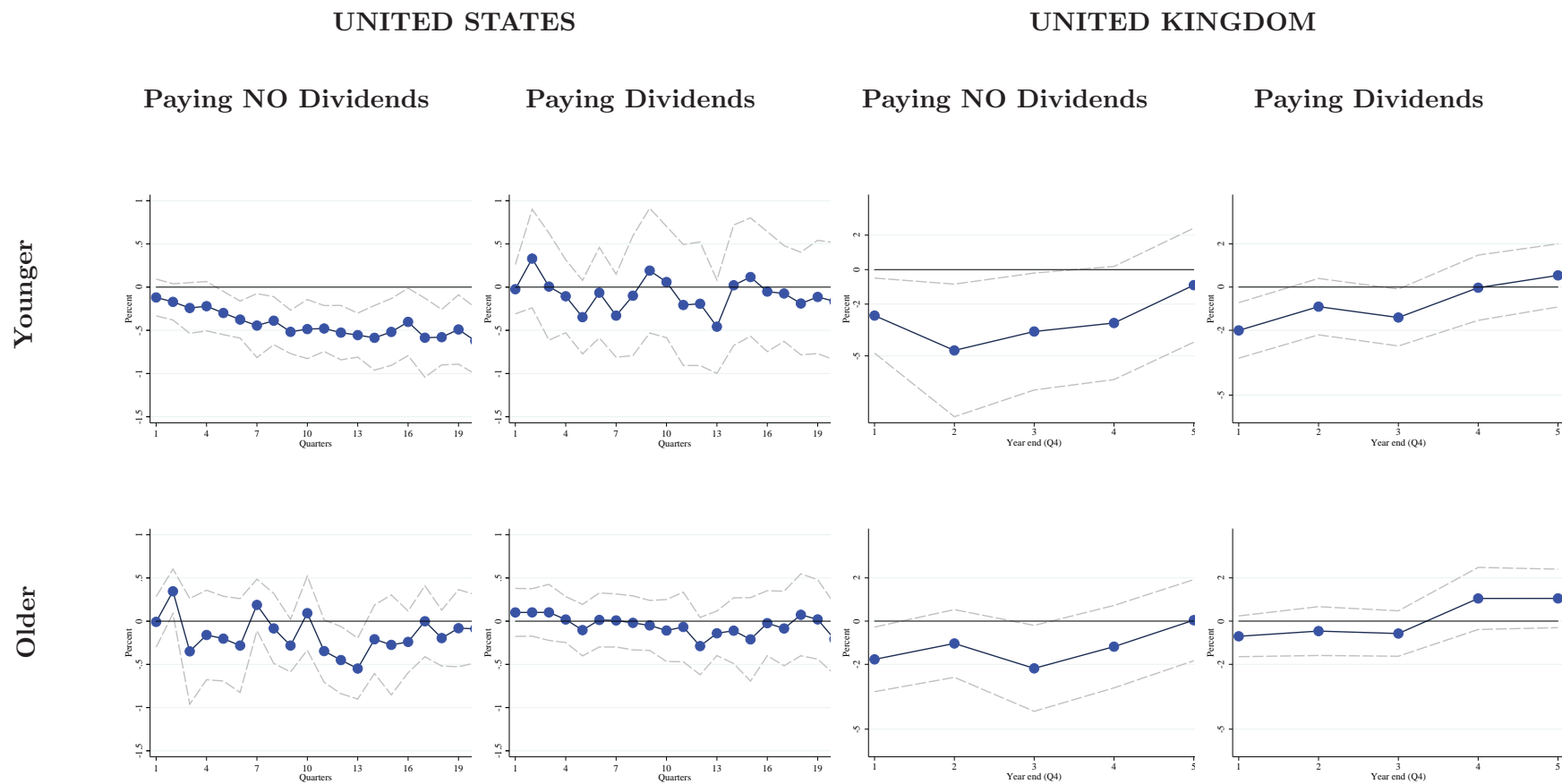
Notes: This figure shows the impulse response functions following a 25bps increase in the interest rates. The interest rate is interacted with binary indicators based on age, dividend status, size and asset growth. Younger refers to < 15 years since incorporation and older refers to > 15 years since incorporation. No dividends means the firm did not pay cash dividends in the previous year. Smaller firms refer to those in the bottom quartile of the size distribution in the previous year. Faster-growing firms are those in the top quartile of the distribution in the previous year. The IRFs are estimated using the local projection IV approach described in the text. Standard errors are clustered by firm and time. For the US the Driscoll-Kraay adjustment is used to correct for potential serial correlation.

Figure 6: Dynamic Effects of Monetary Policy on Investment by Age, Dividends Paid and Leverage/Liquidity



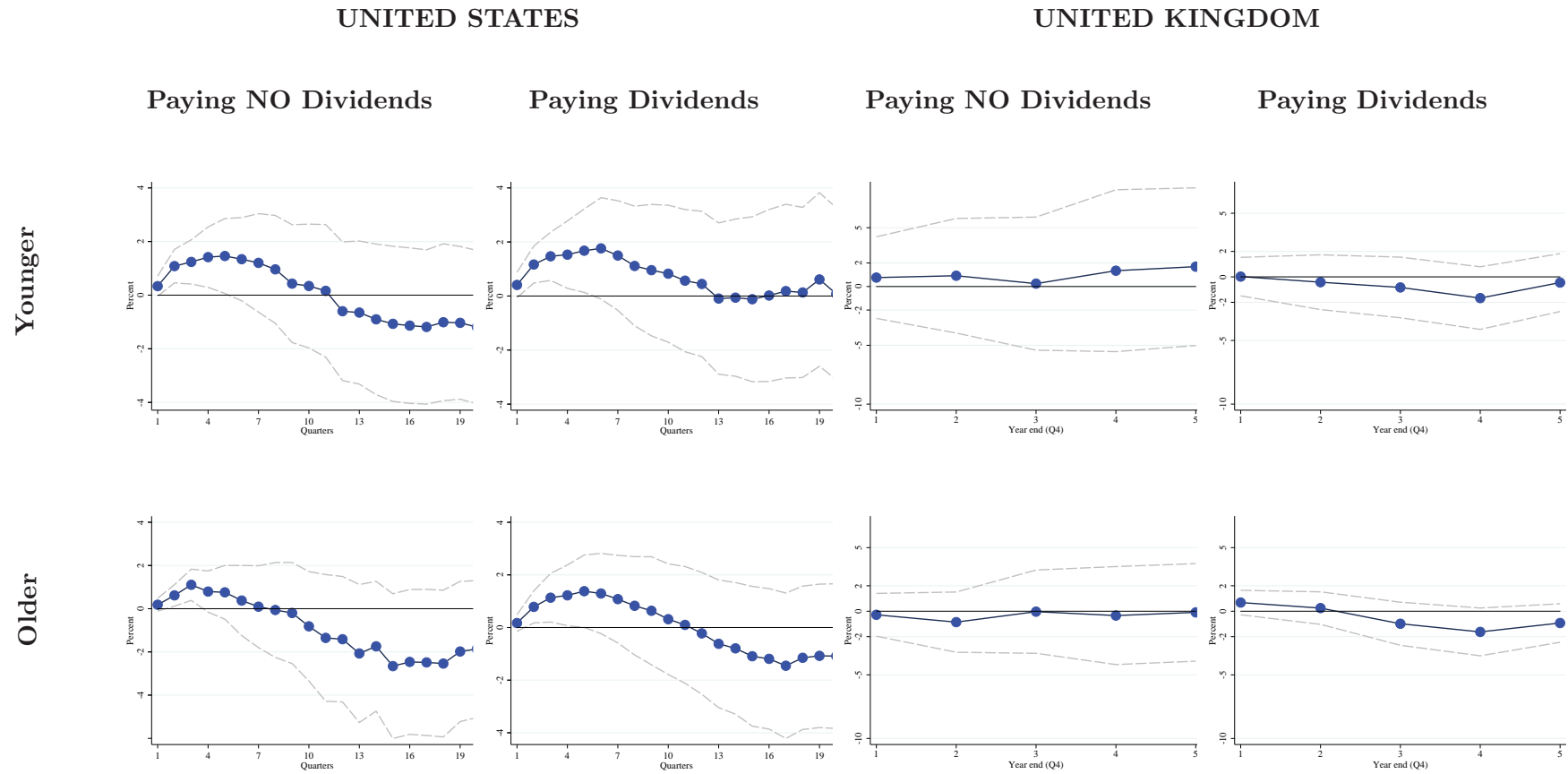
Notes: This figure shows the impulse response functions following a 25bps increase in the interest rates. The interest rate is interacted with binary indicators based on age, dividend status, size and asset growth. Younger refers to < 15 years since incorporation and older refers to > 15 years since incorporation. No dividends means the firm did not pay cash dividends in the previous year. Firms with lower leverage are those in the bottom quartile of the distribution in the previous year. High liquidity are those in the top quartile of the distribution in the previous year. The IRFs are estimated using the local projection IV approach described in the text. Standard errors are clustered by firm and time. For the US the Driscoll-Kraay adjustment is used to correct for potential serial correlation.

Figure 7: Dynamic Effects of Monetary Policy on Borrowings by Age and Dividends Paid



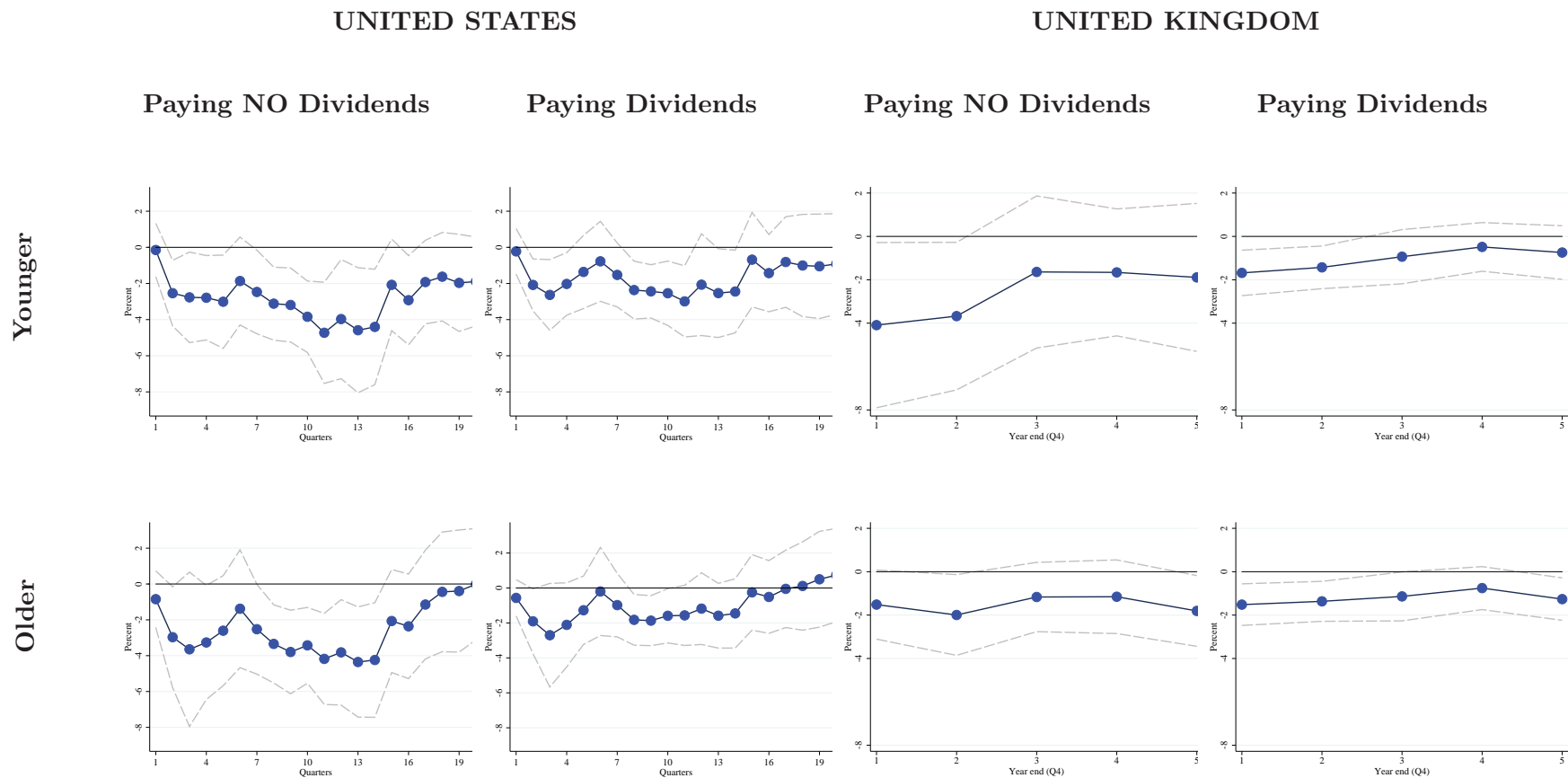
Notes: This figure shows the impulse response functions for the response of real total debt growth following a 25bps increase in the interest rates. The interest rate is interacted with binary indicators based on age and dividend status. Younger refers to < 15 years since incorporation and older refers to > 15 years since incorporation. No dividends means the firm did not pay cash dividends in the previous year. The IRFs are estimated using the local projection IV approach described in the text. Standard errors are clustered by firm and time. For the US the Driscoll-Kraay adjustment is used to correct for potential serial correlation.

Figure 8: Dynamic Effects of Monetary Policy on Interest Payments by Age and Dividends Paid



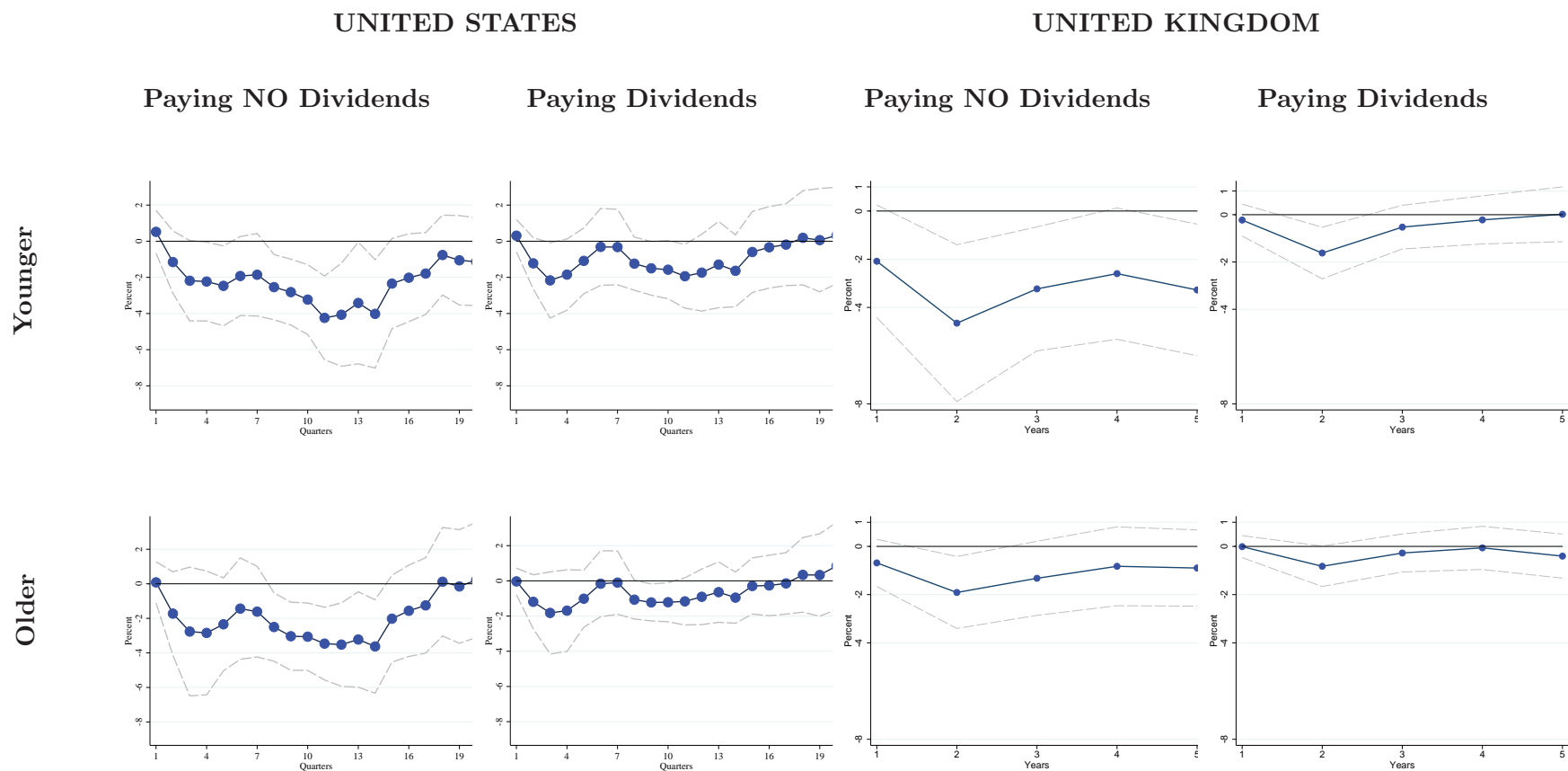
Notes: This figure shows the impulse response functions for the response of log interest expenditures following a 25bps increase in the interest rates. The interest rate is interacted with binary indicators based on age and dividend status. Younger refers to < 15 years since incorporation and older refers to > 15 years since incorporation. No dividends means the firm did not pay cash dividends in the previous year. The IRFs are estimated using the local projection IV approach described in the text. Standard errors are clustered by firm and time. For the US the Driscoll-Kraay adjustment is used to correct for potential serial correlation.

