The marginal propensity to hire*

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December 2017

Job Market Paper
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Abstract

This paper studies the link between firm-level financial constraints and employment decisions, as well as the implications for the propagation of aggregate shocks. I exploit the idea that, when the financial constraint binds, a firm adjusts its employment in response to cash flow shocks. I identify such shocks from changes to *business rates*, a UK tax based on a periodically estimated value of the property occupied by the firm. A 2010 revaluation implied that similar firms, occupying similar properties in narrowly defined geographical locations, experienced different tax changes, allowing me to control for confounding shocks to local demand. I find that, on average, for every £1 of additional cash flow, 39 pence are spent on employment. I label this response the Marginal Propensity to Hire (MPH). I then calibrate a firm dynamics model with financial frictions towards this empirical evidence. As in the data, small and leveraged firms in the model have a greater MPH. Simulating a tightening of credit conditions, I find that the model can account for much of the decline in UK aggregate output and employment observed in the wake of the financial crisis.

Keywords: financial frictions, employment, heterogeneous firms
JEL classification: E24, E44, G01, G32

*I am grateful to Vincent Sterk and Marco Bassetto for invaluable advice and guidance, and also to Morten Ravn for insightful suggestions and discussions. For helpful comments, I also thank Wendy Carlin, Wei Cui, Ralph Luetticke, Franck Portier, Javier Turen, Mimosa Distefano, Silvia Sarpietro and Carlo Galli. I thank the UK Data Service for guidance and assistance with regard to the data. Data contains information provided by the Valuation Office Agency under the Open Government Licence v3.0. The UK Data Service agrees that the outputs are non-disclosive, and cannot be used to identify a person or organisation. The use of the BSD data does not imply the endorsement of the data owner or the UK Data Service at the UK Data Archive in relation to the interpretation or analysis of the data. This work uses research datasets which may not exactly reproduce National Statistics aggregates.

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1 Introduction

The rise in unemployment following the financial crisis has underscored the importance of links between financial and labour markets. The long-standing challenge that this literature faces is the identification of financially constrained firms, which remains difficult. This implies it is also difficult to pin down the role that these constraints actually play for firms' employment decisions and, in turn, for macroeconomic dynamics.

In this paper, I exploit the idea that, when financial constraints bind, a firm adjusts its employment in response to cash flow shocks. I label this response the marginal propensity to hire (MPH). Consider a cash flow shock that is uncorrelated with the firm's production frontier and demand. When unconstrained, the firm is at its optimal size and therefore its employment decisions are neutral to the additional cash flow. When constrained, instead, the firm uses the additional cash flow to hire more workers and expand its size: the MPH is positive in this case.

This paper entails two main contributions. First, I use a novel combination of three large data sets from the UK and a new source of variation to estimate how employment responds to cash flow shocks and how the MPH varies across firms. Second, I use this empirical evidence as an input to discipline a theoretical model that combines firm heterogeneity and financial frictions. I use the calibrated model to shed light on the heterogeneity of the MPH that is found in the data and to study the aggregate responses to a tightening in credit conditions, as well as their relation to the moments of the MPH distribution.

Although cash flows can be measured, it is difficult to come by exogenous variation. I identify cash flow shocks from changes to *business rates*, a UK tax based on a periodically estimated value of the property occupied by the firm. The fact that business rates are not explicitly related to firm performance makes changes to this tax a good candidate for the identification of such shocks. Estimated rental values used to compute the business rates are typically re-assessed every five years, and the infrequency of the revaluation may cause sharp changes to the tax liability.[1] Focusing on the revaluation which took place in 2010, I document that a high degree of variation in tax bill changes persists even at a narrow geographical level and within similar types of properties. When re-estimating the rental values, properties are grouped in valuation schemes by a government agency, which then makes assumptions over the standard property in each scheme; this forms the basis of the revaluation. The creation of more than 60 thousand schemes, which are defined geographically at a very narrow local level, introduces a lot of the aforementioned variation. This allows me to control for relevant confounding factors as local demand shocks. I estimate the MPH by comparing the net hiring of similar firms, occupying

[1] See, for instance, the IFS 2014 Green Budget and the article "Southwold: welcome to the town where business rates are set to rise 177%", published by The Guardian on 9 March 2017.

similar properties, in the same geographical area, which face different revaluations.

I construct a unique dataset that combines employment data at the establishment and firm level with balance sheet data at the firm level and tax data at the property level. Employment data is sourced from the Business Structure Database (BSD), a confidential panel that comprises the near universe of UK firms - around 2.5 million per year - from 1997 to 2016. Balance sheet data between 2006 and 2015, for around 1.5 million firms, are taken from FAME (Financial Analysis Made Easy). Finally, tax bills are calculated using information from the Valuation Office Agency (VOA), which covers 1.9 million business property valuations in England and Wales for 2005 and 2010. My data set has several advantages. First, it allows for the identification of cash flow shocks in a very broad sample, while addressing relevant endogeneity concerns. Second, it enables me to study the role of financial constraints on employment, which has received much less attention than the vast literature on investment-cash flow sensitivity arising from Fazzari et al. (1988). Third, the data used in my work mainly consist of small firms, often young, and that are typically not publicly listed. Private firms may rely more heavily on external finance, as documented by Zetlin-Jones and Shourideh (2017). These features make FAME and the BSD particularly suitable for the study of financial frictions.

I estimate that, for every additional £1 of cash flow generated by the tax revaluation, on average 39 pence are spent on employment. The richness of the data allows me to address relevant endogeneity issues, such as local and idiosyncratic shocks, and anticipation. Firms' employment does not respond to future cash flow shocks and the results are not driven by the non-tradable sector, which is typically more sensitive to local demand. By ruling out relocations and physical changes to the property following the revaluation, I exclude the possibility that the employment response is driven by endogenous location motives or changes to the cost of capital, rather than by the cash flow channel. The MPH varies depending on firm characteristics: I find that employment at small and more leveraged firms is more responsive to cash flow shocks.

I then build a heterogeneous-firm model with financial frictions that is motivated and disciplined by the empirical evidence on the MPH and its heterogeneity. Firms in the model are heterogeneous ex-post due to persistent idiosyncratic productivity and face two financial frictions. First, they cannot issue equity. Second, they need to pay the wage bill in advance of production and face a working capital collateral constraint as in Jermann and Quadrini (2012). The model is rich enough to match a wide range of micro features of the data; at the same time, its tractability enables me to derive a closed-form analytical formula for the MPH. When both financial constraints bind, firms are willing to use additional cash flow to increase their future wealth. This increases their ability to take up working capital loans and thus allows them to hire more workers, implying a positive

MPH. Moreover, constrained firms have a marginal product of labour that is greater than the wage, and I find that this gap is positively correlated with the MPH.

The model is calibrated to reproduce both macro- and micro-economic features of the data, as well as the average MPH estimated in the empirical analysis. I use the model to uncover the mechanisms behind the MPH. First, the model generates a distribution of marginal propensities to hire and endogenously replicates the heterogeneity found in the data. Small and more leveraged firms are more likely to be credit-constrained and display increasingly greater employment-cash flow sensitivities. Second, I use the model to study how each parameter affects the distribution of the MPH by influencing the extensive margin – i.e.: the share of constrained firms –, the intensive margin – i.e.: the firm-level endogenous tightness of financial frictions –, or both. While all the model parameters affect the MPH, I find that the capital endowment of entrants is particularly informative. This parameter can be interpreted as an additional financial friction on start-up loans.

I study the response of the calibrated economy to an unexpected tightening of credit conditions, calibrated to match the fall in net debt in the UK between 2008 and 2011. The model can account for much of the decline in aggregate employment and output experienced by the UK during the Great Recession. I also investigate how relevant moments of the MPH distribution can inform policymakers and macroeconomists about the differential responses to aggregate shocks. Analytically, I show that the response of aggregate employment to a credit tightening depends positively both on the average MPH and on the covariance between MPH and firm size. Given that the model parameters typically affect these moments in opposite directions, which effect prevails in the aggregate is a quantitative question. Numerically, I find that economies with a greater average MPH, achieved by changing the capital endowment of entrants, display a larger and more prolonged fall in aggregate employment following a credit tightening episode.

The findings of this paper have several policy implications. The sensitivity of employment to cash flow may be informative about the design and the effectiveness of policies such as targeted subsidies. For instance, the heterogeneity of the MPH with respect to firm size can be related to the debate on size-dependent policies.[2] Moreover, the model shows that knowing the average MPH and the covariance between MPH and firm size is important in order to assess the sensitivity of aggregate employment to the tightness of the financial friction as well as for the effectiveness of stabilisation policies. I find that both moments fall during a credit tightening. This implies that uniform transfers may be less effective in those periods, given the lower average sensitivity of employment to additional cash flow, while targeting small firms may boost aggregate employment more.

[2] See Guner et al. (2008) on the topic. Cahuc et al. (2014) investigate the effectiveness of hiring credits introduced in France in 2009, which were targeted to firms with less than 10 employees. In recent years, the UK government has put in place a set of small business grants that depend on firm size.

The paper is organised as follows. In Section 2, I describe extensively the business rates, the revaluation process and document evidence of the extent of the variation in tax changes. After describing the data in section 3, I present the main reduced-form findings, in the form of average MPH and its robustness to a wide set of confounding factors (section 4). Sections 4.3 and 4.4 investigate the response to balance sheet variables other than employment and the MPH heterogeneity in the data. The model is presented thereafter (section 5), while section 6 describes the calibration and how different parameters affect the MPH. Finally, section 7 deals with the macroeconomic implications of the MPH.

Related literature

A large body of academic work has studied the sensitivity of investment to cash flow and its relation with financial constraints.[3] The long-standing issue faced with this literature is the identification of cash flow shocks and, in turn, of financially constrained firms. Indeed, cash flow may contain information on future profitability, thus driving a spurious correlation with investment. More recent papers try to identify arguably exogenous shocks to internal funds. Among others, Rauh (2006) exploits defined-benefit pension refunding shocks. My paper proposes a new source of exogenous variation and a large dataset which allows me to study the response of the whole distribution of firms. This includes private, small and young firms, which are expected to be more affected by financial frictions.

My paper shifts the focus from the impact of financial constraints on capital investment to their influence on employment decisions. A few papers have recently studied empirically the interaction between financial constraints and employment. Schoefer (2015) estimates the dollar-for-dollar sensitivity of employment to cash flow and uses this to motivate a search and matching model with wage rigidity among incumbent workers and financial frictions. He borrows identification strategies from the investment literature and estimates employment - cash flow sensitivities ranging between 0.22 and 0.72. His empirical analysis, however, is limited to publicly listed firms. Chodorow-Reich (2013) investigates the effect of bank lending frictions on employment outcomes. Compared to their work, I can measure the size of the cash flow shock and therefore the employment response to £1 of additional cash flow.[4] Giroud and Mueller (2017) find that more leveraged firms cut more their employment in response to consumer demand shocks in the Great Recession.

My paper also fits into the vast literature that incorporates firm-level financial frictions in models of firm dynamics. In corporate finance, most of the literature focuses on the role

[3] See Hubbard (1998) for a survey and Kaplan and Zingales (1997).

[4] Benmelech et al. (2015) also test for the causal effect of financial constraints on firm employment decisions looking at three quasi experiments: exploiting heterogeneity in the maturity of long-term debt, analyzing the impact of bank deregulation across the United States in the 1970s and exploiting a loan supply shock originating in Japan in the 1990s.

played by financial constraints in distorting investment decisions, as surveyed by Strebulaev and Whited (2012).[5] In particular, labour is typically hired on the spot market and firms can always implement the static optimum: this implies that financial frictions have no direct and independent effect on employment decisions.[6] By explicitly modelling a link between labour demand and financial frictions, my model contributes to the literature by formalizing the concept of a marginal propensity to hire out of cash flow shocks and studying its theoretical and quantitative properties.

Finally, this paper is related to a growing macro literature that focuses on firm-level financial frictions, as surveyed by Quadrini (2011). Among seminal and influential contributions, Gertler and Gilchrist (1994) and Bernanke et al. (1999) propose a "financial accelerator" mechanism that amplifies and propagates shocks to the macroeconomy. They suggest that small firms are more affected by financial constraints, a feature corroborated both by the empirical and theoretical parts of my paper. As in Jermann and Quadrini (2012), the financial constraint considered in my model shows up as a labour wedge. Moreover, I embed this framework in a heterogeneous firm setting, shedding light on the interaction between labour and finance in the cross-section. Recent papers have investigated the effect of shocks to financial constraints in a model with firm heterogeneity. Among others, Khan and Thomas (2013) focus on capital misallocation, while Bassetto et al. (2015) on the differential impact on corporate and entrepreneurial sector. Buera et al. (2015) introduce search frictions in a model of producer heterogeneity to argue that a credit crunch can translate onto a protracted increase in unemployment. My paper hints at the relevance of additional statistics, associated with the marginal propensity to hire, to correctly calibrate this type of models and draw macroeconomic implications.