Figure 9: Dynamic Effects of Monetary Policy on the Market Value of Equity by Age and Dividends Paid



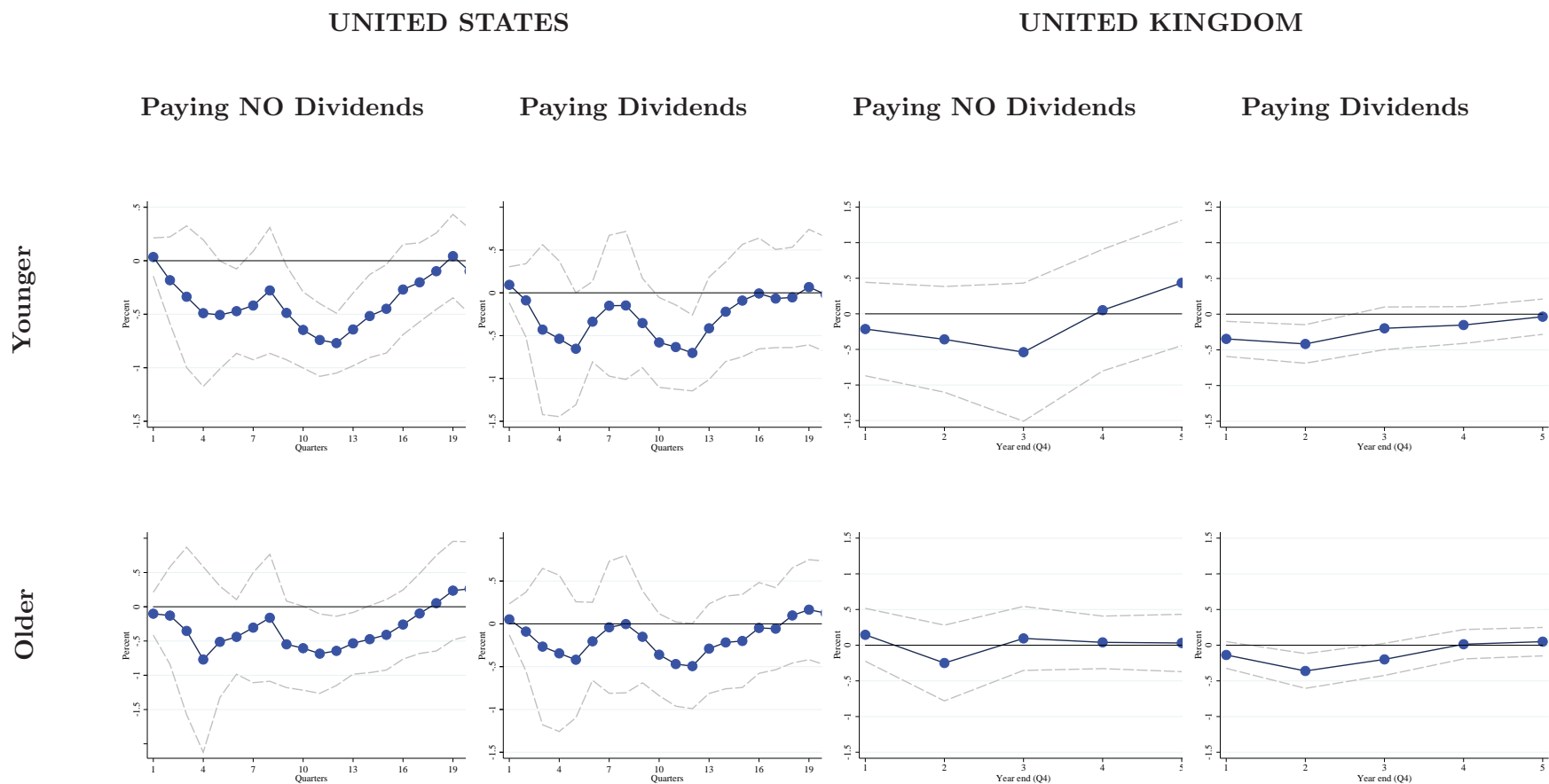
Notes: This figure shows the impulse response functions for the response of equity at market value (natural log of real common shares outstanding \times the share price) following a 25bps increase in the interest rates. The interest rate is interacted with binary indicators based on age and dividend status. Younger refers to < 15 years since incorporation and older refers to > 15 years since incorporation. No dividends means the firm did not pay cash dividends in the previous year. The IRFs are estimated using the local projection IV approach described in the text. Standard errors are clustered by firm and time. For the US the Driscoll-Kraay adjustment is used to correct for potential serial correlation.

Figure 10: Dynamic Effects of Monetary Policy on Share Prices by Age and Dividends Paid



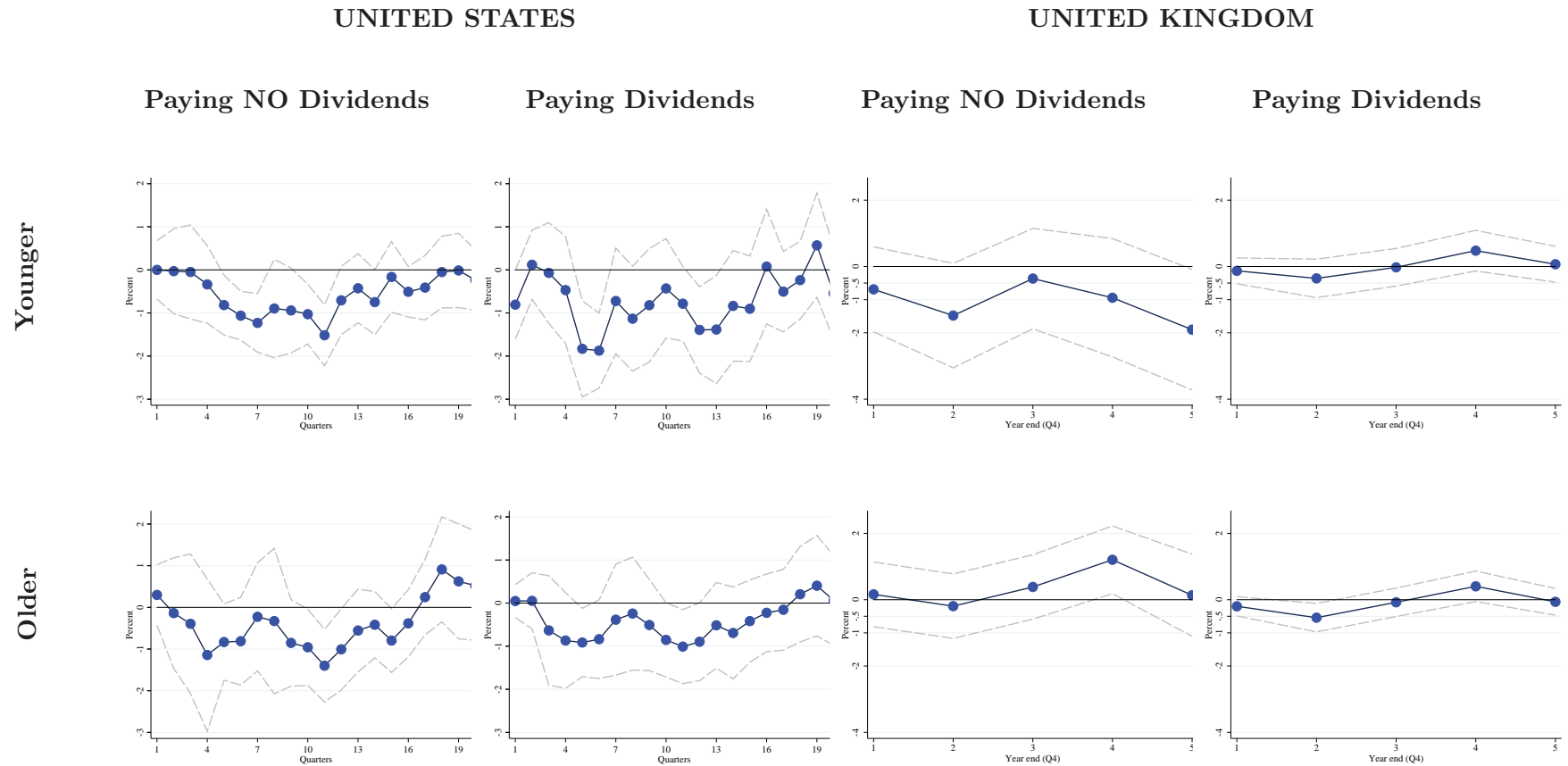
Notes: This figure shows the impulse response functions for the response of share prices (quarter average) following a 25bps increase in the interest rates. The interest rate is interacted with binary indicators based on age and dividend status. Younger refers to < 15 years since incorporation and older refers to > 15 years since incorporation. No dividends means the firm did not pay cash dividends in the previous year. The IRFs are estimated using the local projection IV approach described in the text. Standard errors are clustered by firm and time. For the US the Driscoll-Kraay adjustment is used to correct for potential serial correlation.

Figure 11: Dynamic Effects of Monetary Policy on Sales by Age and Dividends Paid



Notes: This figure shows the impulse response functions for the response of real sales growth (year on year growth) following a 25bps increase in the interest rates. The interest rate is interacted with binary indicators based on age and dividend status. Younger refers to < 15 years since incorporation and older refers to > 15 years since incorporation. No dividends means the firm did not pay cash dividends in the previous year. The IRFs are estimated using the local projection IV approach described in the text. Standard errors are clustered by firm and time. For the US the Driscoll-Kraay adjustment is used to correct for potential serial correlation.

Figure 12: Dynamic Effects of Monetary Policy on Earnings by Age and Dividends Paid



Notes: This figure shows the impulse response functions for the response of real EBITDA (year on year growth) following a 25bps increase in the interest rates. The interest rate is interacted with binary indicators based on age and dividend status. Younger refers to < 15 years since incorporation and older refers to > 15 years since incorporation. No dividends means the firm did not pay cash dividends in the previous year. The IRFs are estimated using the local projection IV approach described in the text. Standard errors are clustered by firm and time. For the US the Driscoll-Kraay adjustment is used to correct for potential serial correlation.

Table 1: Group contributions to the average effect

	Younger		Older	
	No Dividends	Paid Dividends	No Dividends	Paid Dividends
U.S.	75.5%	6.7%	13.0%	4.8%
	[66.1 , 84.8]	[1.8 , 11.6]	[5.1 , 20.9]	[1.7 , 7.6]
U.K.	83.6%	13.1%	2.9%	0.4%
	[70.4 , 96.8]	[2.9 , 23.2]	[-2.2 , 8.1]	[-5.9 , 6.9]

Notes: the first row in each country represents the weighted share of the average IRF explained by the corresponding group; see main text for a detailed description. 95% CI in square brackets, computed from 500 bootstrap repetitions accounting for firm clustering.

Table 2: The correlation of long term debt with collateral values and cash-flows

	United States			
	Younger		Older	
	No Dividends	Paid Dividends	No Dividends	Paid Dividends
Collateral _t	0.0628** (0.0131)	0.0557** (0.0210)	0.0369** (0.0099)	0.0376** (0.0141)
EBITDA _t	0.0068 (0.0160)	0.090* (0.0486)	-0.0032 (0.0094)	0.0484** (0.0183)
EBITDA _{t-1}	0.0076 (0.0126)	-0.0370 (0.0382)	0.0091* (0.0049)	0.0097 (0.0101)
$R^2 = 0.22$				
	United Kingdom			
	Younger		Older	
	No Dividends	Paid Dividends	No Dividends	Paid Dividends
Collateral _t	0.0245** (0.0092)	0.0301** (0.0107)	0.0203 (0.0125)	0.0117 (0.0093)
EBITDA _t	-0.0126 (0.0114)	-0.0159 (0.0273)	0.0160 (0.0218)	0.0694** (0.0191)
EBITDA _{t-1}	-0.0084 (0.0059)	0.0534** (0.0162)	0.0158 (0.0119)	0.0312** (0.0144)
$R^2 = 0.25$				

Notes: **, * denote significance at 5% and 10% level, respectively. Standard errors are in parentheses. Collateral_t and EBITDA_t are measured at the beginning of the year. Firm and time-two-digit-sector fixed effects are included. Additional firm-level controls are leverage, liquidity, cash flow from operations all measured at the beginning of the year, and total assets and Tobin's Q measured at the end of the year. Standard errors are clustered by firm and months/quarters. All level variables are normalised by total assets at the beginning of the year, except EBITDA_{t-1}, which is normalised by assets at the beginning of $t - 1$.

ON-LINE APPENDICES

A Data description and variable definitions

A.1 Sources, definitions and sample selection

Sources. Detailed financial statement data for publicly listed companies are available from Compustat (available from WRDS) for the United States and from Thomson Reuters' WorldScope for the United Kingdom. Firms report at a quarterly frequency in the U.S. and for each fiscal year in the U.K..⁴⁹ In WorldScope, British firms report in different months throughout the year but each firm tends to report always in the same month across the years. Consistent information for a sufficiently large number of firms in both dataset only begins in 1986, when our sample starts. In keeping with the rest of the empirical literature, we exclude firms in the finance, insurance, real estate or public administration sectors.

Information on bond issuance comes from Dealscan, which we merge with the Worldscope dataset in the U.K. and Compustat in the US. For the U.K., the Bureau van Dijk database contains information on credit scores. For the U.S. WRDS contains the S&P credit rating database which comprises rating for (the relatively small number of) firms that issue bonds. We merge this into Compustat.

For the macro data, we use data from the Bureau of Labour Statistics and the Federal Reserve Bank of St. Louis (FRED) for the United States, and from the Office for National Statistics and the Bank of England for the United Kingdom, respectively. For the corporate spread in the United States, we use data from Gilchrist and Zakrajsek (2012). For the average mortgage rate and the corporate spread in the United Kingdom, we use the collated data from (Gerko and Rey, 2017). The financial market surprises come from (Gerko and Rey, 2017) and we thank Peter Karadi for sharing the updated version of the financial market surprises from Gertler and Karadi (2015)

Construction of firm-level variables. We provide definitions of variables used in the analysis (other than the investment ratio and corporate age, which were described in section 3) in table A.1 below.

Size is measured as the book value of assets.⁵⁰ The average Tobin's Q is defined as total assets at market value over total assets at book value.⁵¹ Liquidity is the ratio between cash plus short-term investments and total assets; cash flows are constructed as cash flow from operations, while sales are defined as gross sales and other operating revenue less discounts, returns and allowances.⁵² The construction of firm age is discussed in the text. In short, we use Worldscope information on the incorporation date. For the U.S., we merge Worldscope with Compustat. Where the incorporation date is missing we use BEGDAT from CRSP, which records the date when a firm's stocks started trading. These variables are well populated, unlike the native IPO date variable in Compustat.

Leverage is the ratio of total debt at time t to total assets, where total debt includes both short and long term obligations. Total debt is the sum of short term and long term debt, observed directly

⁴⁹WorldScope provides some variables at the 'interim' quarterly frequency within a fiscal year, as well as information for some private firms. However, such information is scarce, so we restrict to publicly traded firms annual reports.

⁵⁰Employment is scarcely populated in our data, although among the companies for which we observe both variables, the correlation between number of employees and assets value is high.

⁵¹We calculate the market value as the sum of the market value of its outstanding stock at the end of the accounting year (market capitalization) plus the value of its outstanding debt. This is an upper bound on Tobins Q, as deferred taxes have many missing values in the dataset. The results are unchanged when including this variable in the calculation for those firms that provide information.

⁵²In the U.K., we subtract cost of goods sold from this measure.

Table A.1: Variable description

Variable	Definition Compustat (U.S.)	Definition WorldScope (U.K.)
Investment ratio	$\text{capxq}/\text{L.ppentq}$	04601, 02501
Size	atq	02999
Age	Incorpdat (WS), Begdat (CPRS)	18273
Tobin's Q	$(\text{atq} + \text{prccq} \times \text{cshoq} - \text{ceqq} + \text{txditcq}) / \text{atq}$	$(08001 + 02999 - 04101 - 03501)/02999$
Cash-flows	$(\text{oancf} + \text{xint}) / \text{at}$	04860 / 02999
Sales	saleq	01001
EBITDA	$(\text{sale} - \text{cogs} - \text{xsga})$	18198
Leverage	$(\text{dlcq} + \text{dlttq}) / \text{atq}$	03255/02999
Total debt	$\text{dlcq} + \text{dlttq}$	03255
Interest payments	xintq	01251
Collateral	$(\text{ppent} + \text{invt} + \text{rect})$	02501 + 02101 + 02051
Dividends paid	dvq	04551
Share price	$(\text{prchq} + \text{prclq})/2$	05002, 05003
Equity (mkt. value)	$\text{prccq} \times \text{cshoq}$	08001

as total debt in the U.K. We use the change in total debt and long term debt, respectively, to measure net borrowing in both countries to maximise data coverage. Interest payments are measured by the income state variable total interest expenses, which is defined as the interest accrued on total debt. We follow (Lian and Ma, 2018) and measure collateral as the sum of net plant, property and equipment, inventories, and net accounts receivable. Dividends are cash dividends paid. Share prices are quarter averages. We use market capitalisation to measure the value of equity, the number of common stock outstanding multiplied by the share price.

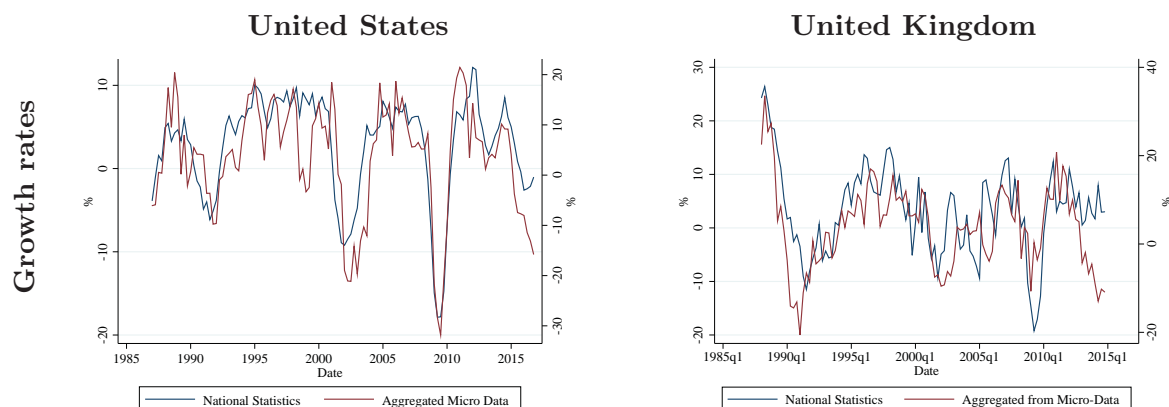
All variables are converted to real values using the aggregate GVA deflator in the United States and the United Kingdom.

Although Compustat is quarterly and data have been assigned (at source) to calendar quarters, some variables are cumulative within the fiscal year. We therefore difference these variables within the fiscal year to create the quarterly series. There are a small numbers of missing observations in Compustat and we follow others in the literature and interpolate missing values.

Aggregation of firm-level investment. The series of investment by publicly traded firms presented in figure A.1 are constructed by aggregating investment recorded by each firm during a *fiscal* period to a *calendar* frequency (quarters). In Compustat, capital expenditure is recorded at quarterly frequency, so the time series can be constructed directly using reported data. We simply add up capital expenditure by quarter and convert this into a real series using the GVA deflator. In the United Kingdom, investment is reported at annual frequency and for each firm's respective fiscal year. We proceed as follows: (i) for each firm, we assign capital expenditures of the fiscal year in each proportions to each of the previous twelve months; (ii) we aggregate investment at the monthly frequency across firms.

Baseline sample restrictions. The sample period is 1986-2016. We further impose a set of sample restrictions: (i) we drop firms within the finance, insurance, real estate (FIRE) and public administration sectors; (ii) we drop observations for which age is negative; (iii) we drop firms which are in the panel for less than 6 years in the UK and 20 quarters in the US (iv) we trim the investment

Figure A.1: Investment over time: aggregated micro data VS. national statistics

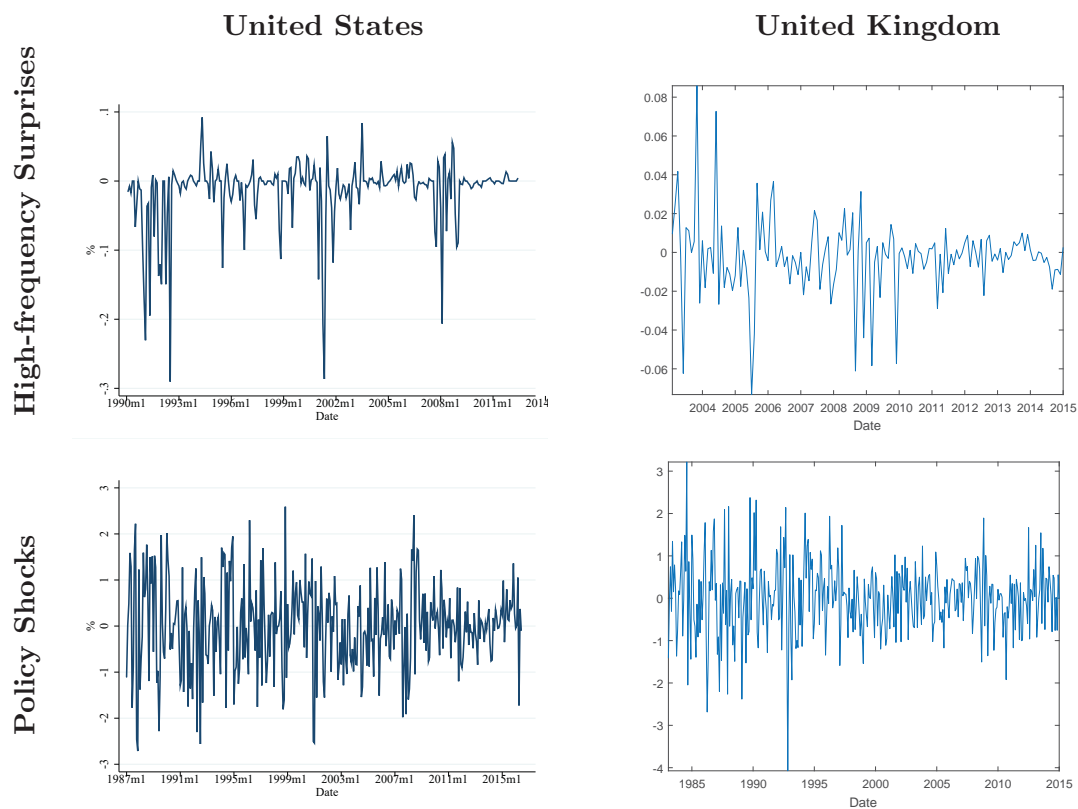


ratio (1% top and bottom in the U.S., top 4% in the U.K.);⁵³ (v) we drop observations if the liquidity ratio is larger than 1; (vi) we trim the top 1% of the leverage ratio; (vii) we trim the top and bottom 1% of real sales growth. Trimming of variables is done separately for each calendar year, except for absolute thresholds such as for the liquidity ratio.

⁵³This accounts for the different sample sizes and potential composition effects in the two countries. The results in the U.S. are robust to trimming 4%, but we choose to maximise the number of observations over identical trimming strategies in both countries. Capex does not have any negative observations in the U.K. after cleaning the sample from short-lived firms and FIRE sectors.

B High-frequency surprises and monetary policy shocks

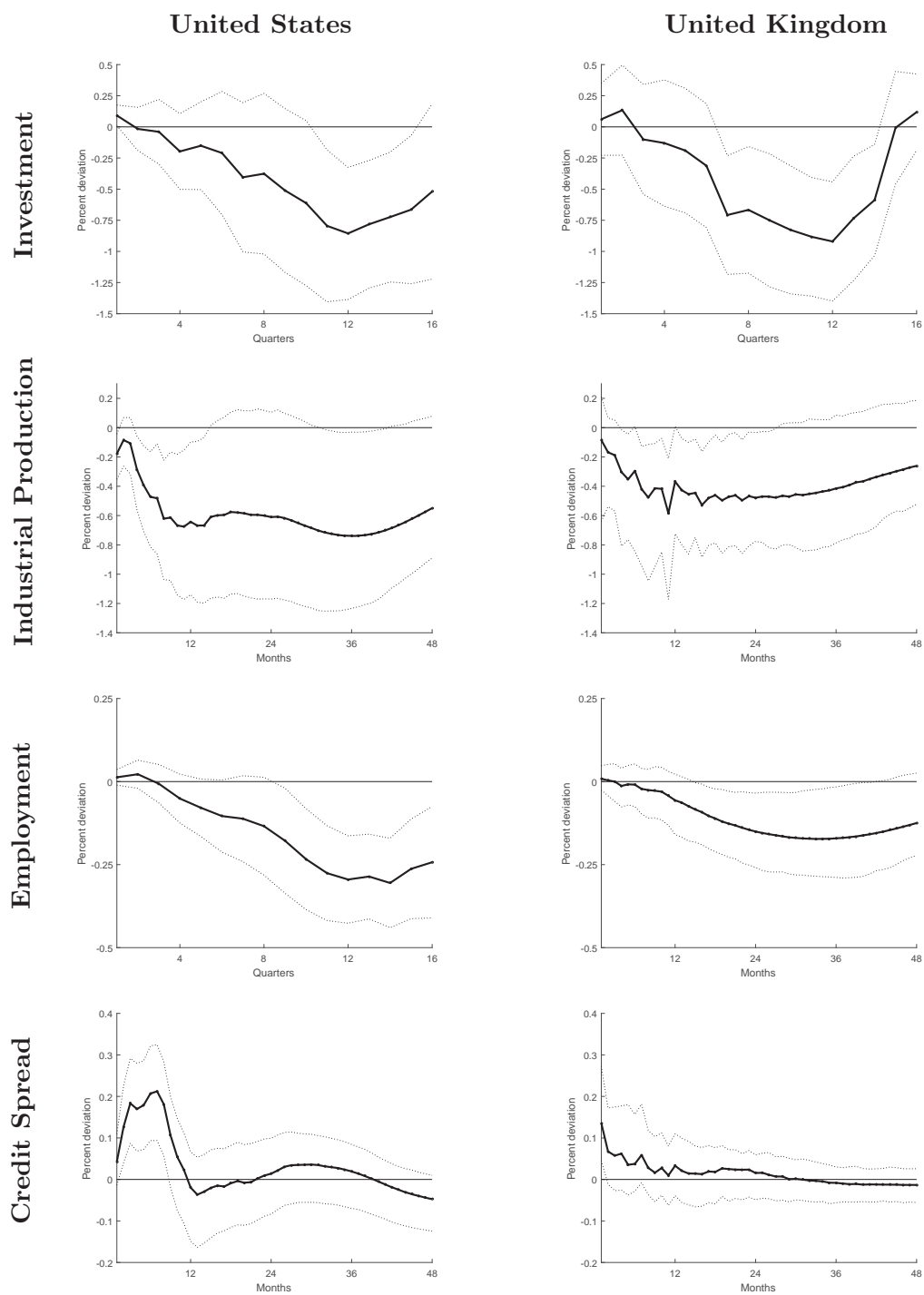
Figure B.1: Time series of monetary policy surprises and shocks



Notes: The top panel shows the raw financial market surprises (Gerko and Rey (2017) and updated Gertler and Karadi (2015)). The bottom panel show the implies monetary policy shocks from the proxy-VAR in these papers. We deviate from these papers in re-estimating the sample period to match that of our micro-data: 1986-2016.

C Evidence based on aggregate time series

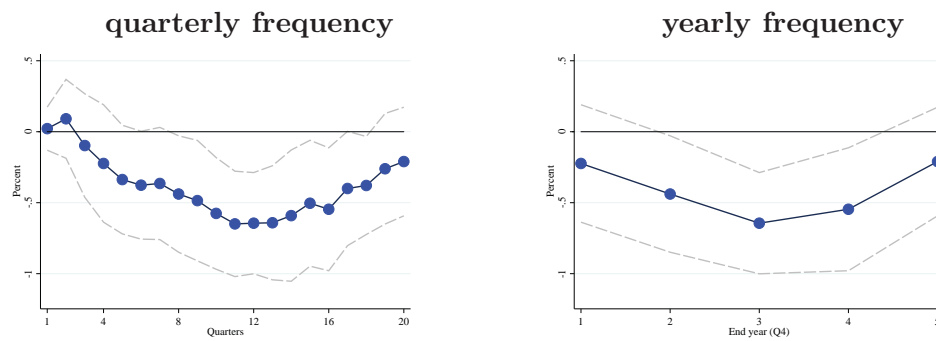
Figure C.1: Dynamic Effects of Monetary Policy on selected national statistics data



Notes: impulse response function to a 25bps increase in the interest rates using local projection IV (top row, investment is quarterly) or the proxy-VAR directly (other rows, where the data and the VAR is monthly). Because of data availability, the model in the top (other) row(s) is estimated at quarterly (monthly) frequency.