2 Business Rates revaluation

Occupiers of business property in the UK pay each year a tax, the *business rates*, which is a percentage of the estimated market rental value of the property.[7] Occupiers are liable to pay the tax regardless whether they own or rent the property. Business rates raised £26.1 billion in 2012-13, which was 4.5% of total fiscal revenues and the equivalent of two thirds of the amount raised by corporate tax. Recurrent taxes levied on business property

[5] An exception is Michaels et al. (2016), who integrate costly external finance with both labor and capital demand. Empirically, they document that wages and leverage are strongly negatively correlated; their model shows that both financing frictions and wage bargaining are important to reproduce this finding.

[6] A separate strand of literature has recently introduced financial frictions in search models. Boeri et al. (2017) study the interaction between labour and financial frictions and its role for firms' incentives to hold liquidity.

[7] Business rates is the common denomination for non-domestic rates. This study uses data for England and Wales. Business rates are also levied in Scotland and Northern Ireland, but they are handled differently.

in the UK are among the highest in the OECD.[8]

The tax liability is calculated by multiplying a percentage, called *business rates multiplier*, by the *rateable value*, which is the estimated market rental value of the property.[9] Every five years, the Valuation Office Agency (VOA) re-estimates the rateable values for English and Welsh properties, and this revaluation triggers the tax changes studied in this paper.[10] Multipliers are instead updated every year in line with the Retail Price Index (RPI). In revaluation years, the multiplier is adjusted so that the average bills increase in line with RPI inflation. This implies that the impact of revaluations is purely redistributive, creating winners - properties for which the tax liability falls after the revaluation - and losers - properties that experience an increase in their tax bills. Since business rates are set nationally, the revaluation is not affected by discretionary incentives of the policymaker.

The revaluation that took effect on 1 April 2010 is the object of this study. I document a large degree of variation in tax changes even at fine local level and among similar properties. Figure 1 shows the average change in the business rates liability due to the revaluation, at the postcode sector level for large offices in the Manchester area. Although there is some spatial correlation across postcode sectors, it is not infrequent to observe neighbouring areas with very different average tax changes. Tax changes vary significantly even at narrower geographical level. For each postcode sector in England and Wales, I compute the standard deviation of tax changes for large offices. The average standard deviation is £8,150 (12% in growth terms) and the average range £29,771 (32%).[11]

What is the source of this large variation? To answer this question, it is useful to present the 2010 revaluation process in more detail. The VOA collected rent information from business tenants and used this to estimate the rateable values, defined as a reasonable rent as of 1 April 2008, under full repairing and insurance terms. Similar properties in an area were grouped together in a valuation scheme; within each scheme, the VOA made assumptions about the standard property, which formed the basis for the valuation of each property in the scheme. Finally, each rateable value was adjusted to account for idiosyncratic differences within the scheme.[12] Hence the source of variation is twofold: it is partly due to the assignment to different valuation schemes, and partly down to property-specific differences within each scheme.

The creation of 60,022 valuation schemes introduced many discontinuities and the

[8]OECD data on receipts from recurrent taxes on immovable property, levied on non-households, as a share of national income in 2011. Data is not available for a small set of countries as US, Japan and Italy.

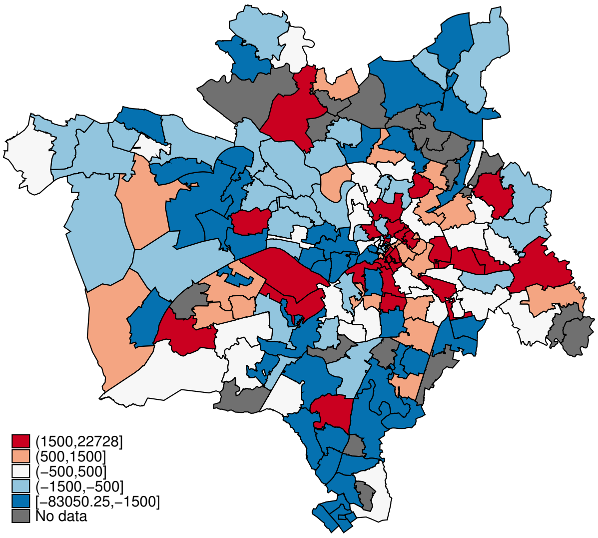
[9]The rateable value broadly represents the annual rent the property could have been let for on the open market on the reference date, on full repairing and insuring terms. Hence the rateable value will be typically different from the rent that is actually be paid on the property.

[10]The last revaluation was delayed by two years and took place in 2017.

[11]On average there are 10 large offices in a postcode sector (median is 4). The average standard deviation increases to £12,763, and the range to £64,960, when looking at postcode sectors with at least 10 properties.

[12]For example a property without air conditioning belonging to a scheme which assumes it.

Figure 1: Business rates revaluation: £ change in tax liability for large offices in Manchester



Notes: Maps plot postcode sectors (e.g.: M1 1). In 2014, there were approximately 12,381 postcode sectors in the UK. Sample of offices in postcode area M, whose size is above the 75th of offices distribution (i.e.: 178 m^2). Properties undergoing material change of circumstances before 2012 are excluded, as well as properties without a valuation scheme and whose 2005 rating list has been altered after 2010. Additional maps shown in Appendix B

large local variation in tax changes shown in the data. More than half of these schemes were smaller than three postcode units or no bigger than one postcode sector, which is typically equivalent to a portion of a street or a few blocks.[13] It is not very plausible, therefore, that there are important local demand shocks that are unique to valuation areas. In addition, the VOA does not hold rent information for all properties, hence it might happen that reported rents drive the representative rateable value of an area away from firms' fundamentals.[14] The rental evidence used to create the valuation schemes and the details of the process are not disclosed, mainly given their confidential nature. As a result, taxpayers are left with little or no explanation to assess the correctness of their rateable value, as suggested by work by the Department for Communities and Local Government.[15] This also suggests that firms find it very hard to anticipate the cash flow shock induced by the revaluation. Finally, the infrequency of the revaluation and the fact that it is based on an antecedent date – two years before the tax change takes place – further disconnects

[13] A postcode unit consists, on average, of 15 properties - either residential or non-domestic. On average, a valuation scheme is found to contain 4 postcode sectors.

[14] The property consulting Ramidus presents the case study of a business in Cambridge Circus, central London. In a parade of six shops, five paid a rent around £30,000 while one £50,000 on a short lease. The VOA used the top rent as the valuation reference. The business owner says: "Our Armaggedon was the 2010 revaluation, when our valuation went from £21,000 to £53,000. [...] The one across the road can get a high rent and we get the increase (in rates). The ultimate result is that I will cut back on staff." (source: "The Business Rates Revaluation in London", 2017).

[15] "The Government's proposals to improve transparency in the business rates valuation and formal challenge system", December 2013.

rateable values from current firms' fundamentals.[16]

The features of the revaluation and the fact that similar properties in the same geographical area experienced different tax changes make the latter a good candidate for the identification of plausibly exogenous cash flow shocks. Most importantly, this relies on the fact that business rates "bear little or no relation to (firms') turnover, profits or ability to pay. Instead, it is arbitrarily based upon notional property values."[17] Section 4 discusses the identification assumptions in detail.

3 Data

I construct a unique dataset that combines employment data at the establishment and firm level with business rates tax data at the property level and balance sheet data at the firm level. The employment data are provided by the Office for National Statistics (ONS) Business Structure Database (BSD). This dataset contains a small number of variables for almost all business organisations in the UK. It consists of a series of annual snapshots, taken around April, of the Inter-Departmental Business Register (IDBR). The IDBR is a live register of data collected via administrative records. I combine them in a longitudinal panel of establishments and firms for the years 1997-2016. The tax data comes from the Valuation Office Agency and contains nearly all - 1.9 million - business property valuations in England and Wales for the 2005 and 2010 rating lists, linked by a property identifier.[18] It contains details of the location and rateable values of each property, as well as property characteristics and the valuation scheme numbers as contained in the Summary Valuation (SMV) files. Balance sheet and income statement data are taken from FAME (Financial Analysis Made Easy), as provided by the Bureau van Dijk. I consider a panel of roughly 1.2 million UK firms, for the years 2006 - 2014, which can be merged with the BSD data. This is a much broader sample than other alternatives often used in literature, as it is not limited to publicly listed firms, as US Compustat, but it mainly contains private limited companies (96% of the sample). Indeed, the UK Companies House requires all incorporated companies to disclose balance sheet information. Appendix A.1 provides extensive information on each data source and the details of the dataset creation.

The main bulk of the analysis uses information on the first two datasets. Tax data at the property level is matched with BSD establishment data; given the confidential nature of

[16]Dentons, the world's largest law firm, commented that commercial property rents fluctuate constantly while business rates are slow to respond, "creating unrealistic rateable values" (source: "Rating – the road to revaluation: Reform", Lexology, March 30 2017).

[17]Source: "Business Rates - an Unfair System", 16 February 2017, Federation of Small Businesses.

[18]This allows me to construct only one tax change. Extending the dataset over time, thus incorporating information on revaluations at different years, would help significantly the identification of the MPH and its heterogeneity, besides the features of the MPH distribution.

the BSD data, business rates unique addresses cannot be used. Hence, I merge the datasets using postcode unit information and create a mapping between establishment-level industry codes and property type. In the UK, a postcode unit is typically very small, generally representing a street, part of a street or even a single property. There are approximately 1.75 million postcodes in the United Kingdom according to the ONS. I keep the establishments that remain active between 2009 and 2011 and do not change location. I am able to match 174,726 establishments with the properties they occupy; this is associated with 135,139 firms. This matching strategy allows me to evaluate firms' responses to *a change in the tax liability they actually face*. On the other hand, it leaves out the establishments that cannot be uniquely matched to their properties. For instance, if in the same postcode unit there is more than one shop and more than one establishment in the retail or wholesale sector. Appendix A.4 shows that the estimated coefficients are qualitatively similar to the benchmark estimates when averaging over postcodes-industry-property type groups.

Appendix A.1 describes the sampling strategy in detail.[19] I exclude the properties incurring in physical changes after the revaluation and before 2012. Indeed, firms have the possibility to reduce their tax bill by changing the features of the property and then reporting a material change of circumstances to the Valuation Office Agency.[20] This may imply a change in employment due to the complementarity with fixed assets and following a response to a change in the user cost of capital; since, instead, I am interested in the balance sheet channel of cash flow shocks, I exclude this possibility. Finally, I drop the construction sector, because of its specific nature when it comes to a property tax. After these sample selections, the dataset contains 82,506 establishment-tax observations.

4 Empirical strategy

The empirical strategy aims at estimating the effect of cash flow shocks induced by the business rates revaluation on firms' employment decisions. I consider the following benchmark specification for a firm i, in the industry sector k occupying a property j in the geographical area m:

$$\Delta_{2009,11}E_{i,k,j,m} = \alpha + \beta\Delta_{2009,10}T_j + \gamma x_{i,2008} + \theta z_{j,2008} + \mu_{k,2008} + P_m + \varepsilon_{i,k,j,m} \quad (1)$$

[19]Excluded observations include public sector establishments, properties without a valuation scheme reference number and establishments that changed enterprise between 2009 and 2011.

[20]Material change of circumstances typically involve matters affecting the physical state or physical enjoyment of the hereditament and the category of occupation of hereditament (Rating Manual Volume 2 Section 5). While potentially still working through the balance sheet, the cash flow shock may depend on the marginal product of capital and driven by other reasons such as endogenous location choices.

where the outcome variable $\Delta_{2009,11}E_{i,k,j,m}$ is the change in employment at the firm i between 2009 and 2011 and $\Delta_{2009,10}T_j$ is the £ change in the tax liability at the property j, induced by the business rates revaluation in 2010. Firms may have multiple establishments and thus occupy multiple properties. In order to directly exploit property and geographic characteristics used for identification, for each firm i I retain the property j associated with the largest (in absolute value) tax change. In appendix A.3 I show that the results are robust to different specifications for multiple-establishment firms, also because 86% of firms in the sample have only one establishment. x, z, μ and P are sets of firm, property, industry and geographical controls, respectively, which are discussed below.[21]

I identify the effects of cash flow shocks on employment changes by comparing similar firms, occupying similar properties in the same geographical area. The coefficient of interest is β. Correct identification hinges on the fact that there is neither omitted variable simultaneously affecting the business rates and employment, nor reverse causality. There are three main possible confounding factors that may affect identification. First, there could be local shocks that simultaneously affect employment and the business rates. Second, shocks idiosyncratic to the firm may affect employment and - via physical improvements - the estimated rateable value of the property. Finally, cash flow changes induced by the revaluation may be anticipated. I now discuss how different controls are aimed at addressing these issues.

The inclusion of postcode area dummies P_m for the location of the property is motivated by the attempt to control for local shocks and anticipation. Being based on rental evidence, tax changes vary across geographical areas. I decide to consider geographical units for which it is reasonable to think that a firm may be aware of the trends in rents and anticipate at least part of the tax change. The benchmark specification considers postcode area dummies. A postcode area is formed by the initial characters of the alphanumeric UK postcode. For instance, the postcode area N stands for North London. In 2014 there were 124 postcode areas in the UK (source: ONS). Standard errors are clustered at this level. I also consider tighter specifications at the postcode district level.[22]

Industry-specific shocks may simultaneously affect tax changes and employment. While business rates in levels could be correlated with firm industry through real estate intensity, it is less clear ex ante how business rates revaluations could reflect industry-specific shocks. A certain industry may have, for instance, experienced a boom which boosted employment and the rents of properties typically used in that industry, thus in turn imply-

[21] All controls are measured before the tax change takes place. Property features may be different before and after the revaluation; moreover, firms may change industry. Section 4.2 looks specifically at these cases.