D U.S. results reported at yearly frequency

Figure D.1: U.S. average effect reported at quarterly and yearly frequency



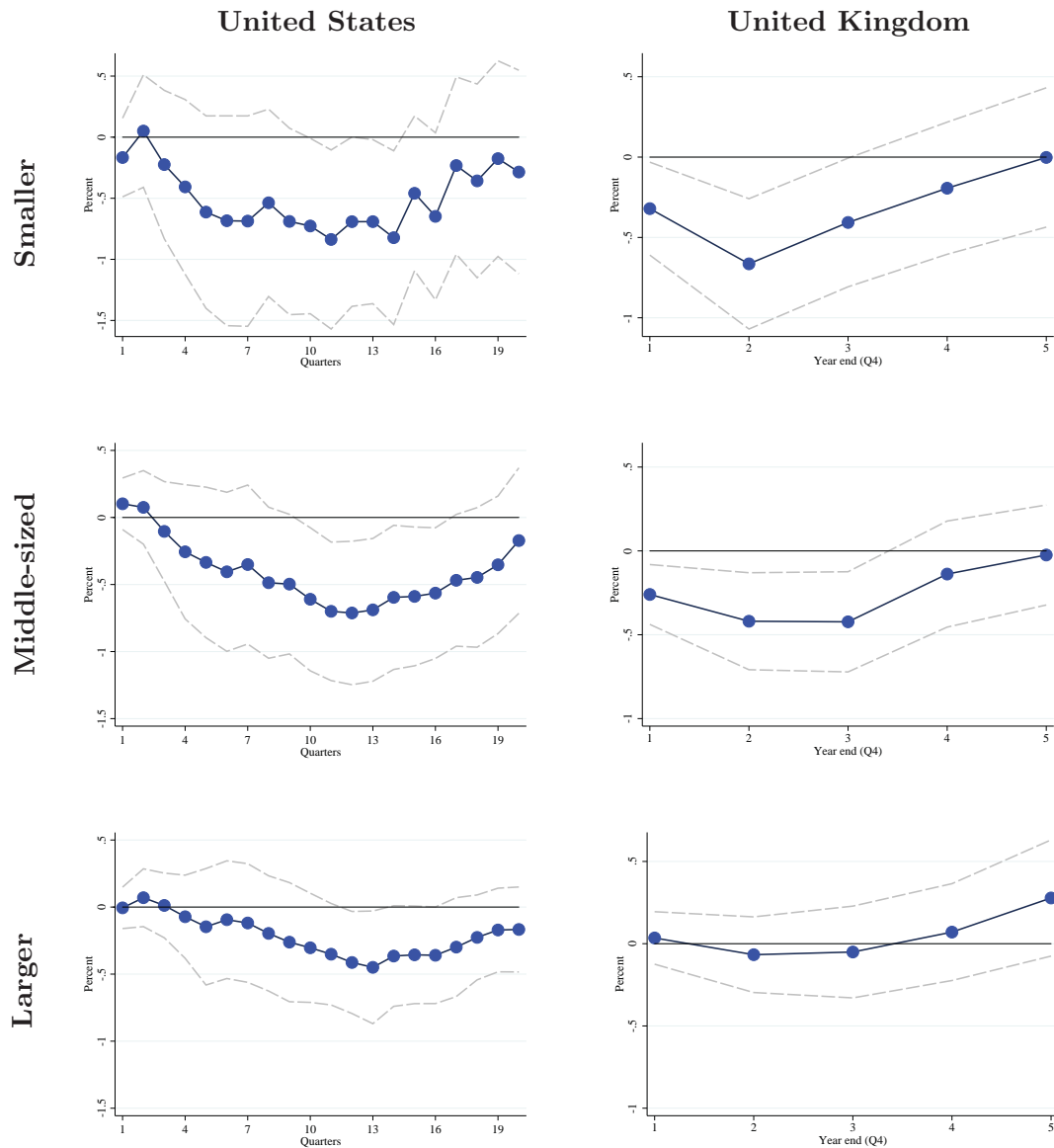
Notes: This figure shows the impulse response functions following a 25bps increase in the interest rates. The IRFs are estimated using the local projection IV approach described in the text. Standard errors are clustered by firm and time. For the US the Driscoll-Kraay adjustment is used to correct for potential serial correlation.

E Grouping by other firms' characteristics

In this Appendix, we present results by splitting the sample according to alternative groupings. More specifically, we explore heterogeneity in the capital expenditure responses by looking *in isolation* (as opposed to double sorting of the sample) at size, growth, leverage, Tobin's Q and dividends.

E.1 Capital expenditure responses by firm size only

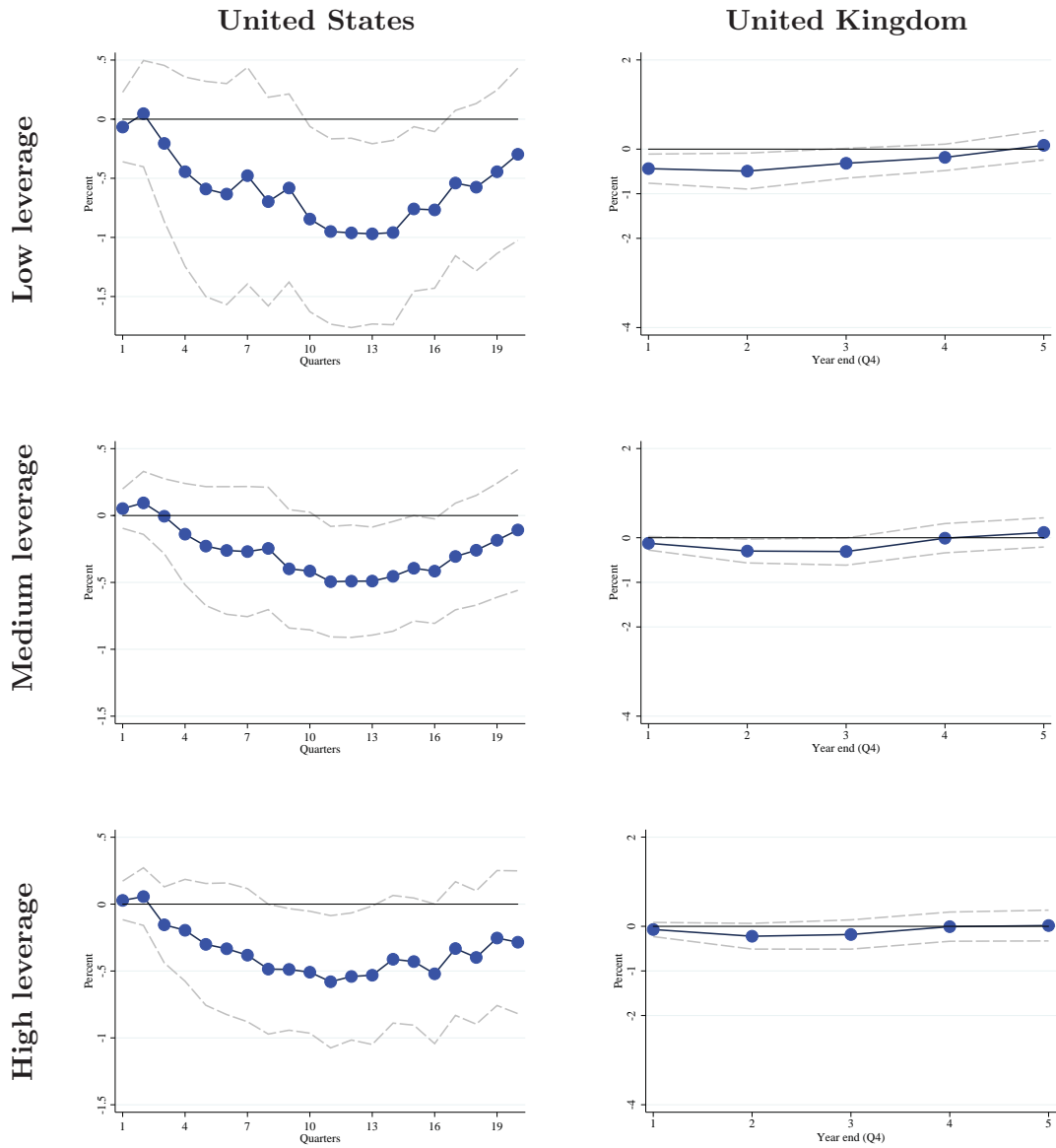
Figure E.1: Dynamic Effects of Monetary Policy on Investment by Size



Notes: This figure shows the impulse response functions following a 25bps increase in the interest rates. The interest rate is interacted with binary indicators based on quartiles of the size distribution. The IRFs are estimated using the local projection IV approach described in the text. Standard errors are clustered by firm and time. For the US the Driscoll-Kraay adjustment is used to correct for potential serial correlation.

E.2 Capital expenditure responses by leverage only

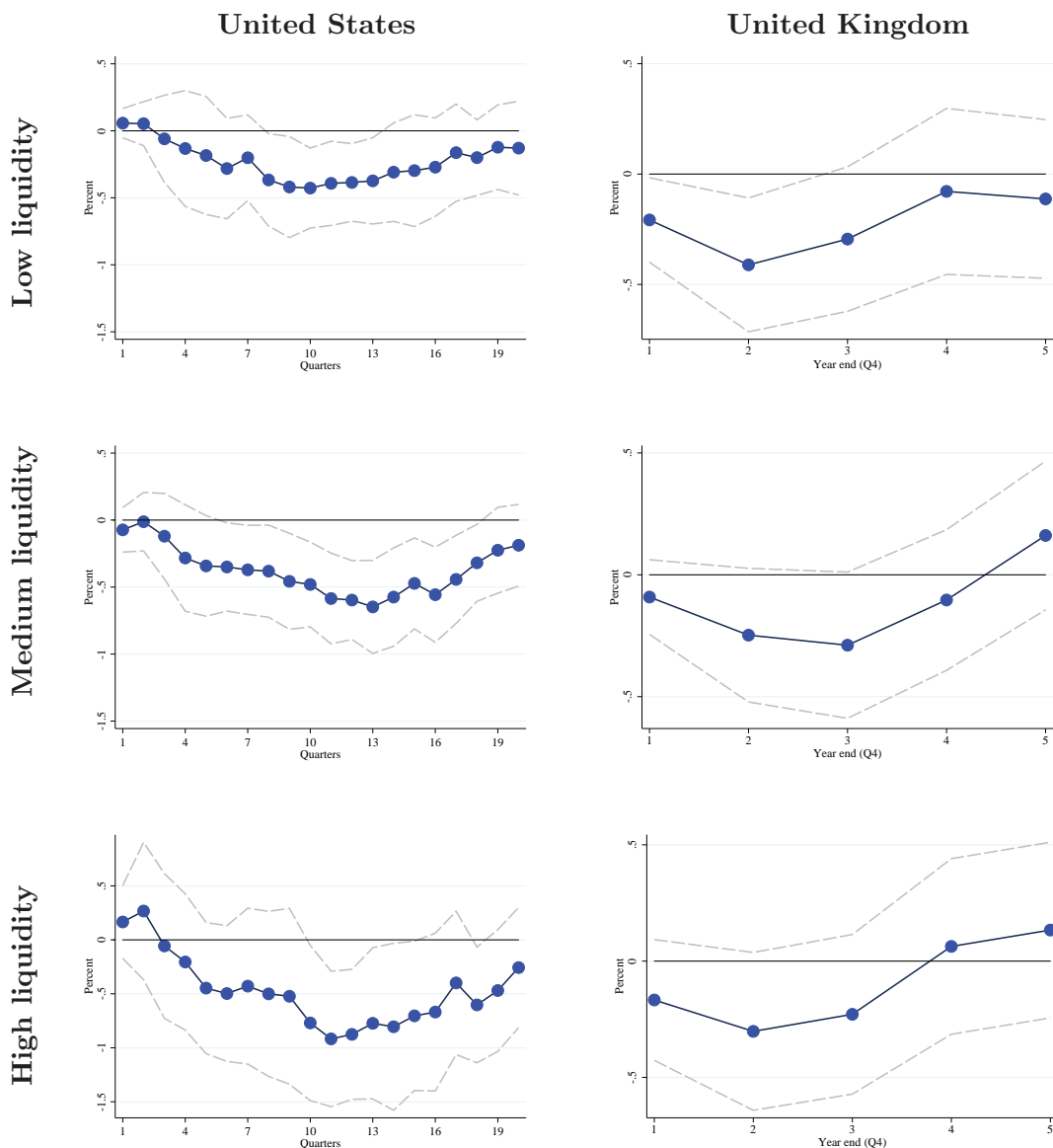
Figure E.2: Dynamic Effects of Monetary Policy on Investment by Leverage



Notes: This figure shows the impulse response functions following a 25bps increase in the interest rates. The interest rate is interacted with binary indicators based on quartiles of the leverage distribution. The IRFs are estimated using the local projection IV approach described in the text. Standard errors are clustered by firm and time. For the US the Driscoll-Kraay adjustment is used to correct for potential serial correlation.

E.3 Capital expenditure responses by liquidity only

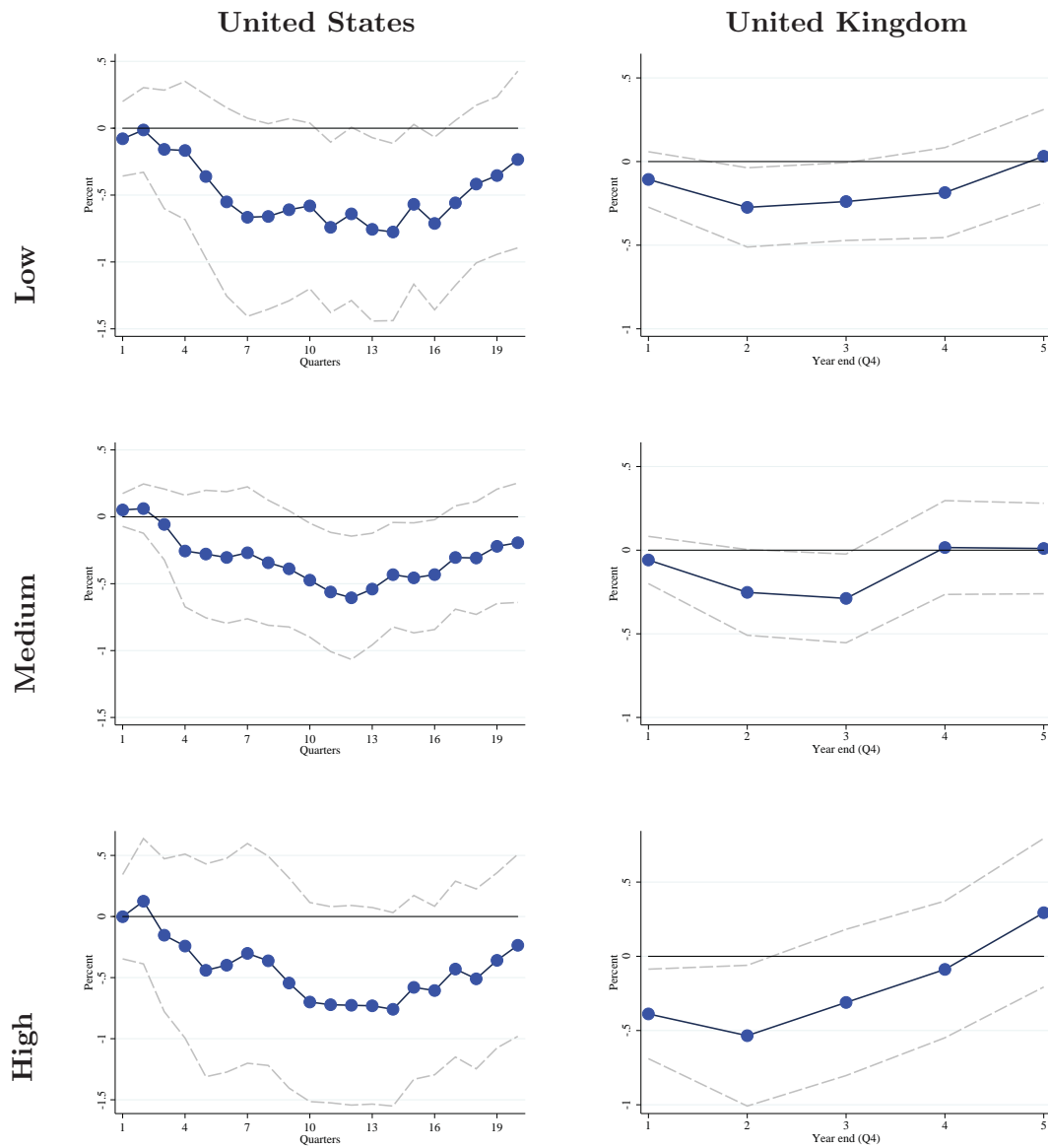
Figure E.3: Dynamic Effects of Monetary Policy on Investment by Liquidity



Notes: This figure shows the impulse response functions following a 25bps increase in the interest rates. The interest rate is interacted with binary indicators based on quartiles of the liquidity ratio distribution. The IRFs are estimated using the local projection IV approach described in the text. Standard errors are clustered by firm and time. For the US the Driscoll-Kraay adjustment is used to correct for potential serial correlation.

E.4 Capital expenditure responses by assets growth only

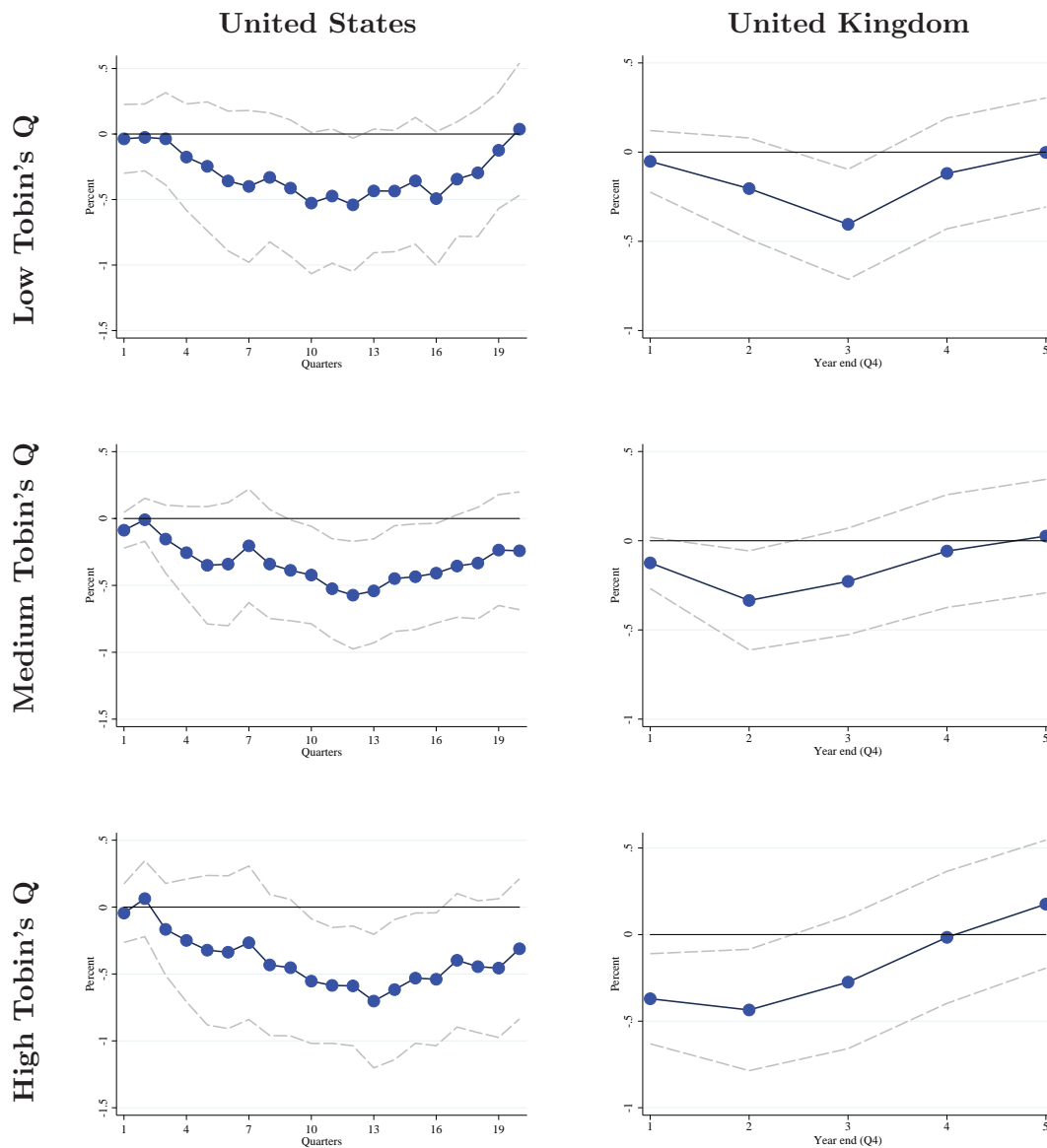
Figure E.4: Dynamic Effects of Monetary Policy on Investment by Firms' Growth



Notes: This figure shows the impulse response functions following a 25bps increase in the interest rates. The interest rate is interacted with binary indicators based on quartiles of the asset growth rate distribution. The IRFs are estimated using the local projection IV approach described in the text. Standard errors are clustered by firm and time. For the US the Driscoll-Kraay adjustment is used to correct for potential serial correlation.

E.5 Capital expenditure responses by Tobin's Q only

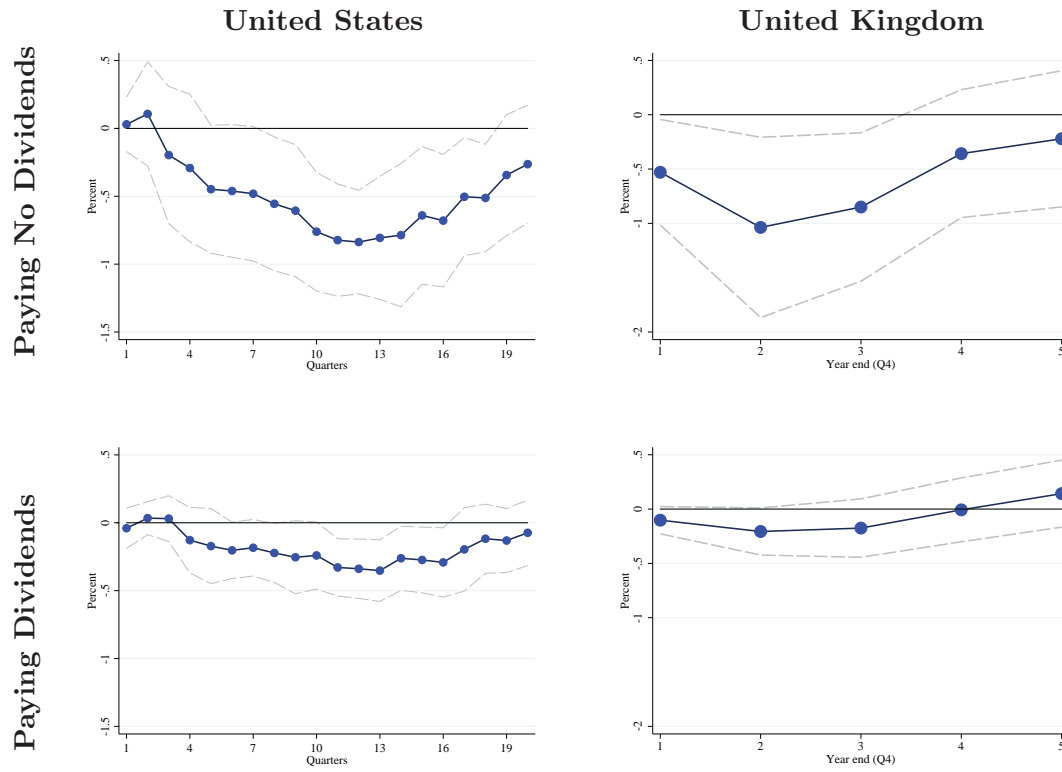
Figure E.5: Dynamic Effects of Monetary Policy on Investment by Tobin's Q



Notes: This figure shows the impulse response functions following a 25bps increase in the interest rates. The interest rate is interacted with binary indicators based on quartiles of the Tobin's Q distribution. The IRFs are estimated using the local projection IV approach described in the text. Standard errors are clustered by firm and time. For the US the Driscoll-Kraay adjustment is used to correct for potential serial correlation.

E.6 Capital expenditure responses by paying dividends status only

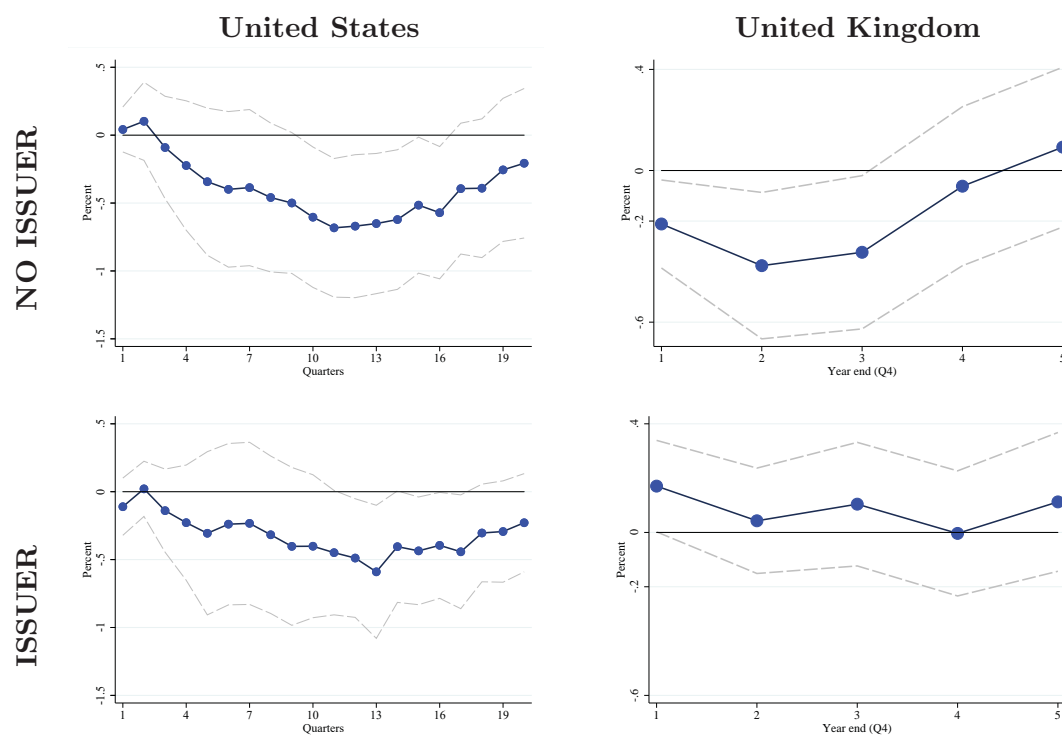
Figure E.6: Dynamic Effects of Monetary Policy on Investment by Paying Dividends



Notes: This figure shows the impulse response functions following a 25bps increase in the interest rates. The interest rate is interacted with binary indicator for whether dividends were paid in the previous year. The IRFs are estimated using the local projection IV approach described in the text. Standard errors are clustered by firm and time. For the US the Driscoll-Kraay adjustment is used to correct for potential serial correlation.

E.7 Capital expenditure responses by issuer status only

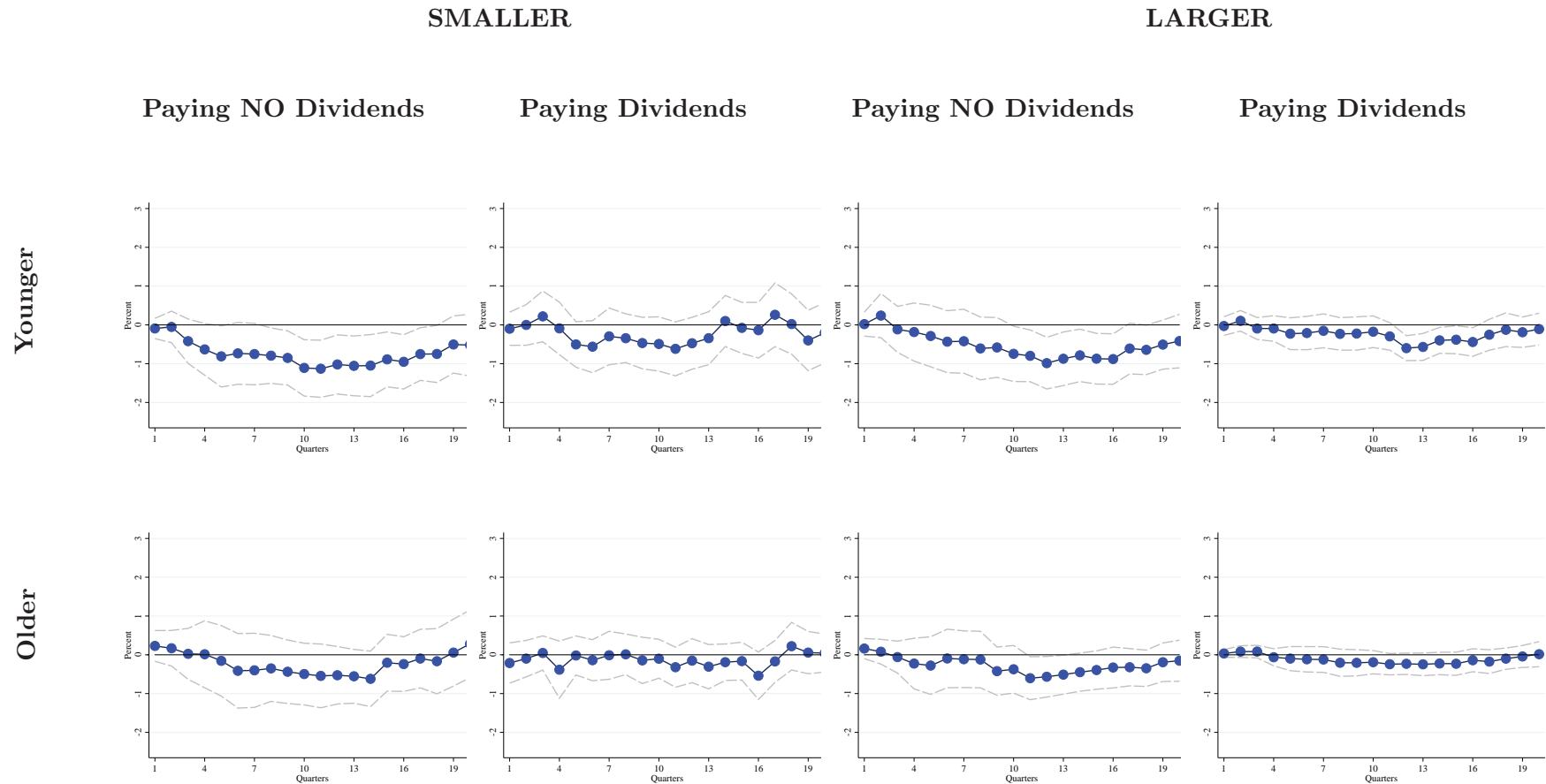
Figure E.7: Dynamic Effects of Monetary Policy on Investment by Issuer Status



Notes: This figure shows the impulse response functions following a 25bps increase in the interest rates. The interest rate is interacted with a binary indicator for whether bonds have been issued in the past. The IRFs are estimated using the local projection IV approach described in the text. Standard errors are clustered by firm and time. For the US the Driscoll-Kraay adjustment is used to correct for potential serial correlation.