[22] A postcode district typically identifies a town and the surrounding villages (e.g.: BA6 for the area of Glastonbury), most part of a bigger city (e.g.: GL1 for the centre of Gloucester, a city with a population of around 130,000 people) or part of a local authority/borough in London (e.g.: N3 for Barnet). In 2014 there were 3,114 postcode districts in the UK according to the ONS.

ing a tax increase upon revaluation. As in most of the endogeneity issues of this paper, we expect that, if present, this channel should bias the MPH downwards. To clean out this possible channel, I control for firm-level industry dummies $\mu_{k,2008}$ defined at the section level of UK SIC 2007 codes.[23]

Finally, I introduce firm controls measured in 2008 and property controls before the revaluation. Property controls consist of property type, the tax bill in 2008 and the property size measured in square meters. I define three dummies for the property type: whether a property is an office, a shop or a factory/warehouse.[24] These dummies play a similar role to industry dummies. Moreover, they control for the possibility that firms partly anticipate the tax change by having information on rent trends for specific types of properties. I complement these dummies with a set of industry dummies before the revaluation at the establishment level.[25] The size of the property and the tax bill may correlate with the size of the tax change. Since identification exploits both the sign and the size of the tax change, it seems sensible to control for these features. The same applies to firm pre-determined characteristics, namely the inverse of average sales of firm i in 2007 and 2008 and the number of firm employees in 2008. Moreover, controlling for firm size helps addressing the concern that the ability to predict the tax change may correlate with firm characteristics, with different anticipation effects and a possible threat to correct identification.

4.1 The average MPH

Table 1 shows the employment effects of the changes in the business rates liability induced by the 2010 revaluation. The explanatory variable of interest, $\Delta_{2009,10}T_{j,m}$, is the difference in tax bill to be paid at the property j before and after the revaluation. The tax bill is obtained by multiplying the multiplier (tax rate) for the specific year by the rateable value estimated by the VOA in that year. After the 2010 revaluation, a transitional relief was introduced in England, aimed at phasing in sharp changes in the tax bills. Tax shocks calculated here are before any relief: appendix A.2 deals extensively with this. The tax change is scaled by firm i average sales in 2007 and 2008, to improve comparability across firms.[26] The dependent variable shown in the first 5 columns is the level change in em-

[23] Examples of section levels are manufacturing, education, information and communication. There are 18 sector sections in the sample.

[24] I construct these dummies by pooling together similar categories, which are by far the most recurrent and represent almost half of the sample. Sometimes a valuation scheme pools different property types together; hence adding these dummies may be "controlling away" some of the effects I am trying to estimate. In unreported results, I show that the estimation results are robust to a broader definition of shops, such that 60% of the properties in the sample are assigned to one of the three property types. Similarly, the MPH coefficient is slightly lower but still significant at 1% if we control for all categories as defined by the VOA.

[25] These may differ from firm-level industry dummies only for firms with multiple establishments. Their inclusion leaves the MPH coefficient basically unchanged.

[26] Results are robust to rescaling by either year.

Table 1: The average MPH

	$\Delta_{2009,11}Emp$					$\Delta_{2009,11}Log(Emp)$		
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)
$\Delta_{2009,10}T$	-0.34^{***}	-0.40^{***}	-0.39^{***}	-0.36^{***}	-0.41^{***}	-0.59^{***}	-0.72^{***}	-0.72^{***}
	(0.10)	(0.11)	(0.11)	(0.11)	(0.16)	(0.17)	(0.17)	(0.18)
Postcode area FE	✓	✓	✓			✓	✓	✓
Industry dummies		✓	✓				✓	✓
Firm controls			✓	✓	✓			✓
Property controls			✓	✓	✓			✓
Postcode area x industry FE				✓				
Postcode district x industry FE					✓			
Observations	63,242	63,242	63,242	63,242	63,242	63,242	63,242	63,242
R^2	0.00	0.01	0.01	0.02	0.03	0.00	0.01	0.01

Note: $\Delta_{2009,11}Emp$ is the change in the number of employees at firm *i*, rescaled as explained in the text. $\Delta_{2009,10}T$ is the scaled tax change as explained in the text. Industry dummies are measured in 2008, at the firm-level, and defined at the section level of UK SIC 2007 codes. Firm controls include firm *i* number of employees in 2008 and the inverse of average sales between 2007 and 2008. Given the timing of the data, it should be noted that I define firm sales in 2008 as the value reported in the business register in April 2008, hence typically referring to the financial year 2007-2008. Property controls consist of the size of the property measured in m^2, the business rates liability in 2008, industry dummies at the establishment level and dummies for whether the property is a factory/warehouse, a shop or an office. Interacting industry dummies at the establishment-level, instead of firm-level, in column IV and V delivers the same results. Standard errors (in parentheses) are clustered at the postcode area level, except for column V in which they are clustered at the postcode district level. *, ** and *** denote significance at the 10%, 5% and 1% level, respectively.

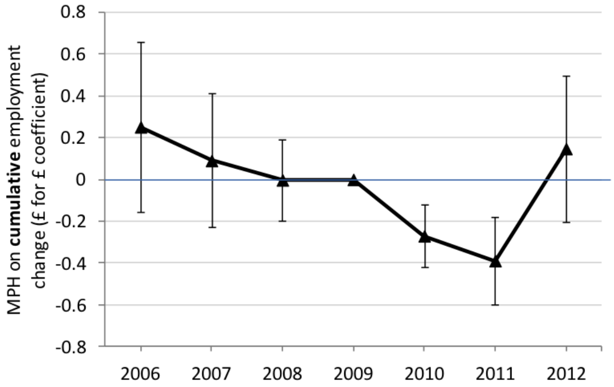
ployment at the firm *i* between 2009 and 2011. I multiply this by a single, constant wage, and divide it by firm *i* average sales in 2007 and 2008. This rescaling allows me to express the MPH coefficient β as the negative of the pound-for-pound sensitivity of employment to the cash flow changes induced by business revaluation in 2010. For the rescaling, I use the median gross annual earning of all employees in 2010, as recorded by the Annual Survey of Hours and Earnings;[27] this amounts to £21,024. The 2009-2011 horizon for employment changes is chosen due to the timeline of the revaluation. Draft revaluations were made public on 30 September 2009, while becoming effective on the 1st April 2010. BSD employment data is a snapshot of the business register as at April each year.

The estimated MPH is fairly insensitive to the inclusion of different sets of controls. Column III suggests that, for every £1 of additional cash flow, 39 pence are spent on employment. This sensitivity increases slightly as we control for a narrower geographical area, the postcode district, interacted with the industry dummies. This tighter specification controls for local shocks specific to an industry in a narrow geographical area, which might have simultaneously affected firms' employment and the estimated rateable values.

Columns VI-VIII show instead the semi-elasticity of employment to the tax shocks. In

[27] See Appendix A.1 for more details. While being convenient in terms of interpretation, a single wage masks a good deal of heterogeneity, which may affect the MPH. For instance, the fact that small firms typically pay lower wages and employ more part-time employees (ASHE 2016) may lead to the overestimation of the MPH. For this reason, the estimated coefficient should be referred to employment changes only, and the wage transformation only as a way to express those changes in £ terms.

Figure 2: Placebo test and the dynamic response of employment



Note: Solid lines refer to the estimated coefficients, while vertical bars show the 95% confidence intervals. For each year, I re-estimate equation (1) using a different outcome variable. 2006 coefficient, for instance, is estimated using the employment changes between 2006 and 2009. Sample sizes change due to firms being born up to 2008 and exiting in 2012. They range from 54,445 for the 2006 coefficient to 63,242 in 2011. Results are robust to restrict the sample such that each year has the same sample size.

this case the dependent variable is the log difference in firm *i* employees between 2009 and 2011. Column VIII suggests that a revaluation that increases the tax bill by 1 percentage point of firm sales reduces employment at the firm, on average, by 0.72 per cent.

4.2 Endogeneity, anticipation and local demand

The correct estimation of the MPH crucially depends on the extent to which the identification assumptions are violated. In this section I explore this issue in greater detail, show the robustness of the results and argue that, if present, possible endogeneity issues should bias the MPH downwards.

I start by testing whether past employment responds to future cash flow shocks as a direct check for reverse causality problems and anticipation effects. In Figure 2 I re-estimate equation (1) for different horizons of employment changes. The coefficient shown for 2006, for instance, shows the pound-for-pound response of employment changes between 2006 and 2009 to the (negative of) cash flow shock triggered by the revaluation in 2010.

Although the coefficients on past employment changes are positive, they are not statistically significant. This provides empirical support to the identification assumptions. First, it alleviates the concern that the estimated MPH is affected by reverse causality: that would be the case, for instance, if cash flow shocks were systematically induced by physical improvements to the property, also correlated with employment changes. Second, the placebo test suggests that there are no significant local shocks simultaneously affecting employment and the revaluation shocks, which would make the research design invalid. This is particularly relevant considered the fact that rateable values are re-estimated using rental evidence measured in 2008, two years before the tax actually changes. Finally, the

Table 2: Local demand and mean reversion

	$\Delta_{2009,11}Emp$	
	(I)	(II)
$\Delta_{2009,10}T$	-0.34^{***}	-0.36^{***}
	(0.12)	(0.11)
$\Delta_{2009,10}T$ x (Non-tradable)	-0.25	
	(0.30)	
Non-tradable	0.001	
	(0.002)	
$\Delta_{2007,09}Emp$ x $\Delta_{2009,10}T$		-0.31
		(0.78)
$\Delta_{2007,09}Emp$		-0.06^{***}
		(0.01)
Observations	63,242	58,252
R^2	0.01	0.01

Note: Same notes and controls of column III of Table 1 apply besides those explicitly mentioned. $\Delta_{2007,09}Emp$ is also rescaled as in Table 1. Non-tradable sector comprises establishments in the food service activities (SIC codes 56101-56302) and retail sector (SIC codes 47110-47990). Different sample sizes are due to the fact that some firms are born in 2008. Standard errors (in parentheses) are clustered at the postcode area level. *, ** and *** denote significance at the 10%, 5% and 1% level, respectively.

insignificance of pre-treatment responses downplays the role of anticipation effects.

Figure 2 also sheds light on the dynamic response of employment. First, employment already responds in 2010. Draft revaluations were announced on 30 September 2009 and businesses had to start paying the new bill in April 2010, which is also when employment is captured from the business register. Hence the coefficient is mainly picking up a news effect, as well as the response to early payments. The MPH is greater in 2011, however, suggesting that employment responds more as the business needs to pay the new tax bill in full. Finally, the employment response fades completely away in 2012. This could be consistent with interpreting the tax changes as liquidity shocks: in the model, the employment response will be formalised through a financial constraint on working capital loans. Moreover, firms will presumably adjust along other margins over time. For example, renters might be able to renegotiate their rents, at least in the medium run.

I then consider additional robustness checks addressed at specific endogeneity issues. To further check for the possibility that local demand shocks confound the estimates, I test whether the non-tradable sector responds in a systematically different way to tax changes. In the spirit of Mian and Sufi (2014) and Giroud and Mueller (2017), I isolate the MPH of the non-tradable sector, by interacting the tax shock with a non-tradable sector dummy.[28]

[28] An alternative test could consist of interacting the tax shock with a dummy taking 1 if a property is a shop. This also delivers an insignificant interaction with the non-tradable sector, even when using the aforementioned broader definition of shops, which includes restaurants or hairdressing salons.

Table 3: Idiosyncratic shocks

	$\Delta_{2009,11}Emp$	
	(I)	(II)
$\Delta_{2009,10}T$	-0.40^{***}	-0.39^{***}
	(0.12)	(0.11)
Industry change dummy		-0.008**
		(0.003)
Property type change dummy		-0.005
		(0.004)
Increase in m^2 dummy		0.001
		(0.002)
Property size unchanged	✓	
Observations	53,444	63,242
R^2	0.01	0.01

Note: Same notes and controls of column III of Table 1 apply besides those explicitly mentioned. Standard errors (in parentheses) are clustered at the postcode area level. *, ** and *** denote significance at the 10%, 5% and 1% level, respectively.

If business rates revaluations were proxying local demand shocks, we would expect the non-tradable sector to respond less to tax changes because of higher sensitivity to local demand. In contrast, the non-tradable sector displays an even greater MPH, although not significant, as shown in Column I of Table 2. There may clearly be other reasons behind this finding; for instance, firms in the non-tradable sector may have, on average, a different balance sheet structure.

Revaluations are based on rental evidence in 2008, hence two years before the tax actually changes. In the event of systematic mean reversion, the coefficients may be biased by endogeneity with respect to past employment growth. Consider a small area that is doing well in 2008: employment growth would be positive and revaluations may bring along an increase in the tax liability. If employment growth mean reverts in 2010, when the revaluation takes place, the MPH coefficient may be spuriously measuring this mean reversion. In the spirit of Giroud and Mueller (2017), in column II I explicitly control for 2007-09 employment growth, as well as its interaction with the tax shock. Although there are signs of mean reversion, the average MPH remains roughly unchanged.

Finally, I specifically address the possibility that idiosyncratic shocks may affect firm employment and - via physical improvements - the estimated rateable value and, in turn, the tax change. Column I of Table 3 restricts the sample to the cases in which the size of a property, measured in square meters, is the same before and after the revaluation. The estimated MPH is unchanged, further limiting the concerns about idiosyncratic shocks and anticipation. In column II, I explicitly control for property-specific changes around the revaluation. In particular, I augment specification (1) by including three additional controls: a dummy that takes 1 if the firm changed industry between 2008 and 2010, another dummy taking 1 for changes to the property type before and after the revaluation and a third dummy taking 1 when the post-revaluation property size is larger than before. None of these events affects the employment response to the cash flow shock.

The data allow me to control for observable property characteristics. Although unobservable features, like quality, may drive part of the tax change, it is unlikely that this can systematically bias the relationship between employment and tax changes.[29]

4.3 Balance sheet responses

I now examine how firms' balance sheets and other key variables are affected by cash flow shocks induced by the business rates revaluations. I match the BSD-VOA sample used in the previous section with the FAME dataset. Since balance sheet reporting requirements depend on the legal status of the firm and its features, I am able to match roughly half of the sample. Appendix A.7 describes the FAME dataset in detail.

Balance sheet data can be used to estimate the response of firm variables other than employment to cash flow shocks, which are shown in Table 4. Column I shows the pound-for-pound sensitivity of employment to tax shocks, as estimated previously, for the restricted balance sheet sample. The coefficient is of similar magnitude and significance.

I then estimate equation (1) for different outcome variables related to the balance sheet of the firms. The response of investment to cash flow shocks has been the object of a very extensive literature, since the seminal contributions of Fazzari et al. (1988) and Kaplan and Zingales (1997). Different reporting requirements imply that the granularity of balance sheet data is a function of firm characteristics; for this reason, I define investment as the difference in fixed assets plus depreciation, when the latter is reported. To be in line with earlier analysis for employment, the time frame is 2009-11.[30]

The estimated coefficient suggests that business rates revaluations that increase the firm tax liability imply a reduction in capital investment, although insignificantly different from zero. To be more in line with the existing literature on investment - cash flow sensitivity, column III uses as a dependent variable capital investment between 2009 and

[29] A business occupying a property without air conditioning, for example, may anticipate to be included in a valuation scheme that assumes air conditioning for the representative property. This seems to be beyond the firm capabilities, however, especially given the absence of underlying rental information. In the same way, it is hard to think about a mechanism by which a business adds air conditioning to its property, this translates into an increase in the tax bill, and then reverberates into a negative change in employment through a channel different than the tax change.

[30] Appendix A.7 shows robustness to different definitions of investment. The reporting month for the balance sheet data ranges from July to end of year; results do not change qualitatively when looking at changes between 2008 and 2011.

Table 4: Balance sheet responses

	$\Delta_{2009,11}Emp$	$I_{2009-11}$	$I_{2009-11} - I_{2006-08}$	$\Delta_{2009,11}Debt$	$\Delta_{2009,11}NetDebt$
	(I)	(II)	(III)	(IV)	(V)
$\Delta_{2009,10}T$	-0.40^{**}	-0.24	-0.47	-0.53	-0.57
	(0.18)	(0.26)	(0.42)	(0.34)	(0.41)
Observations	24,646	24,646	19,771	24,609	24,609
R^2	0.02	0.02	0.01	0.01	0.01

Note: $I_{a-(a+k)}$ is fixed assets in $a+k$ minus fixed assets in a plus depreciation in $a+k$, when reported. Debt is current liabilities plus long-term debt. Appendix A.7 describes the variable creation in detail, especially in relation with balance sheet reporting requirements. All dependent variables are rescaled by past sales. Standard errors (in parentheses) are clustered at the postcode area level. Same notes and controls of column III of Table 1 apply. *, ** and *** denote significance at the 10%, 5% and 1% level, respectively.

2011 net of capital investment between 2006 and 2008. The estimated coefficient is still negative and insignificant. In terms of magnitude, it suggests that for every additional £1 of cash flow, 47 pence transmit into additional investment. This is within the range of sensitivities typically estimated in the literature.[31] Many reasons may lie behind the insignificant response of investment. Among others, the sampling strategy, which excludes material change of circumstances, strongly restricts the response of investment that accrues to property and plant. Moreover, the majority of the firms in the sample are small and own little if no fixed capital.

Finally, it seems that firms *act as* financially constrained and reduce their debt when faced with an increase in the tax liability. Column IV suggests that firms borrow 53 pence more for every £1 of additional cash flow, although the coefficient is insignificantly different from 0. Giroud and Mueller (2017) find that, while on average firms increase their leverage ratio when faced with a negative demand shock, more leveraged firms are less able to borrow more. The findings shown in Table 4 consider a change in the level of debt, to interpret the coefficients in pound-for-pound terms as for the rest of the analysis. Hence, in principle, the negative coefficient may simply be the result of a scale effect: following a tax hike, constrained firms cut on labour and capital, and also need to reduce their stock of debt since a binding financial constraint prevents them from raising their leverage ratio. Column V looks at the response of net debt, defined as debt minus firm cash holdings. The estimated propensity is slightly greater, although still insignificant.[32]

[31] Rauh (2006), for instance, estimates a 0.65 dollar-for-dollar sensitivity of investment to cash flow, using mandatory defined-benefit pension refunding shocks.

[32] This finding may seem at odds with the positive cash-cash flow sensitivity found by Almeida et al. (2004). Indeed, in unreported results I find that firms hoard slightly more cash when faced with a tax hike, although the coefficient is insignificantly different from 0.

Table 5: MPH heterogeneity in the data

	$\Delta_{2009,11}Emp$				
	A = Size	A = Age	A = Labour productivity	A = Leverage ratio	A = Net leverage ratio
Samples:	Whole	Whole	Whole	FAME	FAME
	(I)	(II)	(III)	(IV)	(V)
$\Delta_{2009,10}T$ x $(A \leq \underline{A})$	-0.42^{***}	-0.40^{**}	-0.38^{**}	-0.32	-0.16
	(0.11)	(0.16)	(0.14)	(0.26)	(0.23)
$\Delta_{2009,10}T$ x $(A > \underline{A})$	1.24	-0.38^{**}	-0.52^{***}	-0.46^{**}	-0.64^{**}
	(0.82)	(0.14)	(0.14)	(0.26)	(0.25)
$(A \leq \underline{A})$	-0.001	-0.001	-0.02^{***}	0.002	0.003
	(0.002)	(0.002)	(0.01)	(0.002)	(0.002)
Observations	63,242	63,242	63,242	24,633	24,633
R^2	0.01	0.01	0.01	0.02	0.02

Note: Standard errors (in parentheses) are clustered at the postcode area level. Same notes and controls of column III of Table 1 apply. *, ** and *** denote significance at the 10%, 5% and 1% level, respectively. Size is the number of firm *i* employees in 2008; the cutoff $\underline{A}$ is 25 employees. Small firms are 87% of the whole sample. Age is the firm age in 2008. The cutoff is 5 years of age; 26% of firms are classified as young in the whole sample. Labour productivity is the ratio between firm sales in 2008 and the number of employees at the firm in 2008. The cutoff is the median in the whole sample, which is roughly £66,000 per employee. Median values have been rounded to the nearest hundred to avoid disclosure issues. Leverage ratio is the ratio of total debt (current liabilities and long-term debt) over total assets. I consider the firm average leverage ratio between 2007 and 2008. The cutoff is the median, 0.60. Net leverage ratio is the ratio of total debt (current liabilities and long-term debt) net of cash over total assets. I consider the firm average net leverage ratio between 2007 and 2008. The cutoff is the median, 0.395.

4.4 MPH heterogeneity

How does the MPH vary across firms? The model in section 5 will formalise the link between MPH and financial constraints, and its resulting heterogeneity by firm characteristics. The richness of the data, however, also allows me to test whether firm features associated with financial constraints in the literature are associated with stronger employment sensitivity. Table 5 decomposes the coefficients by a set of proxies.

Small firms appear to be the main determinant of the estimated MPH. In column I firms have been grouped according to their number of employees in 2008, defining small firms as those with less than 25 employees. When interacting the tax shock by a firm age dummy, the difference is less stark; young firms (5 years of age or less) display the same MPH as old firms. Employment at productive firms, classified as those whose sales-employment ratio in 2008 was above median, responds more to tax shocks.

Finally, more leveraged firms display a greater MPH on average. Column *IV* classifies as leveraged the firms whose total debt to total assets ratio before the tax revaluation was above the cross-sectional median of the sample. In column *V* I show that if we net leverage ratio with cash holdings, the difference in MPH among groups is even more pronounced.

This finding suggests the importance of firms' liquid assets in assessing the link between financial constraints and employment. In previous work, I show that cash-intensive firms cut their workforces by less during the Great Recession.

The ex-ante classification of firms by financial constraint proxies has been the object of controversy in the literature.[33] The findings shown in table 5 suggest that small firms are more affected by financial frictions. Gertler and Gilchrist (1994) proposed size as a proxy for financial constraints, motivated by the fact that small firms exhibit a higher degree of idiosyncratic risk and are more bank-dependent. Since then, the literature has debated over the differential tightness of financial constraints by firm size, and the resulting sensitivity of small and large firms over the business cycle. Recent work on this include Mehrotra and Crouzet (2017). The MPH heterogeneity also suggests that balance sheet positions may be related to the endogenous tightness of financial constraints. My findings echo Giroud and Mueller (2017), who find that more leveraged firms displayed a greater sensitivity to consumer demand in the Great Recession. The structural model presented in the next section formally links the MPH with financial constraints and endogenously reproduces the heterogeneity observed in the data.

5 The model

The empirical findings presented in the previous sections motivate a model of firm dynamics in which financial constraints affect hiring decisions directly. In this section I propose a model that combines a working capital collateral constraint, as in Jermann and Quadrini (2012), with firm heterogeneity. The model is tractable enough to derive an analytical form for the MPH; at the same time, it generates rich cross-sectional dynamics that are consistent with the empirical findings.

5.1 The firm problem

The economy is populated by a large number of firms, each using pre-determined capital stock k and labour n to produce a final good. Each firm operates a decreasing returns to scale production function and produces output y according to:

$$y_t = z_{j,t} k_t^{\nu} n_t^{\alpha} \quad , \nu + \alpha < 1 \tag{2}$$

where $z_{j,t}$ is a stochastic and persistent idiosyncratic productivity that follows a Markov chain: $z \in Z \equiv z_1, .., z_{N_z}$, with $Pr(z_{t+1} = z_i | z_t = z_j) = \pi^z_{ji} \geq 0$ and $\sum_{i=1}^{N_z} \pi^z_{ji} = 1$. Capital k_t is chosen at time $t-1$ while labor n_t can be flexibly changed at time t. Capital evolves

[33] See, for instance, Farre-Mensa and Ljungqvist (2016)

according to $k_{t+1} = (1-\delta_k)k_t + i_t$ where i_t is investment and δ_k is the depreciation rate. Each firm can also invest in a financial asset. When b is positive, the firm is borrowing, at an interest rate r that is the same used to discount the next period expected value. When b is negative, the firm is saving and the asset earns an interest income $r(1-\upsilon)$. This tax penalty of savings ensures that currently unconstrained firms distribute positive dividends even when attaching a positive probability to be constrained in the future.[34] The model is in partial equilibrium, therefore assuming that wages and interest rates are fixed. The firm distributes dividends d_t to their shareholders and cannot issue equity: hence $d_t \geq 0$.[35]

Finally, the firm pays a lump-sum tax τ_t. I normalise this tax to 0. In the following section I will define the MPH as marginal changes in employment that stem from marginal changes in τ_t. While business rates may depend on firm's capital, the revaluation changes considered in the empirical analysis are effectively akin lump-sum cash flow shocks, especially given the sample selection that excludes relocations and establishment closures. By modelling the MPH this way, I can generalise its implications to a generic cash flow shock and, more broadly, relate them to the link between financial constraints and employment.

The firm budget constraint reads as follows:

$$y_t - wn_t - \tau_t - i_t + b_{t+1} - R(b_t)b_t = d_t \tag{3}$$

Where $R(b_t) = \begin{cases} 1+r & \text{if } b_t > 0 \\ 1+r(1-\upsilon) & \text{if } b_t \leq 0 \end{cases}$.

The focus of the model is on understanding how financial frictions affect firms' employment decisions. In order to limit the possibility that firms accumulate sufficient resources such that the enforcement constraint is never binding, I assume that each firm faces a constant probability π^e of being forced to exit the economy in any given period. This assumption will also allow me to match micro features of the data as well as the empirical evidence on the MPH. The timing goes as follows. A firm starts a period with pre-determined capital stock k_t, inter-temporal debt b_t it incurred in the previous period and its current idiosyncratic productivity level $z_{j,t}$. The firm learns immediately whether it will survive to the following period.