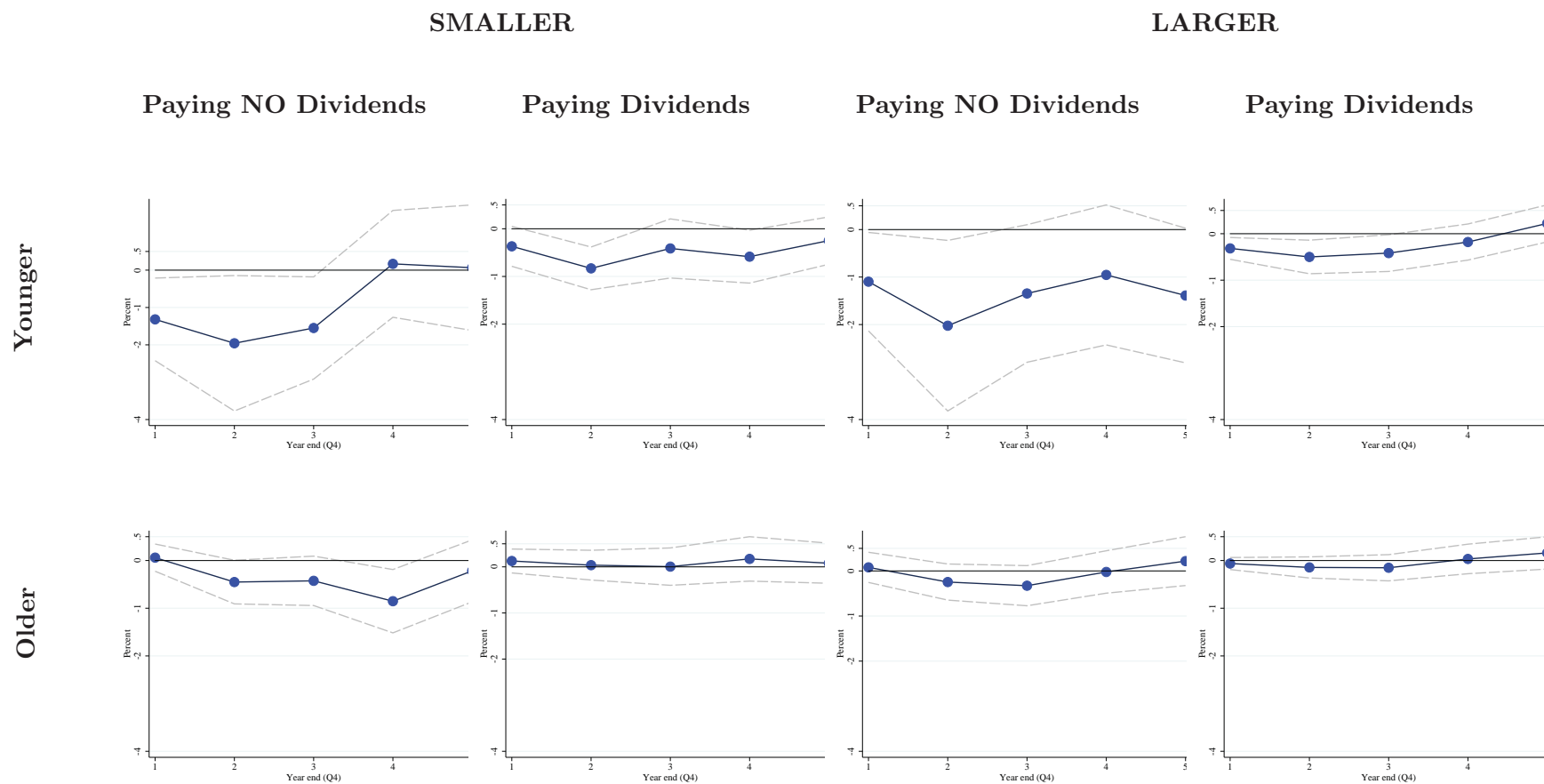
F Controlling for other firms' characteristics

Figure F.1: Dynamic Effects of Monetary Policy on Investment by Age, Dividends Paid and Size for the United States



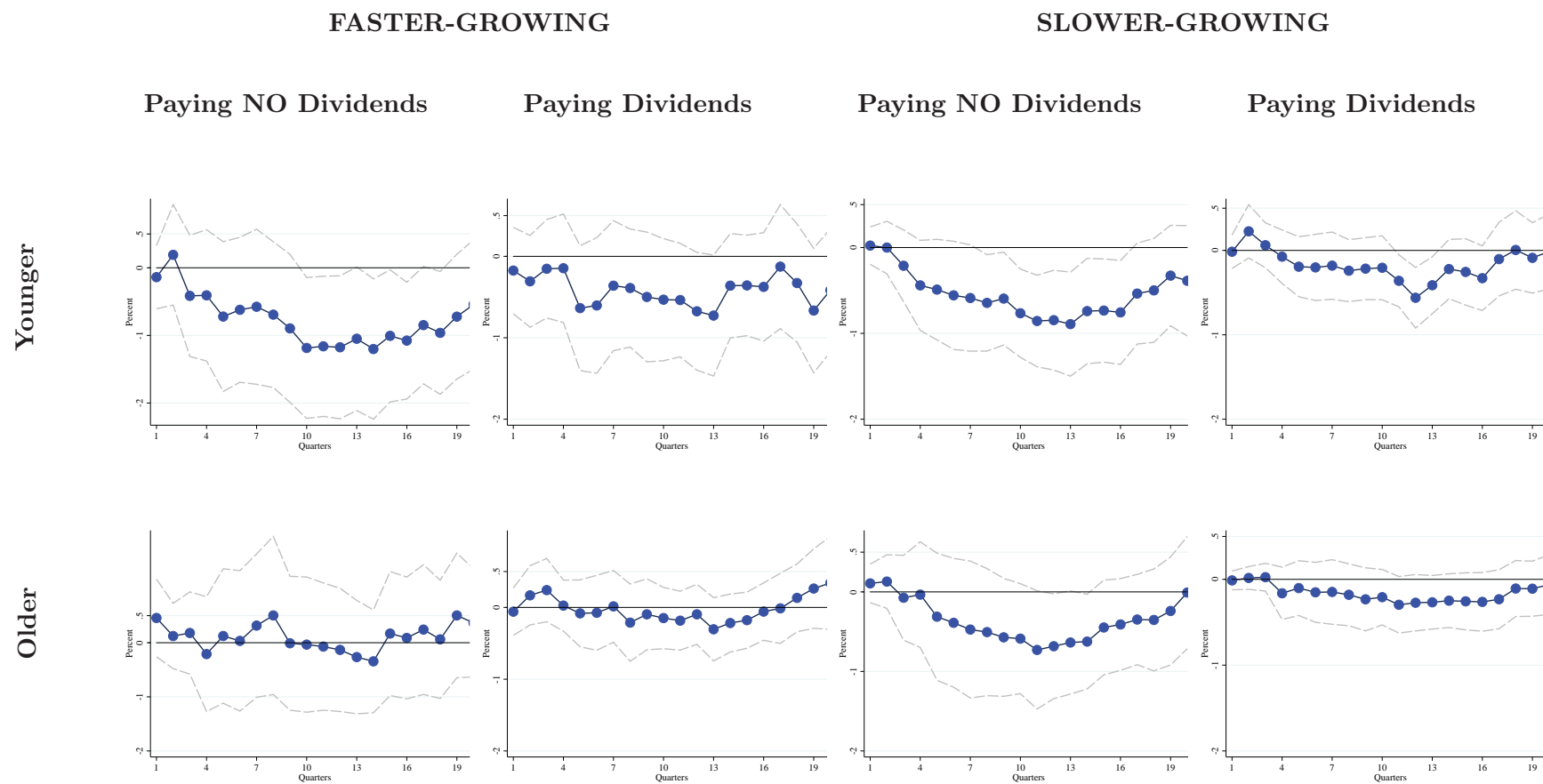
Notes: This figure shows the impulse response functions following a 25bps increase in the interest rates. The interest rate is interacted with binary indicators based on age, dividend status, size. Younger refers to < 15 years since incorporation and older refers to > 15 years since incorporation. No dividends means the firm did not pay cash dividends in the previous year. Smaller firms refer to those in the bottom quartile of the size distribution in the previous year. The IRFs are estimated using the local projection IV approach described in the text. Standard errors are clustered by firm and time. For the US the Driscoll-Kraay adjustment is used to correct for potential serial correlation.

Figure F.2: Dynamic Effects of Monetary Policy on Investment by Age, Dividends Paid and Size for the United Kingdom



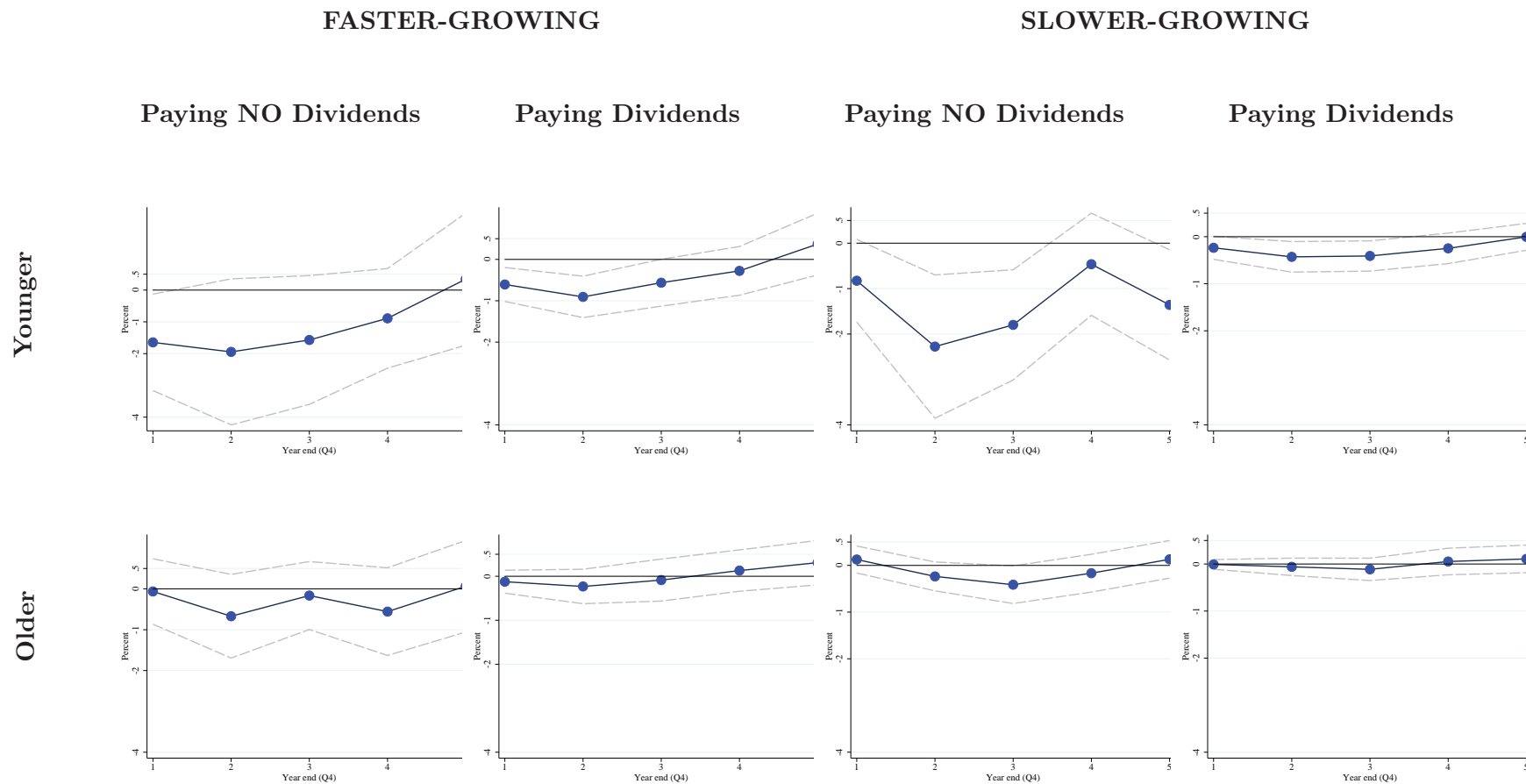
Notes: This figure shows the impulse response functions following a 25bps increase in the interest rates. The interest rate is interacted with binary indicators based on age, dividend status, size. Younger refers to < 15 years since incorporation and older refers to > 15 years since incorporation. No dividends means the firm did not pay cash dividends in the previous year. Smaller firms refer to those in the bottom quartile of the size distribution in the previous year. The IRFs are estimated using the local projection IV approach described in the text. Standard errors are clustered by firm and time. For the US the Driscoll-Kraay adjustment is used to correct for potential serial correlation.

Figure F.3: Dynamic Effects of Monetary Policy on Investment by Age, Dividends Paid and Asset Growth for the U.S.



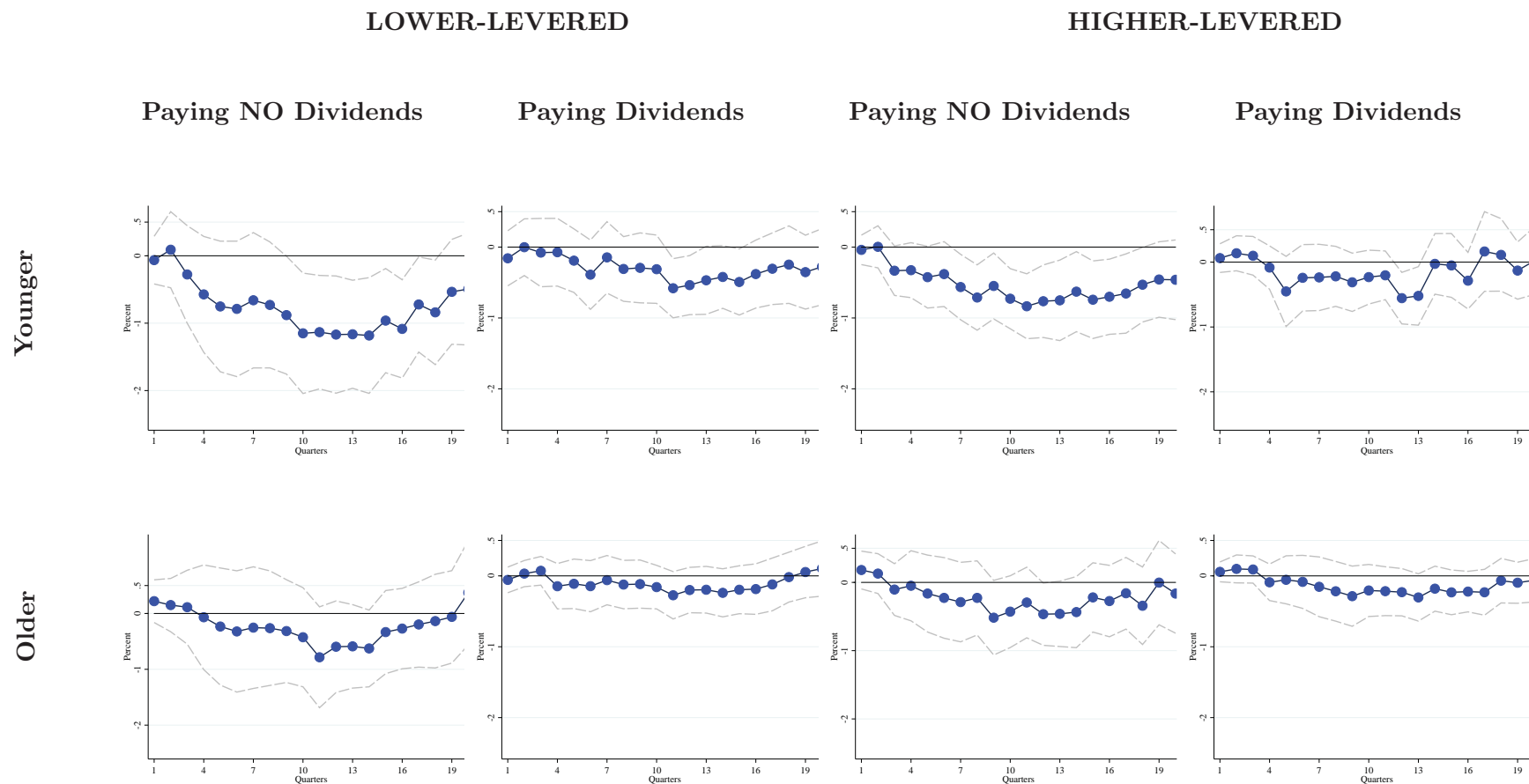
Notes: This figure shows the impulse response functions following a 25bps increase in the interest rates. The interest rate is interacted with binary indicators based on age, dividend status, asset growth. Younger refers to < 15 years since incorporation and older refers to > 15 years since incorporation. No dividends means the firm did not pay cash dividends in the previous year. Faster growing firms refer to those in the top quartile of the distribution in the previous year. The IRFs are estimated using the local projection IV approach described in the text. Standard errors are clustered by firm and time. For the US the Driscoll-Kraay adjustment is used to correct for potential serial correlation.

Figure F.4: Dynamic Effects of Monetary Policy on Investment by Age, Dividends Paid and Asset Growth for the U.K.