I will start by focusing on the firms that survive to the following period. Following

[34] A tax penalty is commonly used in corporate finance literature (e.g.: Riddick and Whited (2009)). Section 6.1 deals with the quantitative relevance of this assumption. Most importantly, the average MPH is not affected: υ limits net financial savings of firms paying dividends, whose MPH is 0 anyway.

[35] While this is certainly a stringent assumption, it helps to match the average MPH estimated in the data. Moreover, it ensures it is possible to derive a closed-form analytical formula for the marginal propensity to hire. The properties of the model are qualitatively preserved as long as equity issuance remains costly. Appendix E investigates the quantitative importance of costly equity issuance.

Jermann and Quadrini (2012), I assume that there is a cash flow mismatch between payments made at the beginning of the period and the realization of revenues. In particular, I assume that the wage bill needs to be financed in advance of production, so that worker compensation is financed by intra-period loans, such that $l_t = wn_t$. I assume that the firm does not pay any interest on these loans. Before producing, a firm chooses labour n_t, investment i_t, dividend payment d_t and the new inter-temporal debt b_{t+1}. At the end of the period revenues are realised, the firm pays investment, the lump-sum tax, dividend payout and the debt liabilities $R(b_t)b_t$. Before repaying the intra-period loan l_t, the firm decides whether it wants to default or not.

Since firms can default on their obligations, their ability to borrow is bounded by the limited enforceability of debt contracts. I follow Jermann and Quadrini (2012) and assume that, at the time of contracting the loan, the recovery value of capital is uncertain. In case of default, the lender may be able to recover the full value k_{t+1} with probability ϕ, while with the complement probability the lender recovers nothing from the borrower. Appendix C describes how we can derive the following enforcement constraint based on the predicted outcome of renegotiation between the firm and the lender in case of default:

$$l_t \leq \phi(k_{t+1} - b_{t+1}) \tag{4}$$

As for most of the collateral constraints used in the literature, more capital relaxes the constraint, while more debt makes it tighter. The specific choice of this constraint is entirely motivated by its analytical tractability, since it allows me to derive a closed-form analytical formula for the MPH. The crucial feature required for the results of this paper is that working capital depends on labour. In other words, that the financial friction affects employment decisions directly.

If the firm learns that it will not survive, I assume that will not carry capital and debt to the following period.[36] This implies that the exiting firm cannot hire any worker, and thus cannot produce. The value of exiting firms is just their current stream of dividends: $V_e(k_t, b_t) = (1-\delta_k)k_t - R(b_t)b_t$. Since dividends cannot go negative, the value of exiting firms cannot be negative either. This introduces an additional constraint $\frac{b_t}{k_t} \leq \frac{(1-\delta_k)}{1+r}$. Note that this constraint applies to all firms: I want to rule out the possibility that surviving firms take up too much debt and find themselves insolvent after learning about their exit.

Every period, the fraction π^e of firms that exits the economy is replaced by the same number of new firms. Each new firm is assumed to enter the economy with zero debt b_t, initial capital stock $k_t = k_0$ and idiosyncratic productivity drawn from the ergodic

[36] In principle, exiting firms may have the incentive to do so in order to take up an intra-period loan and produce. I assume that the lender also observes that the firm will be dead in the following period, and thus does not believe any promise of the firm to repay new inter-temporal debt next period.

distribution implied by $\left\{\pi^z_{ij}\right\}$.

We can summarise the optimisation problem for surviving firms - those that learn, at the beginning of the period, they will survive to the following period - as follows:

$$V(k_t, b_t, z_{j,t}) = \max_{d_t, k_{t+1}, b_{t+1}, n_t} \left\{ d_t + \frac{1}{1+r} \sum_{i=1}^{N_z} \pi^z_{ji} V_0(k_{t+1}, b_{t+1}, z_{i,t+1}) \right\}$$

subject to:

$$z_{j,t} k_t^{\nu} n_t^{\alpha} - w n_t - \tau_t - k_{t+1} + (1-\delta_k) k_t + b_{t+1} - R(b_t) b_t = d_t \geq 0 \tag{5}$$

$$w n_t \leq \phi (k_{t+1} - b_{t+1}) \tag{6}$$

$$V_0(k_{t+1}, b_{t+1}, z_{i,t+1}) = \pi^e V_e(k_{t+1}, b_{t+1}, z_{i,t+1}) + (1-\pi^e) V(k_{t+1}, b_{t+1}, z_{i,t+1}) \tag{7}$$

$$V_e(k_t, b_t, z_{j,t}) = [(1-\delta_k) k_t - R(b_t) b_t] \geq 0 \tag{8}$$

5.2 The analytical MPH

Firms' optimal employment decisions are given by the following first order condition:

$$\left(\alpha z_{j,t} k_t^{\nu} n_t^{\alpha-1} - w\right)(1+\xi_t) = \overline{w} \mu_t \tag{9}$$

Where ξ is the Lagrange multiplier associated with the non-negativity of dividends, while μ the Lagrange multiplier on the working capital collateral constraint. Let us focus on a partial equilibrium framework and normalise the wage to 1. I define with $n^* = g(k_t, b_t, z_{j,t})$ the policy function for employment that solves the firm problem. Then, I define the marginal propensity to hire out of cash flow shocks as the negative of the derivative of optimal employment with respect to the lump-sum tax: $MPH = \frac{\partial n^*}{\partial(-\tau_t)}$.

In order to derive an analytical formula for this object, I first solve the model assuming that $\tau_t = 0$. Then, I divide the firms in two groups: I define positive-MPH firms those for which *both* the working capital constraint and the non-negativity of dividends are binding. I can combine the two binding constraints and derive the following expression:

$$z_{j,t} k_t^{\nu} (n^*)^{\alpha} - n^* - \frac{n^*}{\phi} - \tau_t + (1-\delta_k) k_t - R(b_t) b_t = 0$$

Differentiating this equation with respect to $-\tau_t$, we get:[37]

$$MPH = \frac{1}{1 + \frac{1}{\phi} - MPL} \tag{10}$$

[37] Using the negative of the tax change is done entirely for presentation purposes. This facilitates the interpretation of the MPH as the sensitivity of employment to cash flow.

Where $MPL = \alpha z_{j,t} k_t^{\nu} (n^*)^{\alpha-1}$. It is important to notice that these steps rely on the assumption that a marginal change in τ_t does not make one of the two constraints slack. In other words, I am assuming that the marginal cash flow shock does not affect the constraint status of the firms. This may instead happen in reality; in appendix E I show that the MPH can be calculated to take this into account, at the price of losing its analytical tractability.

The formula derived above could be defined as the MPH for already-constrained firms. Most importantly, it holds only if $\mu_t > 0$ and $\xi_t > 0$. When the collateral constraint is slack, firms choose labour in an unconstrained way. They set the marginal product of labour equal to the wage, and so the MPH is 0.

To summarise, taking μ_t and ξ_t as given, the MPH is:

$$MPH = \begin{cases} \frac{1}{1+\frac{1}{\phi}-MPL} & \text{if } \mu_t > 0 \text{ and } \xi_t > 0 \\ 0 & \text{otherwise} \end{cases} \tag{11}$$

6 Quantitative exploration

6.1 Calibration

I summarise the distribution of firms over (k,b,z) using the probability measure λ on the Borel algebra $S = K$ x B x Z, where $k \in K$, $b \in B$ and $z \in Z$. Define the stationary distribution of firms $\lambda^*(S)$, which is obtained iterating over the following law of motion of the firms' distribution until convergence:

$$\lambda_{t+1}(A, z_i) = (1-\pi^e) \int_M \pi^z_{ji} \lambda_t(d[k \text{ x } b \text{ x } z_j]) + \pi^e \chi(k_0) H(z_i) \text{ , } \forall (A, z_i) \in S$$

where $M = (k,b,z_j) | (k^*(k,b,z_j), b^*(k,b,z_j)) \in A$, k^* and b^* are the policy functions for capital and debt respectively. $\chi(k_0) = \{1 \text{ if } (k_0, 0) \in A \text{ ; } 0 \text{ otherwise } \}$, which basically says that new entrants are born with k_0 capital and 0 debt. They also draw a idiosyncratic productivity from the ergodic distribution $H(z_i)$.

One period is one year, in line with the data used to estimate the MPH. The probability of exit π^e is set to 0.1, in order to match an average firm exit rate of 10% in the UK. This is the average death rate of businesses between 2010 and 2015 as published by the ONS Business demography bulletin. I estimate the firm death rate for earlier years using the Business Structure Database, finding similar magnitudes: 10% in 2005, 9.7% in 2006. The real interest rate r is 4 percent, as in Khan and Thomas (2013) . The tax on interest

Table 6: Parameter values

r	υ	π^e	δ_k	α	ν	ρ_z	σ_ε	ϕ	χ
0.04	0.20	0.10	0.107	0.65	0.25	0.66	0.11	0.50	0.05

Notes: r is the interest rate, π^e the exogenous probability of firm exit, δ_k the depreciation rate, α and ν the exponents on labour and capital in the production function, ρ_z is the persistence of firm-level productivity, σ_ε the standard deviation of its innovations, ϕ and χ the share of average capital that pins down the capital endowment of entrants.

savings υ is set to 20% following Michaels et al. (2016).[38] As mentioned before, the wage is normalized to 1.

The remaining parameters are calibrated jointly to match the same number of moments. Table 6 lists the parameter values, while the upper panel of Table 7 the model fit to the targeted moments. Although all parameters affect all targeted moments, we can identify more pronounced dependence of some parameters on a particular moment.

First, I target a labour share of 0.6. This the 1987-2013 average of the ratio between private non-financial corporations (PNFCs) total compensation of employees over the PNFCs gross value added in the UK. Although financial frictions imply that not all firms set their marginal product of labour to the wage, α is still particularly informative of this moment. The depreciation rate δ_k pins down the aggregate investment to capital ratio. The 1997-2013 average of the ratio between PNFCs gross fixed capital formation and PNFCs net capital stock is 0.107. The targeted capital-output ratio is the average of the ratio between the PNFCs net capital stock and the PNFCs gross value added over the same period. In spite of the presence of financial frictions and exogenous exit, ν is still very informative of this moment, conditional on the depreciation rate.[39]

The remaining moments are calculated using the BSD-VOA and FAME-BSD-VOA samples used for the empirical findings at section 4. The parameter governing the financial friction, ϕ, has a role in determining many moments related to the debt position of the economy. I decide to target the share of net savers, defined as the share of firms whose net financial debt b is negative. In the lower panel of Table 7 I show that the model performs well also with respect to other moments of the net leverage ratio distribution.

The model economy matches the average MPH, computed at the firm-level as explained in the previous section. While all parameters affect the MPH, the capital en-

[38] A positive υ implies that firms at the optimal size do not carry a large amount of net financial savings. Its quantitative role, however, is negligible: driving υ to 0 rises the share of net savers to 24%, lowers the average net leverage ratio to 0.21 and rises its standard deviation 0.45. Most importantly, leaves the average MPH basically unaffected at 0.376. Indeed, a positive υ increases the share of firms facing a binding working capital constraint and a slack non-negativity of dividends. Both constraints are required to bind for the MPH to be positive, which implies it is not very sensitive to this parameter.

[39] Without any frictions, the capital-output ratio would be $\frac{\nu}{r+\delta_k}$. Financial frictions and firm exit affect the capital stock. Assuming that exiting firms do not produce, however, lowers aggregate output relative to the capital stock, and thus bring the capital-output ratio closer to its frictionless counterpart.

Table 7: Model fit

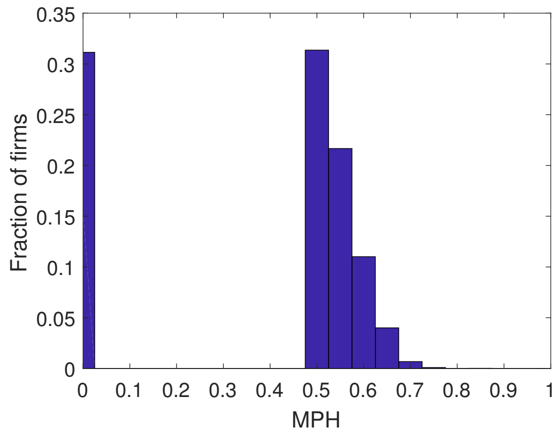
Targeted Moments	Model	Data
Labour share	0.60	0.60
Capital-output ratio	1.72	1.68
Share of net savers	0.21	0.21
Standard deviation of employment growth rates	0.31	0.30
Average MPH	0.39	0.39
Non-targeted Moments	Model	Data
Autocorrelation of TFP growth rates	-0.18	-0.23
Standard deviation of sales growth rates	0.35	0.33
Standard deviation of net leverage ratios	0.34	0.43
Average net leverage ratio	0.27	0.35
Correlation of net leverage ratios and log of employment	-0.45	0.07
Correlation of net leverage ratios and log of total assets	-0.44	-0.01

Notes: Labour share, capital-output ratio and investment ratio in the data are calculated using data from the United Kingdom National accounts, blue book 2016, published by the ONS. All the other moments are computed using the BSD-VOA and the FAME-BSD-VOA samples used in section 4. Firm-level values for debt and capital are end-of-period, to be in line with balance sheet data. See Appendix D for the calculation of the moments. Employment growth rates are calculated both in the model and in the data as the symmetric weighted employment growth $\frac{2(n_{i,t}-n_{i,t-1})}{n_{i,t}+n_{i,t-1}}$, as in Moscarini and Postel-Vinay (2012)

dowment of new entrants - as a share of aggregate capital - is particularly informative. Increasing the share decreases the average MPH. This parameter can be thought as governing an additional financial friction on startups, which defines the startup capital of new firms. The parameter delivered by the benchmark calibration, $\chi = 5\%$, implies a ratio of newly-born average employment to average employment of 10.1%, very close to Davis and Haltiwanger (1992) findings.

I assume that idiosyncratic productivity follows an AR(1) log-normal process, such that $\log(z_{t+1}) = \rho_z \log(z_t) + \varepsilon_{t+1}$, with $\varepsilon_{t+1} \sim N\left(0, \sigma_\varepsilon^2\right)$. When solving and simulating the model, I discretise the firms' log-normal productivity process by the means of Tauchen and Hussey (1991), using 7 values. The calibrated standard deviation of innovations to idiosyncratic productivity, σ, allows the model to match the standard deviation of employment growth rates. Finally, I set the persistence of firm-level productivity, ρ, to the same value estimated by Khan and Thomas (2013). This value gets the model very close to the serial correlation of TFP growth rates. In the model, by defining TFP growth rate

Figure 3: Distribution of MPH in the model



as $\Delta_t ln(z) = ln(z_t) - ln(z_{t-1})$, we can exploit the properties of the AR(1) process to find a closed-form formula for the serial correlation:[40] $corr(\Delta_t ln(z), \Delta_{t+1} ln(z)) = \frac{\rho-1}{2}$. In the data, I estimate the log of TFP as a Solow residual, using the calibrated values for α and ν as labour and capital share.

The lower panel of Table 7 shows that the model does a good job in matching additional moments, although not explicitly targeted in the calibration. In particular, both the standard deviation and the average of net leverage ratios are very close to the data. In contrast with the data, however, the model predicts a negative correlation of leverage ratios with size, both if measured with total assets or the number of employees. In the model, all debt is taken up by firms for investment purposes; this, coupled with exogenous firm exit, implies that small firms are necessarily more leveraged.

6.2 Properties of the MPH

Section 5.2. already presented some of the properties of the MPH in the model. In this section I show explicitly how firm observable characteristics are correlated with the MPH. By doing so, I will use the calibrated model as a tool to rationalise the MPH heterogeneity observed in the data.

First, the model generates a distribution of MPHs, as shown in figure 3. ϕ determines the lower bound of positive propensities, as can be seen in equation (11). 68% of the firms in the calibrated model display a positive MPH; the largest firm-level MPH is 0.90. The share of constrained firms may seem high; the implied share of firms not paying dividends, however, seems in line with existing evidence, especially given the fact that the model is

[40] To show this, we use the following findings. First, the autocovariance of TFP growth rates is $\frac{\rho-1}{1+\rho}\sigma_\varepsilon^2$. Second, the variance of the log of productivity is $\frac{\sigma_\varepsilon^2}{1-\rho^2}$. Third, the variance of TFP growth rates is $\frac{2\sigma_\varepsilon^2}{1+\rho}$.

calibrated to data heavily skewed towards small and private firms.[41]

As in the data, small firms have a greater MPH. The correlation with lagged labour is -0.35 and can be visualized in figure 4a. Two forces affect this correlation; first, conditional on being positive, the MPH is negatively correlated with size, due to the relationship with the MPL shown in section 5.2. Second, smaller firms are more likely to have a positive MPH. It is important to notice that firm exit contributes to this finding.[42] Nevertheless, even in presence of firm exit, the correlation can become positive under certain calibrations, as shown in the following section.

The model also predicts that more leveraged firms have a greater MPH, as found in the data. The correlation with net leverage ratio is 0.81, and figure 4b shows that there even exists a cutoff ratio above which all firms have a positive MPH. As noticed for size, the relationship between MPH and leverage is sustained through two different channels. On the extensive margin, highly leveraged firms face a binding collateral constraint and therefore are more likely to display a positive MPH. Conditional on this, more leveraged firms are also smaller and, most importantly, have a large MPL, which results in greater firm-level MPH. Finally, higher labour productivity in the model is associated with greater MPH. Indeed, the firms in the model will have a binding working capital collateral constraint when their marginal product of labour is greater than the wage.

The properties highlighted in this section refer to the analytical MPH, derived as in section 5.2.[43] Appendix E solves the model for different tax shocks and numerically estimates the propensities of labour, capital and debt. This highlights two potential channels of internal propagation. First, when constrained firms increase employment in response to a positive cash flow shock, they also make more profits and thus have additional disposable resources. Second, greater disposable income may induce firms to borrow more inter-temporally - anticipating a larger wealth in the future - and further propagate the response to the shock.[44]

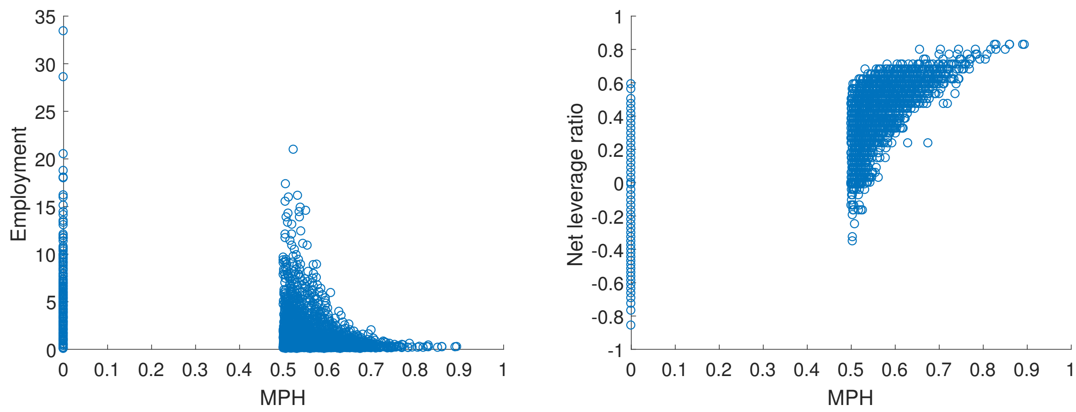
[41]Michaely and Roberts (2011) find that 59% of UK private firms do not pay any dividend, while the share falls to 29% for publicly listed firms. Their sample of private firms, moreover, excludes small and medium firms.

[42]Without exit, the model typically displays a firm-level productivity z cutoff, above which firms have a positive MPH. If the endogenous tightness of the financial frictions is weak, the correlation between productivity and size is positive enough that the correlation between size and MPH is also positive.

[43]In order to check for accuracy, I numerically evaluate the MPH out of a change in the net financial asset b using the policy functions that solve the model. The resulting average MPH at the stationary distribution is also 0.39.

[44]The effect on labour is ambiguous: on one hand higher inter-temporal debt sustains more capital investment, potentially relaxing the collateral constraint. On the other hand, it crowds out labour by making the constraint tighter.

Figure 4: MPH heterogeneity in the model



(a) MPH and size

(b) MPH and net leverage ratios

Notes: Figures plot simulated data for the sample of surviving firms used to compute the moments in Table 7. Size is measured in terms of employment. In panel (a), model-generated employment has been rescaled so that 1 is the mean employment in the model-generated distribution. To be in line with the data, size and net leverage ratios are lagged one period with respect to the MPH, to identify pre-determined conditions. The contemporaneous correlation between MPH and size is -0.23. See appendix D for further details.

6.3 Comparative statics

The marginal propensity to hire in the model can be interpreted as a measure of the endogenous tightness of the financial frictions. As such, parameters other than those governing the financial friction itself affect the MPH. In this section I focus on four parameters, and discuss their role in affecting the MPH. In particular, I underline how the average MPH is effectively the result of two channels; an extensive margin, which measures how many firms in the economy are constrained, and an intensive margin, which quantifies the firm-level intensity of the financial constraints.[45] Telling these two channels apart is useful in order to identify the role played by each parameter in affecting the MPH.

Figure 5 shows how the average MPH changes as we change one parameter at a time, and leaving all the others fixed at the values shown in Table 6.

Endowing new entrants with more capital, by the means of increasing χ, is very effective in lowering the average MPH, as can be seen in the first panel. A larger initial capital stock implies that firms take less time to mature. In other words, more firms accumulate enough wealth - before exiting - to be able to absorb a negative cash flow shock by reducing dividends or taking up more debt: for this reason, their MPH is 0. This channel can be visualized in the first panel of figure 7: a larger capital endowment of newly born firms is associated with a lower share of firms with positive MPH. Greater χ, however, also acts

[45]The intensity of financial constraints can also be expressed as the average MPH for constrained firms. This statistic can be easily backed out dividing the average MPH by the share of firms with positive MPH. The maximum firm-level MPH, shown in figure 6, also gives an idea of the dispersion of the MPH distribution; since the lower bound of the MPH is ϕ, this allows us to work out the range of propensities.

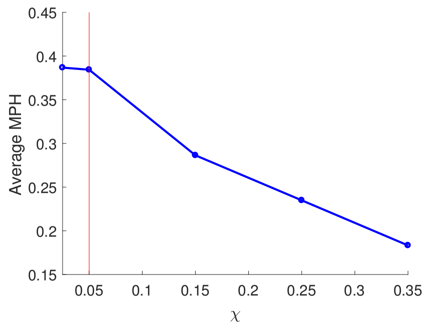
along the intensive margin of the MPH, as shown in Figure 6. Equation 10 shows that the MPH is inversely correlated with the marginal product of labour. In the model, smaller firms are more likely to have a larger gap between labour productivity and the wage. This gap governs the intensity of the employment response to cash flow shocks.

The second panel of Figures 5-7 shows that the exogenous tightness of the collateral constraint, ϕ, affects the average MPH through two counteracting forces. On one hand, greater ϕ increases the lower bound of positive MPH, as can be seen in equation 10, shifting the MPH distribution to the right. Greater ϕ implies that firms can get a larger intra-period loan for a given future wealth. £1 of additional cash flow will transmit into more employment given the capacity to borrow more. On the other hand, it reduces the share of constrained firms because it makes it easier to borrow. In the quantitative exercise considered here, the first effect prevails.

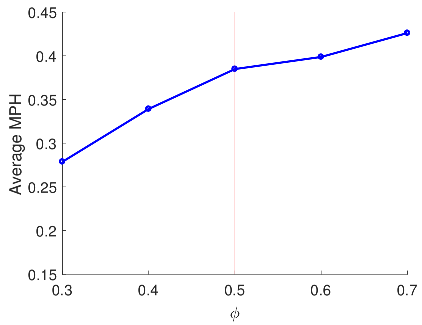
Finally, neither the persistence nor the standard deviation of firm-level productivity play a quantitatively important role for the average MPH. σ_ε affects the MPH through two, opposite, margins. A larger variance increases the maximum firm-level MPH by acting through the marginal product of labour. On the other hand, it may trigger a precautionary savings motive that reduces the share of constrained firms.

Figure 8 shows how the correlation between MPH and size is affected by the different parameters. First, it is not always true that economies with a greater average MPH will also display a more negative relationship between MPH and labour. Second, we notice that, even in presence of firm exit, the correlation can turn positive if newly born firms are endowed with a large initial capital stock. We have noticed earlier how entry and exit can break the relationship between productivity and size; in particular, the smaller the new entrants the greater the probability they are credit-constrained, since they will not have enough wealth to sustain the employment growth suggested by their idiosyncratic productivity.