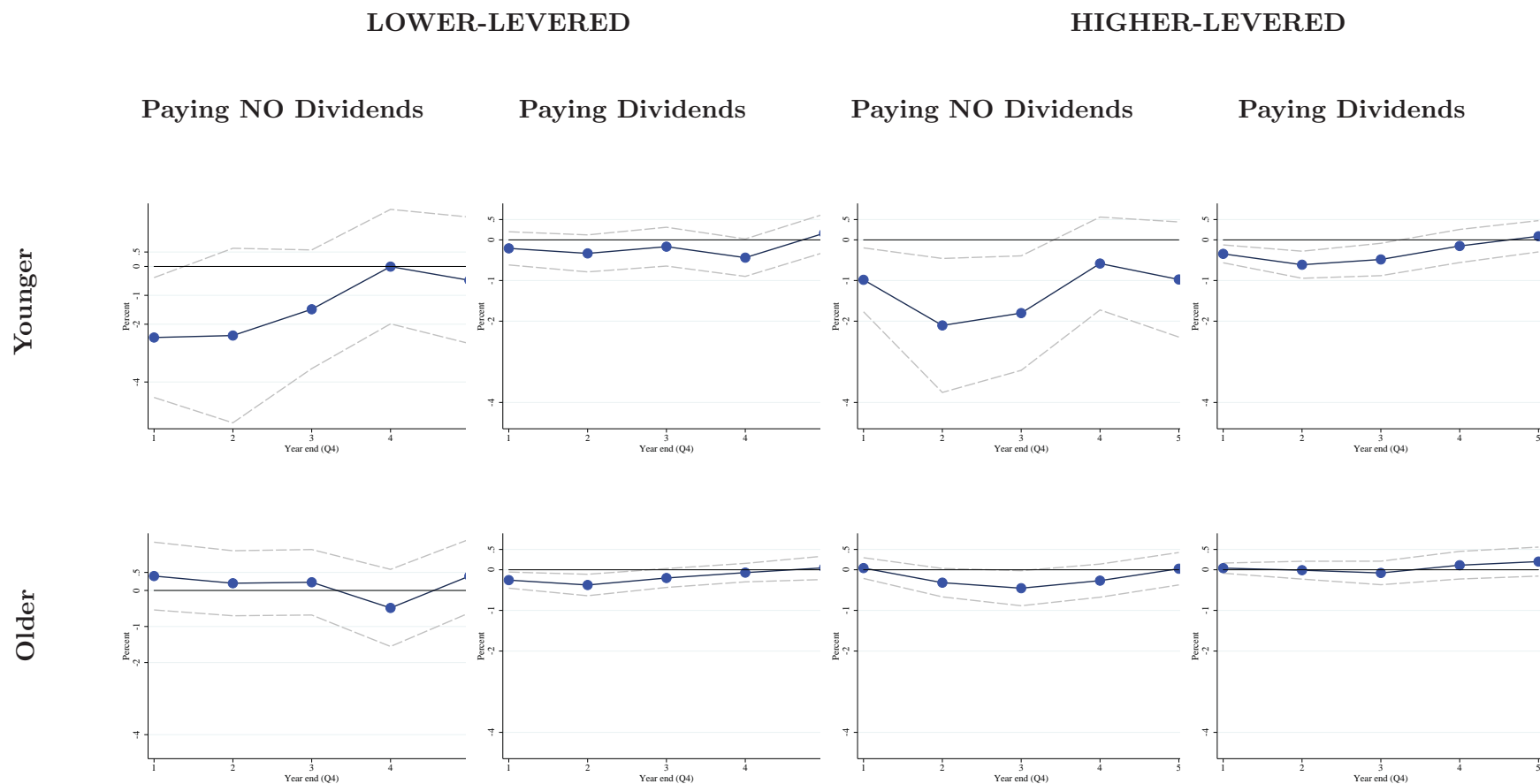
Notes: This figure shows the impulse response functions following a 25bps increase in the interest rates. The interest rate is interacted with binary indicators based on age, dividend status, asset growth. Younger refers to < 15 years since incorporation and older refers to > 15 years since incorporation. No dividends means the firm did not pay cash dividends in the previous year. Faster growing firms refer to those in the top quartile of the distribution in the previous year. The IRFs are estimated using the local projection IV approach described in the text. Standard errors are clustered by firm and time. For the US the Driscoll-Kraay adjustment is used to correct for potential serial correlation.

Figure F.5: Dynamic Effects of Monetary Policy on Investment by Age, Dividends Paid and Leverage for the U.S.



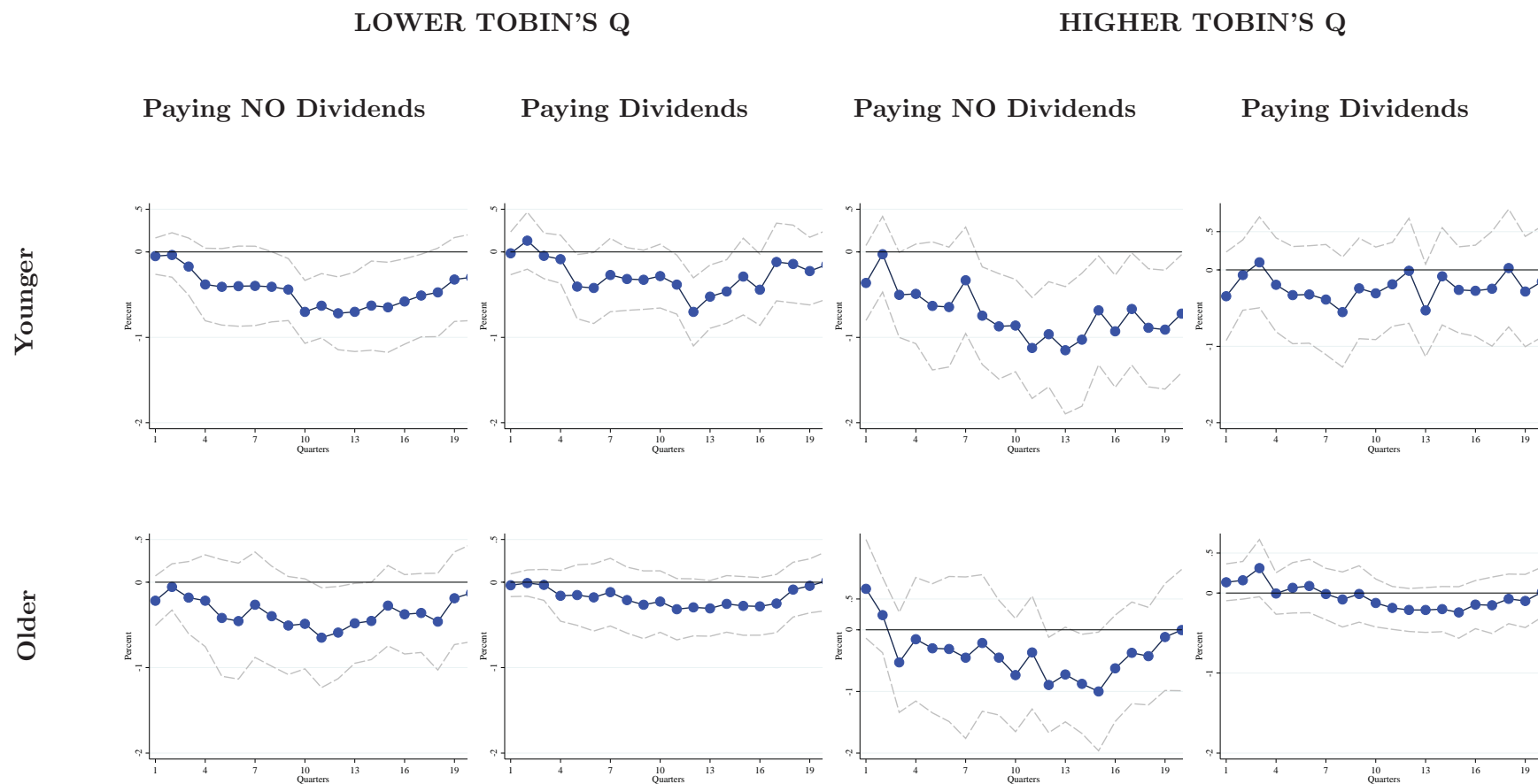
Notes: This figure shows the impulse response functions following a 25bps increase in the interest rates. The interest rate is interacted with binary indicators based on age, dividend status, leverage. Younger refers to < 15 years since incorporation and older refers to > 15 years since incorporation. No dividends means the firm did not pay cash dividends in the previous year. Lower leverage firms refer to those in the bottom quartile of the distribution in the previous year. The IRFs are estimated using the local projection IV approach described in the text. Standard errors are clustered by firm and time. For the US the Driscoll-Kraay adjustment is used to correct for potential serial correlation.

Figure F.6: Dynamic Effects of Monetary Policy on Investment by Age, Dividends Paid and Leverage for the U.K.



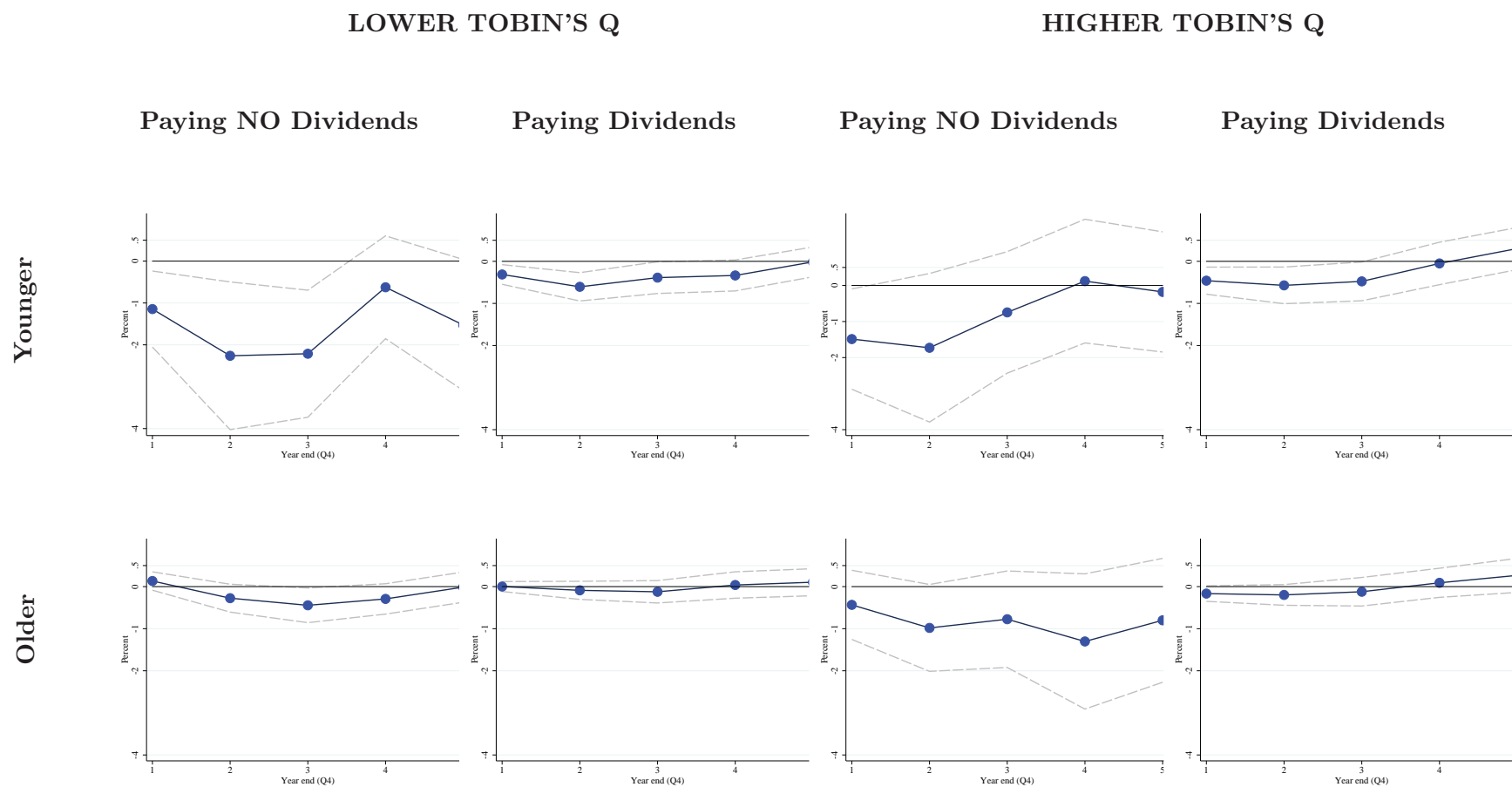
Notes: This figure shows the impulse response functions following a 25bps increase in the interest rates. The interest rate is interacted with binary indicators based on age, dividend status, leverage. Younger refers to < 15 years since incorporation and older refers to > 15 years since incorporation. No dividends means the firm did not pay cash dividends in the previous year. Lower leverage firms refer to those in the bottom quartile of the distribution in the previous year. The IRFs are estimated using the local projection IV approach described in the text. Standard errors are clustered by firm and time. For the US the Driscoll-Kraay adjustment is used to correct for potential serial correlation.

Figure F.7: Dynamic Effects of Monetary Policy on Investment by Age, Dividends Paid and Tobin's Q for the U.S.



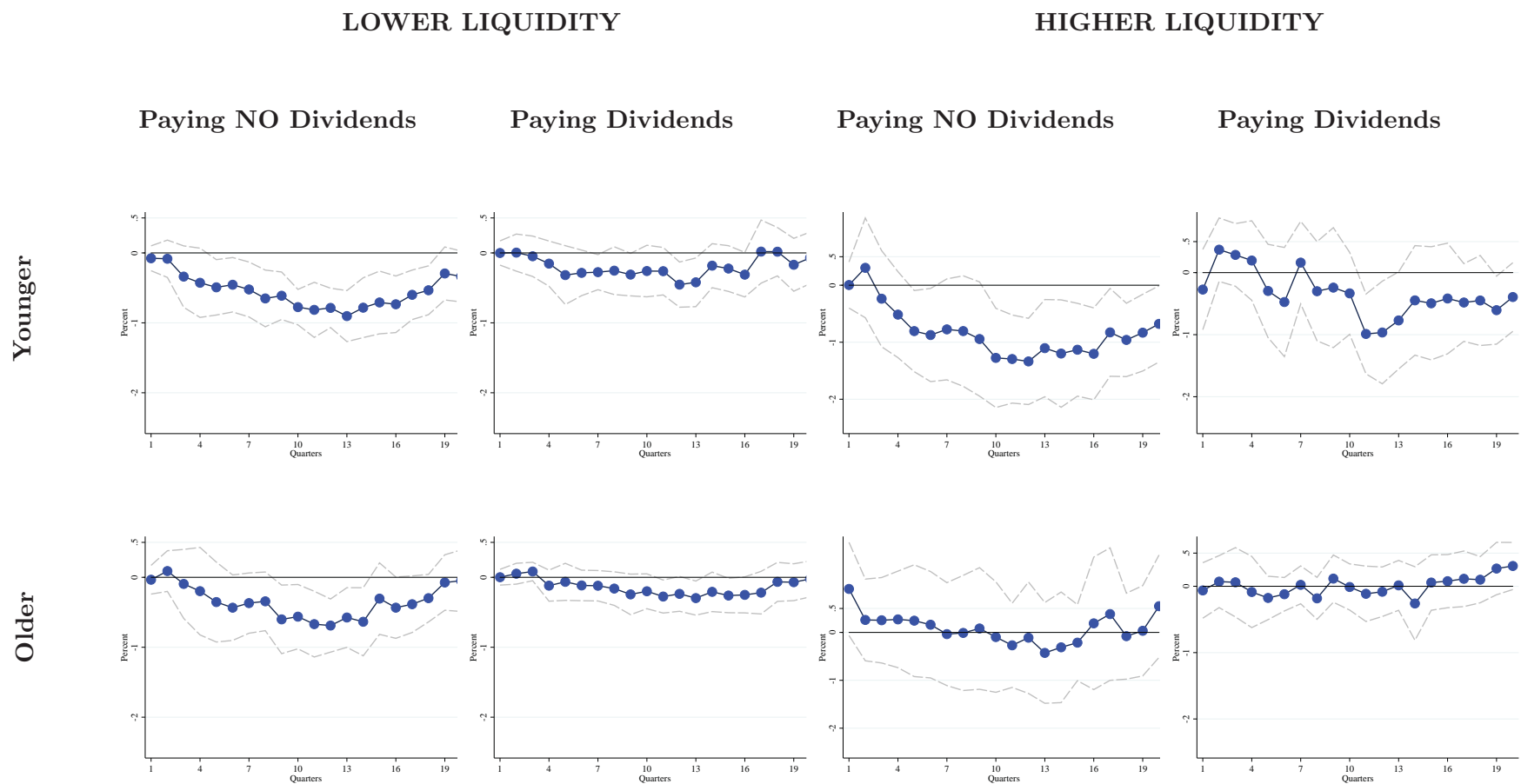
Notes: This figure shows the impulse response functions following a 25bps increase in the interest rates. The interest rate is interacted with binary indicators based on age, dividend status, Tobin's Q. Younger refers to < 15 years since incorporation and older refers to > 15 years since incorporation. No dividends means the firm did not pay cash dividends in the previous year. Higher Tobin's Q refers firms refer to those in the top quartile of the distribution in the previous year. The IRFs are estimated using the local projection IV approach described in the text. Standard errors are clustered by firm and time. For the US the Driscoll-Kraay adjustment is used to correct for potential serial correlation.