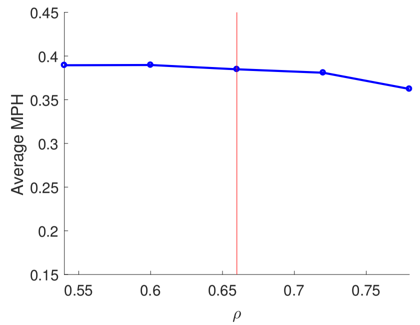
Figure 5: Average MPH



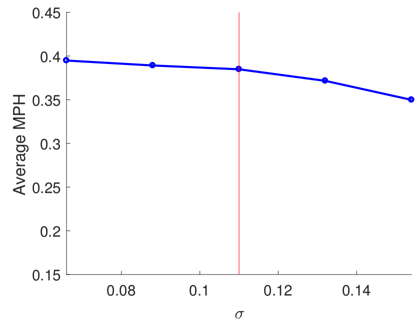
(a) Entrants' capital (%), χ



(b) Credit variable, ϕ

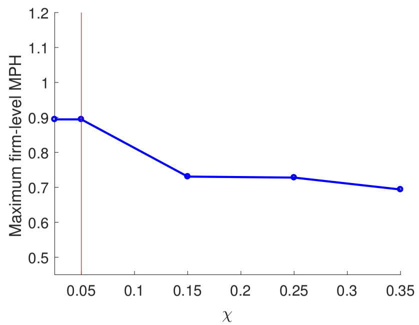


(c) Persistence of firm-level productivity, ρ_z

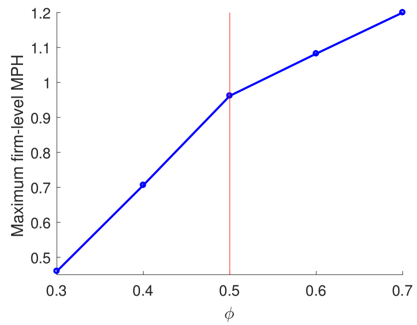


(d) Standard deviation of ε, σ_ε

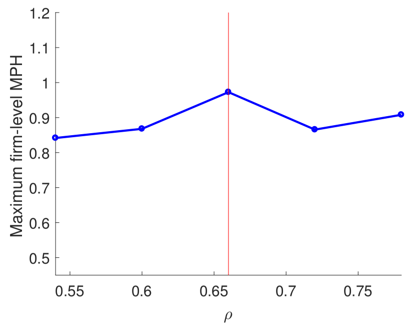
Figure 6: Maximum firm-level MPH



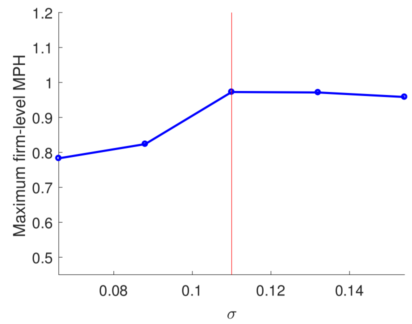
(a) Entrants' capital (%), χ



(b) Credit variable, ϕ

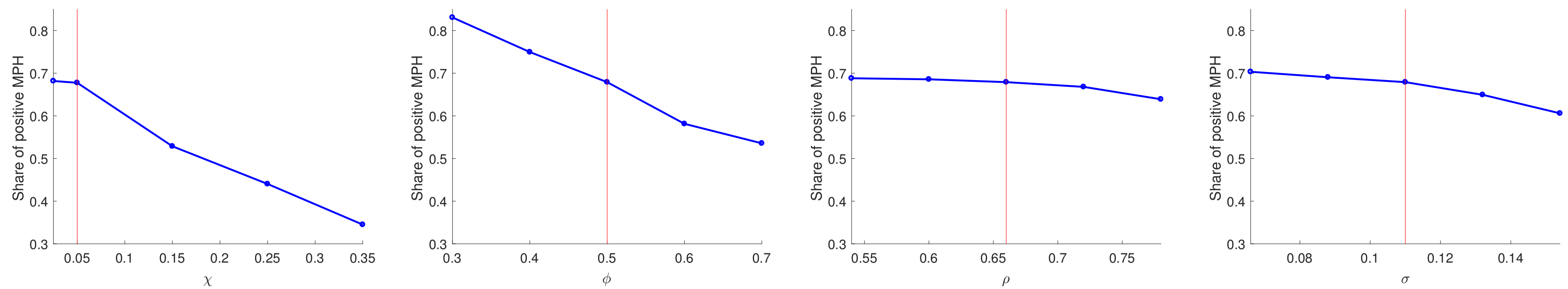


(c) Persistence of firm-level productivity, ρ_z



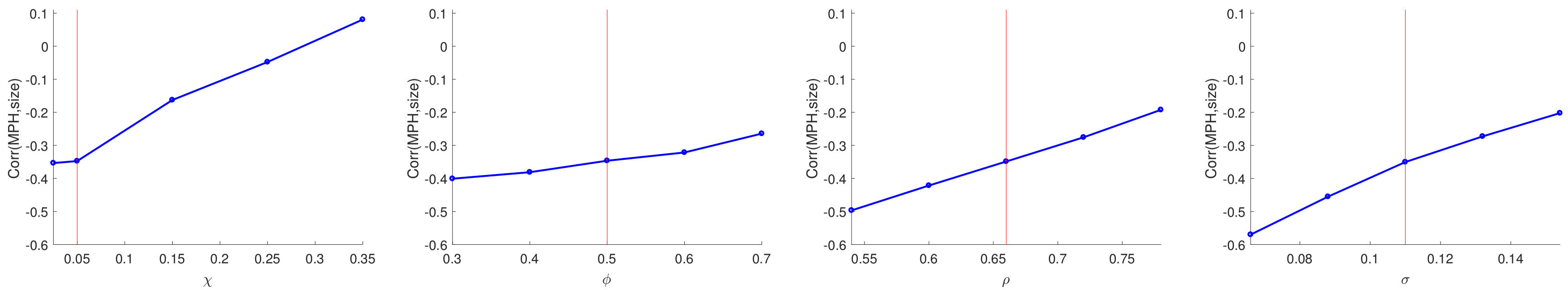
(d) Standard deviation of ε, σ_ε

Figure 7: Share of firms with positive MPH



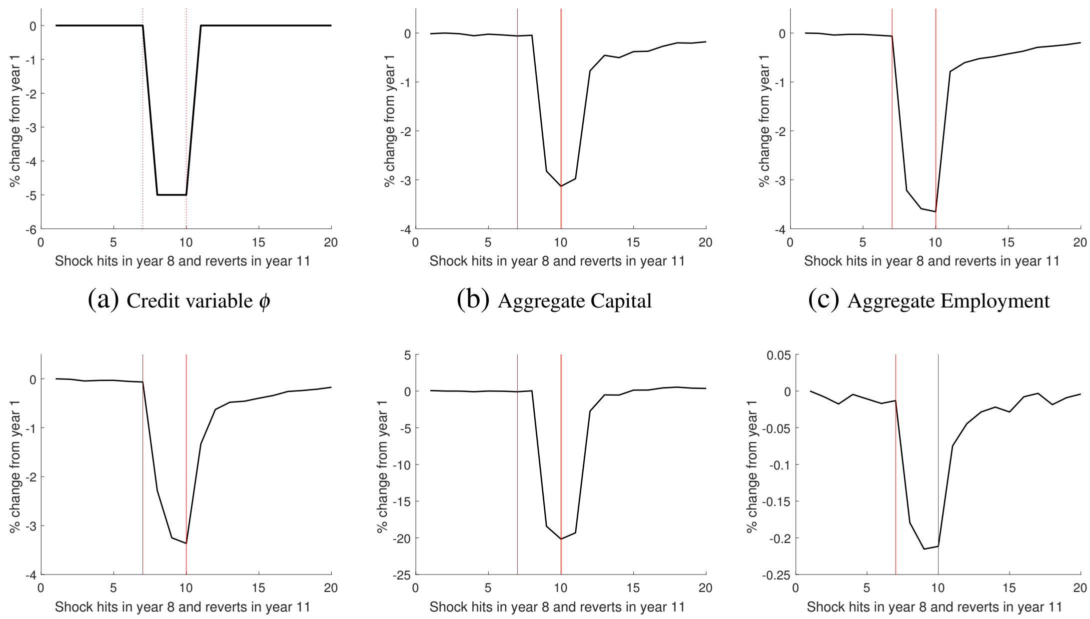
(a) Entrants' capital (%), χ (b) Credit variable, ϕ (c) Persistence of firm-level productivity, ρ_z (d) Standard deviation of ε, σ_ε

Figure 8: Correlation between MPH and size



(a) Entrants' capital (%), χ (b) Credit variable, ϕ (c) Persistence of firm-level productivity, ρ_z (d) Standard deviation of ε, σ_ε

Figure 9: Aggregate responses to a credit shock



(a) Credit variable ϕ (b) Aggregate Capital (c) Aggregate Employment

(d) Aggregate Output (e) Aggregate Net debt (f) Aggregate endogenous TFP

Notes: Aggregate capital and net debt are computed using the beginning-of-period k_t and b_t respectively. Endogenous TFP is the Solow Residual obtained from $log(Y_t) - \alpha log(N_t) - \nu log(K_t)$. All variables are plotted in % deviation from year 1. The model is solved twice for two different values of ϕ. Then the economy is simulated for 100 years over a panel of 200,000 firms. The initial conditions are drawn from the invariant distribution at the steady state level of ϕ. This stays constant for 50 years, drops to the lower value for 3 years and then reverts back. The simulation is repeated for 100 separate economies, with different path of idiosyncratic productivity all consistent with the transition matrix. Then the aggregate variables shown are the averages across economies.

7 Macro implications

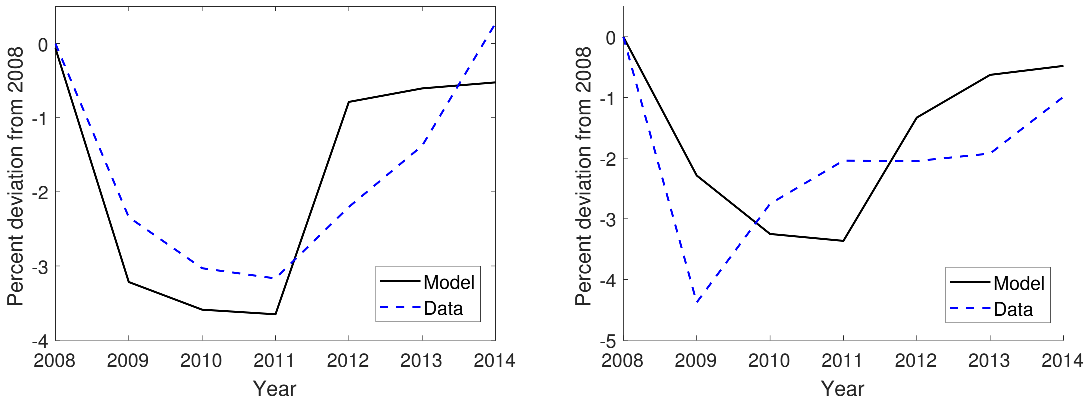
In this section I investigate the macroeconomic implications of calibrating the model to the empirical evidence on the MPH. First, I show that, when simulating a credit tightening, the model can account for much of the decline in aggregate employment and output experienced by the UK in the Great Recession. Second, I investigate how relevant moments of the MPH distribution are related to the dynamics of aggregate employment in the wake of a credit tightening. Finally, I show how these MPH moments evolve during a credit crunch and how this matters for policy.

7.1 Credit tightening experiment

I use the calibrated model to study an economy response to a credit tightening when the average MPH is as high as in the data. I consider an unanticipated shock that tightens the collateral constraint.[46] Figure 9 shows the response of aggregate capital, net debt, employment, output and endogenous TFP to an unanticipated 5% drop in ϕ, lasting 3

[46]Recent papers have investigated the macroeconomic responses to credit supply shocks. Among others, Khan and Thomas (2013) and Buera et al. (2015)

Figure 10: Model performance to the UK economy



(a) Aggregate Employment (b) Aggregate Output

Notes: Model simulations as explained in figure 9. In the data, aggregate employment is measured as the employment rate (aged 16-64) in UK, from the ONS. Aggregate output is UK GDP in chained volume, from the ONS. GDP has been converted in logs, de-trended with HP filter over the period 1950-2014, and then plotted as percentage point deviations from the de-trended value in 2008.

years. The size of the credit tightening is calibrated so that the model generates a 20% fall in net debt, in line with the drop measured in the UK between 2008 and 2011.[47]

The model generates a large and protracted fall in aggregate employment and output. Tighter collateral constraints also induce a fall in endogenous TFP, albeit quantitatively limited. A tighter collateral constraint reduces firms' ability to borrow, both inter- and intra-temporally. First, they need to cut labour whenever facing a binding financial constraint. Second, their ability to borrow intertemporally is also impaired. Both channels reduce firms' cash flows, implying a reduction in capital investment and an internal propagation of the response.

Quantitatively, the model can account for much of the decline in aggregate employment and output experienced by the UK during the Great Recession, as shown in figure 10.

7.2 The MPH and different responses to a credit tightening

Do economies with different MPH respond differently to a credit tightening? In order to start answering this question, I differentiate aggregate employment with respect to ϕ. I then exploit the analytical formula of the MPH to work out how employment at constrained firms responds to a change in ϕ. In order to present more clearly the link between MPH moments and the response of aggregate employment to a credit tightening, let me then abstract from the effect of changes in ϕ on the share of constrained firms

[47]Unconsolidated financial balance sheet of UK non-financial corporations, as reported by the ONS. Net debt measured in the data as total loans plus debt securities minus currency and transferrable deposits with UK MFIs.

and postpone its analysis. I therefore consider a (approximate) sensitivity of aggregate employment to ϕ, which can be decomposed as follows in the spirit of Olley and Pakes (1996):[48]

$$\frac{\partial N}{\partial \phi} \approx \int \frac{n_i}{\phi^2} MPH_i di = \frac{1}{\phi^2} \left[E(MPH)E(n) + COV(MPH, n) \right) di \tag{12}$$

Two forces are in place. Greater average MPH, ceteris paribus, implies a greater sensitivity of aggregate employment to ϕ. As discussed before, this depends, in turn, on both how many firms are constrained and the firm-level intensity of the financial friction. In an economy in which employment choices are more often and more severely impaired by borrowing restrictions, a further tightening of credit conditions will intuitively result in greater employment losses. On the other hand, aggregate employment will respond more to a credit tightening the more positive the covariance between employment and the MPH. When larger firms are more severely affected by financial frictions, a tightening of credit conditions will cause larger employment losses due to the greater employment share of these firms. As shown in figures 5-8, the two forces often go in the opposite direction.