Figure F.8: Dynamic Effects of Monetary Policy on Investment by Age, Dividends Paid and Tobin's Q for the U.K.



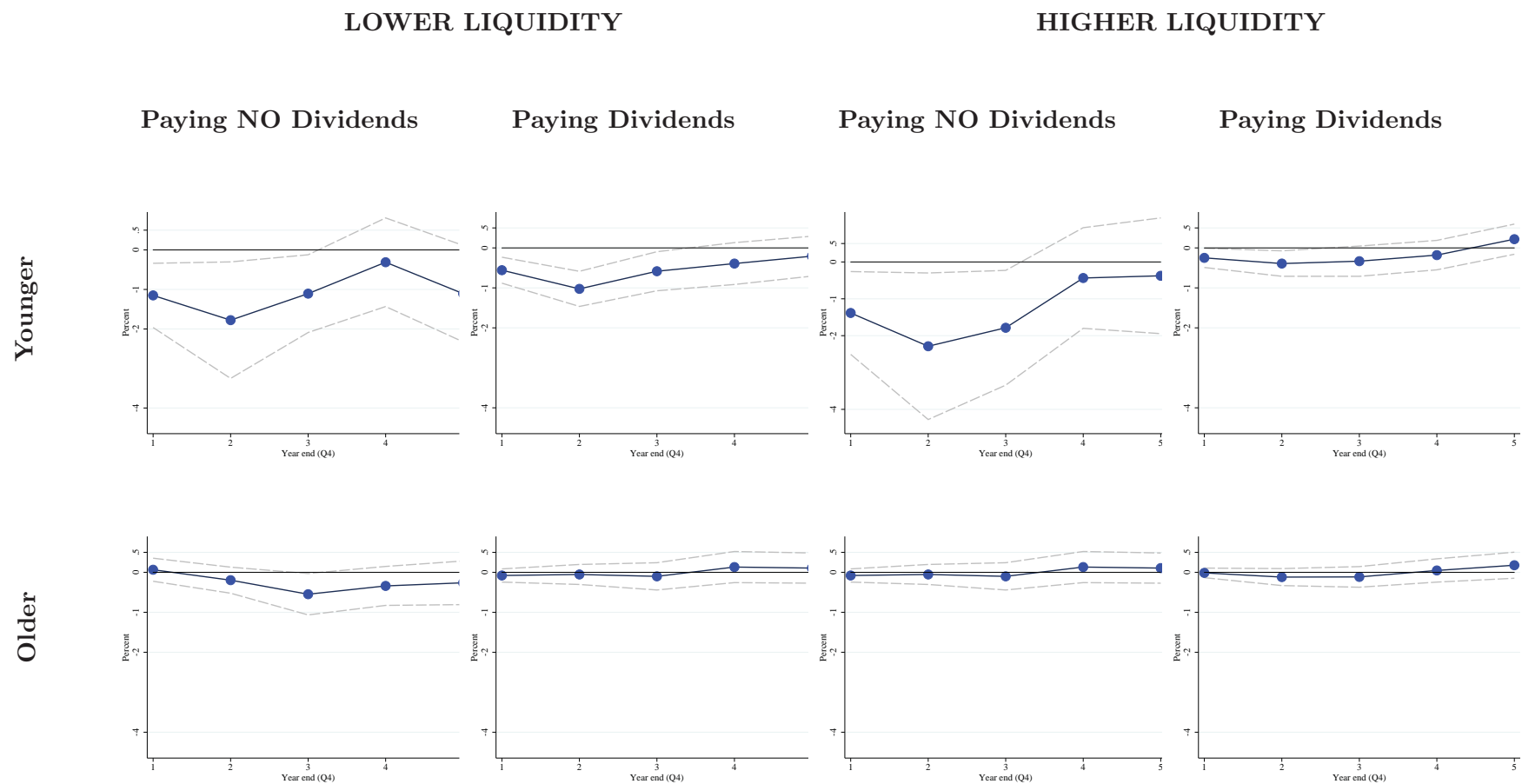
Notes: This figure shows the impulse response functions following a 25bps increase in the interest rates. The interest rate is interacted with binary indicators based on age, dividend status, Tobin's Q. Younger refers to < 15 years since incorporation and older refers to > 15 years since incorporation. No dividends means the firm did not pay cash dividends in the previous year. Higher Tobin's Q refers firms refer to those in the top quartile of the distribution in the previous year. The IRFs are estimated using the local projection IV approach described in the text. Standard errors are clustered by firm and time. For the US the Driscoll-Kraay adjustment is used to correct for potential serial correlation.

Figure F.9: Dynamic Effects of Monetary Policy on Investment by Age, Dividends Paid and Liquidity for the U.S.



Notes: This figure shows the impulse response functions following a 25bps increase in the interest rates. The interest rate is interacted with binary indicators based on age, dividend status, the liquidity ratio. Younger refers to < 15 years since incorporation and older refers to > 15 years since incorporation. No dividends means the firm did not pay cash dividends in the previous year. Higher liquidity refers firms refer to those in the top quartile of the distribution in the previous year. The IRFs are estimated using the local projection IV approach described in the text. Standard errors are clustered by firm and time. For the US the Driscoll-Kraay adjustment is used to correct for potential serial correlation.

Figure F.10: Dynamic Effects of Monetary Policy on Investment by Age, Dividends Paid and Liquidity for the U.K.



Notes: This figure shows the impulse response functions following a 25bps increase in the interest rates. The interest rate is interacted with binary indicators based on age, dividend status, the liquidity ratio. Younger refers to < 15 years since incorporation and older refers to > 15 years since incorporation. No dividends means the firm did not pay cash dividends in the previous year. Higher liquidity refers firms refer to those in the top quartile of the distribution in the previous year. The IRFs are estimated using the local projection IV approach described in the text. Standard errors are clustered by firm and time. For the US the Driscoll-Kraay adjustment is used to correct for potential serial correlation.

BANCO DE ESPAÑA PUBLICATIONS

WORKING PAPERS

- 1801 OLYMPIA BOVER, LAURA HOSPIDO and ERNESTO VILLANUEVA: The impact of high school financial education on financial knowledge and choices: evidence from a randomized trial in Spain.
- 1802 IGNACIO HERNANDO, IRENE PABLOS, DANIEL SANTABÁRBARA and JAVIER VALLÉS: Private Saving. New Cross-Country Evidence Based on Bayesian Techniques.
- 1803 PABLO AGUILAR and JESÚS VÁZQUEZ: Term structure and real-time learning.
- 1804 MORITZ A. ROTH: International co-movements in recessions.
- 1805 ANGELA ABBATE and DOMINIK THALER: Monetary policy and the asset risk-taking channel.
- 1806 PABLO MARTÍN-ACEÑA: Money in Spain. New historical statistics. 1830-1998.
- 1807 GUILHERME BANDEIRA: Fiscal transfers in a monetary union with sovereign risk.
- 1808 MIGUEL GARCÍA-POSADA GÓMEZ: Credit constraints, firm investment and growth: evidence from survey data.
- 1809 LAURA ALFARO, MANUEL GARCÍA-SANTANA and ENRIQUE MORAL-BENITO: On the direct and indirect real effects of credit supply shocks.
- 1810 ROBERTO RAMOS and CARLOS SANZ: Backing the incumbent in difficult times: the electoral impact of wildfires.
- 1811 GABRIEL JIMÉNEZ, ENRIQUE MORAL-BENITO and RAQUEL VEGAS: Bank lending standards over the cycle: the role of firms' productivity and credit risk.
- 1812 JUAN S. MORA-SANGUINETTI and ROK SPRUK: Industry vs services: do enforcement institutions matter for specialization patterns? Disaggregated evidence from Spain.
- 1813 JAMES CLOYNE, CLODOMIRO FERREIRA and PAOLO SURICO: Monetary policy when households have debt: new evidence on the transmission mechanism.
- 1814 DMITRI KIRPICHEV and ENRIQUE MORAL-BENITO: The costs of trade protectionism: evidence from Spanish firms and non-tariff measures.
- 1815 ISABEL ARGIMÓN, CLEMENS BONNER, RICARDO CORREA, PATTY DUIJM, JON FROST, JAKOB DE HAAN, LEO DE HAAN and VIKTORS STEBUNOV: Financial institutions' business models and the global transmission of monetary policy.
- 1816 JOSE ASTURIAS, MANUEL GARCÍA-SANTANA and ROBERTO RAMOS: Competition and the welfare gains from transportation infrastructure: evidence from the Golden Quadrilateral of India.
- 1817 SANDRA GARCÍA-URIBE: Multidimensional media slant: complementarities in news reporting by US newspapers.
- 1818 PILAR CUADRADO, AITOR LACUESTA, MARÍA DE LOS LLANOS MATEA and F. JAVIER PALENCIA-GONZÁLEZ: Price strategies of independent and branded dealers in retail gas market. The case of a contract reform in Spain.
- 1819 ALBERTO FUERTES, RICARDO GIMENO and JOSÉ MANUEL MARQUÉS: Extraction of inflation expectations from financial instruments in Latin America.
- 1820 MARIO ALLOZA, PABLO BURRIEL and JAVIER J. PÉREZ: Fiscal policies in the euro area: revisiting the size of spillovers.
- 1821 MARTA MARTÍNEZ-MATUTE and ALBERTO URTASUN: Uncertainty, firm heterogeneity and labour adjustments. Evidence from European countries.
- 1822 GABRIELE FIORENTINI, ALESSANDRO GALESÌ, GABRIEL PÉREZ-QUIRÓS and ENRIQUE SENTANA: The rise and fall of the natural interest rate.
- 1823 ALBERTO MARTÍN, ENRIQUE MORAL-BENITO and TOM SCHMITZ: The financial transmission of housing bubbles: evidence from Spain.
- 1824 DOMINIK THALER: Sovereign default, domestic banks and exclusion from international capital markets.
- 1825 JORGE E. GALÁN and JAVIER MENCÍA: Empirical assessment of alternative structural methods for identifying cyclical systemic risk in Europe.
- 1826 ROBERTO BLANCO and NOELIA JIMÉNEZ: Credit allocation along the business cycle: evidence from the latest boom bust credit cycle in Spain.
- 1827 ISABEL ARGIMÓN: The relevance of currency-denomination for the cross-border effects of monetary policy.
- 1828 SANDRA GARCÍA-URIBE: The effects of tax changes on economic activity: a narrative approach to frequent anticipations.
- 1829 MATÍAS CABRERA, GERALD P. DWYER and MARÍA J. NIETO: The G-20 regulatory agenda and bank risk.
- 1830 JACOPO TIMINI and MARINA CONESA: Chinese exports and non-tariff measures: testing for heterogeneous effects at the product level.
- 1831 JAVIER ANDRÉS, JOSÉ E. BOSCA, JAVIER FERRI and CRISTINA FUENTES-ALBERO: Households' balance sheets and the effect of fiscal policy.

- 1832 ÓSCAR ARCE, MIGUEL GARCÍA-POSADA, SERGIO MAYORDOMO and STEVEN ONGENA: Adapting lending policies when negative interest rates hit banks' profits.
- 1833 VICENTE SALAS, LUCIO SAN JUAN and JAVIER VALLÉS: Corporate cost and profit shares in the euro area and the US: the same story?
- 1834 MARTÍN GONZÁLEZ-EIRAS and CARLOS SANZ: Women's representation in politics: voter bias, party bias, and electoral systems.
- 1835 MÓNICA CORREA-LÓPEZ and BEATRIZ DE BLAS: Faraway, so close! Technology diffusion and firm heterogeneity in the medium term cycle of advanced economies.
- 1836 JACOPO TIMINI: The margins of trade: market entry and sector spillovers, the case of Italy (1862-1913).
- 1837 HENRIQUE S. BASSO and OMAR RACHEDI: The young, the old, and the government: demographics and fiscal multipliers.
- 1838 PAU ROLDÁN and SONIA GILBUKH: Firm dynamics and pricing under customer capital accumulation.
- 1839 GUILHERME BANDEIRA, JORDI CABALLÉ and EUGENIA VELLA: Should I stay or should I go? Austerity, unemployment and migration.
- 1840 ALESSIO MORO and OMAR RACHEDI: The changing structure of government consumption spending.
- 1841 GERGELY GANICS, ATSUSHI INOUE and BARBARA ROSSI: Confidence intervals for bias and size distortion in IV and local projections – IV models.
- 1842 MARÍA GIL, JAVIER J. PÉREZ, A. JESÚS SÁNCHEZ and ALBERTO URTASUN: Nowcasting private consumption: traditional indicators, uncertainty measures, credit cards and some internet data.
- 1843 MATÍAS LAMAS and JAVIER MENCÍA: What drives sovereign debt portfolios of banks in a crisis context?
- 1844 MIGUEL ALMUNIA, POL ANTRÀS, DAVID LÓPEZ-RODRÍGUEZ and EDUARDO MORALES: Venting out: exports during a domestic slump.
- 1845 LUCA FORNARO and FEDERICA ROMELI: The paradox of global thrift.
- 1846 JUAN S. MORA-SANGUINETTI and MARTA MARTÍNEZ-MATUTE: An economic analysis of court fees: evidence from the Spanish civil jurisdiction.
- 1847 MIKEL BEDAYO, ÁNGEL ESTRADA and JESÚS SAURINA: Bank capital, lending booms, and busts. Evidence from Spain in the last 150 years.
- 1848 DANIEL DEJUÁN and CORINNA GHIRELLI: Policy uncertainty and investment in Spain.
- 1849 CRISTINA BARCELÓ and ERNESTO VILLANUEVA: The risk of job loss, household formation and housing demand: evidence from differences in severance payments.
- 1850 FEDERICO TAGLIATI: Welfare effects of an in-kind transfer program: evidence from Mexico.
- 1851 ÓSCAR ARCE, GALO NUÑO, DOMINIK THALER and CARLOS THOMAS: A large central bank balance sheet? Floor vs corridor systems in a New Keynesian environment.
- 1901 EDUARDO GUTIÉRREZ and ENRIQUE MORAL-BENITO: Trade and credit: revisiting the evidence.
- 1902 LAURENT CAVENAILE and PAU ROLDAN: Advertising, innovation and economic growth.
- 1903 DESISLAVA C. ANDREEVA and MIGUEL GARCÍA-POSADA: The impact of the ECB's targeted long-term refinancing operations on banks' lending policies: the role of competition.
- 1904 ANDREA ALBANESE, CORINNA GHIRELLI and MATTEO PICCHIO: Timed to say goodbye: does unemployment benefit eligibility affect worker layoffs?
- 1905 CORINNA GHIRELLI, MARÍA GIL, JAVIER J. PÉREZ and ALBERTO URTASUN: Measuring economic and economic policy uncertainty, and their macroeconomic effects: the case of Spain.
- 1906 CORINNA GHIRELLI, JAVIER J. PÉREZ and ALBERTO URTASUN: A new economic policy uncertainty index for Spain.
- 1907 SERGIO PUENTE and ELENA VOZMEDIANO: Minimum and bargained wages: pass-through and labor market performance.
- 1908 SERGIO MAYORDOMO and OMAR RACHEDI: The China syndrome affects banks: the credit supply channel of foreign import competition.
- 1909 MÓNICA CORREA-LÓPEZ, MATÍAS PACCE and KATHI SCHLEPPER: Exploring trend inflation dynamics in Euro Area countries.
- 1910 JAMES COSTAIN, ANTON NAKOV and BORJA PETIT: Monetary policy implications of state-dependent prices and wages.
- 1911 JAMES CLOYNE, CLODOMIRO FERREIRA, MAREN FROEMEL and PAOLO SURICO: Monetary policy, corporate finance and investment.