The analysis so far has clearly pointed at the relevance of MPH statistics for the response of aggregate employment to a credit tightening. Nevertheless, it abstracts from the response of the share of constrained firms, it is necessarily applied to local changes in ϕ and focuses on the response upon impact. I now compare numerically how economies that differ with respect to their average MPH respond differently to the credit tightening shock considered in figure 9. This exercise crucially depends on the way in which different values of the average MPH are achieved. I decide to focus on χ, given that the quantitative properties of the MPH are particularly sensitive to this parameter.

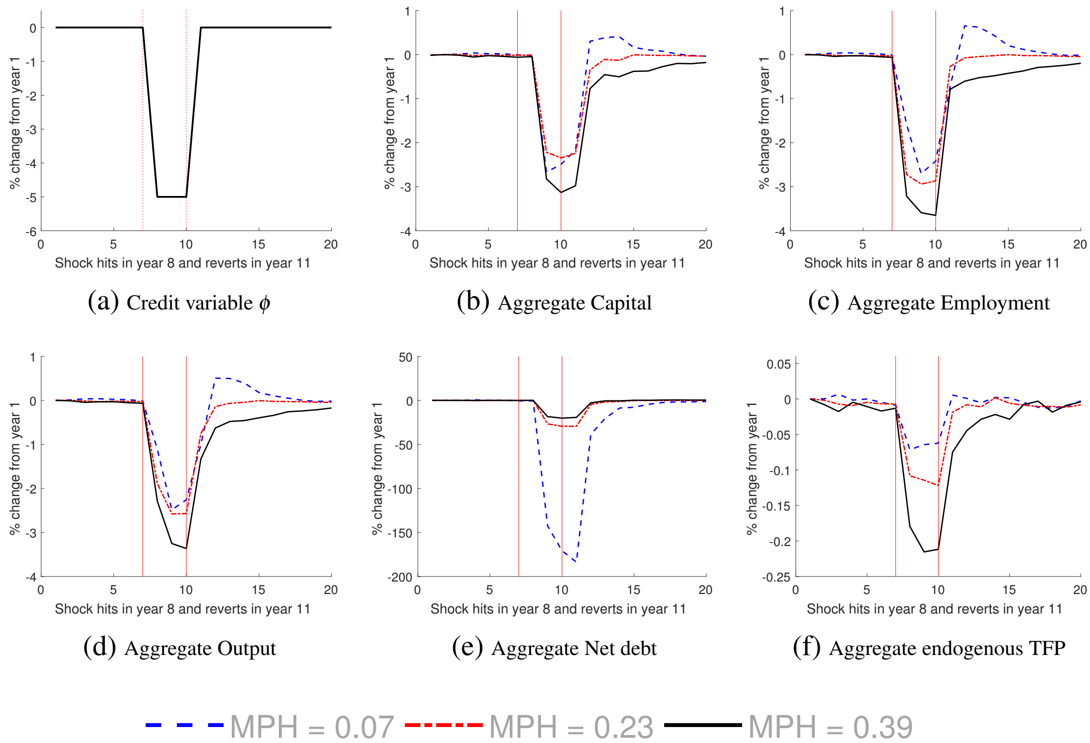
Figure 11 shows the impulse response functions for three different economies. The solid black line refers to the benchmark calibrated economy with an average MPH of 0.39. The second economy, in red, achieves an average MPH of 0.23 by the means of increasing χ to 25%.[49] In the dashed blue-line economy firms never exit: the average MPH is 0.07.

Aggregate responses are clearly ordered by the average MPH of the economy. The drop in aggregate employment upon impact can be tied to the analytical analysis pursued at the beginning of this section. A greater average MPH implies, ceteris paribus, a stronger response of aggregate employment. The benchmark economy, however, has also the lowest covariance between employment and the MPH. According to equation 12 this should imply, ceteris paribus, a weaker response of aggregate employment. The former effect dominates in the aggregate. The blue economy, for instance, has a covariance of 0.0178,

[48] Full derivation in Appendix F.

[49] This implies that the entrants' employment size is 37% of the average.

Figure 11: Aggregate responses to a credit shock: different MPH by changing χ



(a) Credit variable ϕ (b) Aggregate Capital (c) Aggregate Employment

(d) Aggregate Output (e) Aggregate Net debt (f) Aggregate endogenous TFP

Notes: Aggregate capital and net debt are computed using the beginning-of-period k_t and b_t respectively. Endogenous TFP is the Solow Residual obtained from $log(Y_t) - \alpha log(N_t) - \nu log(K_t)$. All variables are plotted in % deviation from year 1. The model is solved twice for two different values of ϕ. Then the economy is simulated for 100 years over a panel of 200,000 firms. The initial conditions are drawn from the invariant distribution at the steady state level of ϕ. This stays constant for 50 years, drops to the lower value for 3 years and then reverts back. The simulation is repeated for 100 separate economies, with different path of idiosyncratic productivity all consistent with the transition matrix. Then the aggregate variables shown are the averages across economies.

compared with -0.0058 in the benchmark: this is not enough, however, to overturn the fact that the average MPH is more than 5 times lower than in the black economy. In turn, aggregate employment falls by 1.6% upon impact when the MPH is low, and 3.3% when it is high. Most importantly, note that only the benchmark economy is in line with the data with regard to the covariance between MPH and firm size. The alternative calibrations shown in the figure, in contrast, imply that larger firms will exhibit greater marginal propensities to hire, at odds with the empirical evidence shown in Table 5. We can also use equation 12 and the numerical impulse responses to back out the portion of the initial drop in aggregate employment accounted for by the firms becoming constrained after the credit shock. This is 7.4% in the black economy, 1.8% in the intermediate and 10% in the low-MPH economy.[50]

Economies with different average MPH also display different aggregate dynamics, beyond the response upon impact. When the MPH is low, a credit tightening implies

[50] It should be noted, however, that part of this gap may be due to the inaccuracy of the first-order Taylor approximation.

a short-lived drop of employment and capital - note that they both start recovering during the crisis - and an overshooting when ordinary credit conditions are restored. Net debt drops substantially and absorbs part of the credit tightening. The higher the average MPH, the larger both the drop of employment and capital and its persistence; in the benchmark economy, the credit tightening propagates implying that, 5 years after the end of the credit contraction, aggregate output is still 0.4% below its pre-crisis levels. A credit supply shock implies a drop in endogenous TFP, as also found by Khan and Thomas (2013): tighter financial frictions imply stronger misallocation of resources. In particular, productive firms with little wealth take more time to expand towards their optimal size. The greater the MPH, the stronger this effect: TFP drops 4 times more in the benchmark economy than in the low-MPH economy.

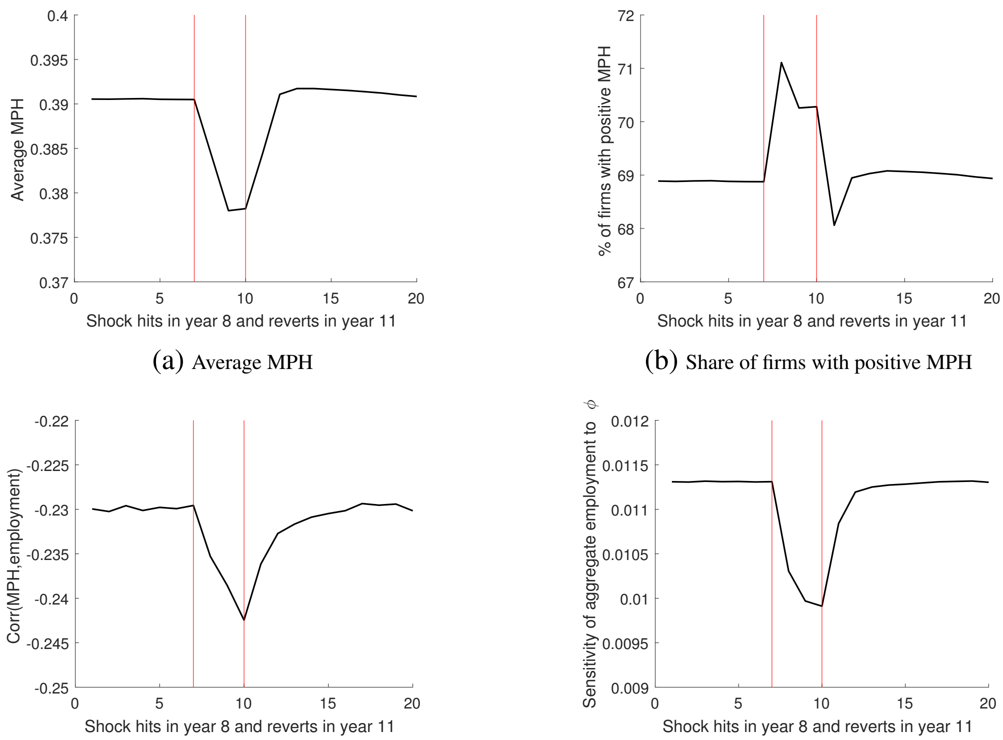
This section has shed some light on the interaction between the MPH and the aggregate dynamics following a credit tightening. While simulation exercises suggest that economies with greater average MPH display a larger and more prolonged fall in aggregate employment, this may be specific to the way in which different MPH moments have been achieved - i.e.: by changing χ. Moreover, equation 12 clearly shows that additional moments as the covariance between MPH and size are important. Analysing in greater detail the features of the MPH distribution seems a promising avenue to better understand the transmission mechanism of credit supply shocks onto aggregate employment and is left to future research.

7.3 The MPH during a credit tightening

What happens to the MPH during a credit crisis? In section 6.3 we have seen how ϕ affects the marginal propensity to hire along two opposite margins. When the collateral constraint is tighter, more firms will be at the binding constraint, which implies that the share of firms with positive MPH will increase. This is shown in figure 12b. On the other hand, ϕ is negatively correlated with the firm-level analytical MPH, as shown in equation 10. Indeed, ϕ measures the firm's capacity to leverage up on future wealth and borrow intra-temporally. For a given £1 of additional cash flow, firms will be able to borrow less the lower ϕ, thus transmitting in fewer additional employment expenditures and therefore a lower MPH. This effect prevails on average, implying the small dip in the average MPH seen in figure 12a.

This finding suggests that stabilisation policies in the form of uniform lump-sum transfers may be less effective in boosting aggregate employment during credit tightening periods. While the analytical MPH abstracts from the effect of lump-sum cash flow shocks on changes in the constraint status of the firm, it is not clear ex ante why the size of these transfers should have differential effects along this margin during a credit tightening pe-

Figure 12: The MPH in a credit crisis



(a) Average MPH

(b) Share of firms with positive MPH

(c) Correlation between MPH and size

(d) Sensitivity of aggregate employment to ϕ

Notes: Notes to figure 9 apply. The correlation plotted in 12c is contemporaneous. Panel (d) shows the approximate sensitivity of aggregate employment to ϕ, as computed in equation 12

riod. A credit crunch makes also more mildly negative the correlation between MPH and size, as shown in figure 12c. This suggests that policies targeted at small firms should be more effective during this type of recessions. Finally, in figure 12d I plot the approximate response of aggregate employment to ϕ computed using equation (16). In this context, we can interpret this statistic from a policy perspective. Suppose the policymaker was able to affect the tightness of financial frictions by acting on ϕ, this statistic would give the approximate sensitivity of aggregate employment, with the usual caveat of abstracting from the response of the extensive margin. This sensitivity falls slightly during the credit tightening period. The fall in the average MPH, in aggregate employment, and in the covariance between employment and MPH all push down the sensitivity during a credit crunch. ϕ itself, however, has fallen, implying that the drop is less pronounced. As before, this finding suggests that policies aimed at acting directly on the tightness of financial frictions may be less effective during credit crunches.

8 Conclusions

The interaction between firm-level financial constraints and employment decisions has received a lot of attention following the Great Recession and the financial crisis. In this paper, I first empirically show that financial constraints matter for firms' employment decisions. I exploit the idea that, when financial constraints bind, a firm adjusts its employment in response to cash flow shocks. I use a novel combination of three large data sets in the UK and a new source of variation to estimate this response, which I label the Marginal Propensity to Hire. In particular, I exploit the changes to a UK tax based on a periodically estimated value of the property occupied by the firm. I find that, on average, for every £1 of additional cash flow, 39 pence are spent on employment. Moreover, small and leveraged firms display a greater MPH. I then build a model of firm dynamics and financial frictions and calibrate it to macro and micro features of the data, including the average MPH. The model sheds light on the nature of employment - cash flow sensitivities and can replicate the empirical evidence on the cross-sectional heterogeneity of the MPH. The empirical evidence on the MPH and its distribution can be used as a tool to inform quantitative macro models. In this paper I show that, simulating a tightening of credit conditions, the calibrated model can account for much of the decline in aggregate output and employment observed in the wake of the financial crisis. In ongoing work, I am using the theoretical apparatus and its link with the empirical findings to tackle another big macro question, namely how much misallocation do financial frictions create.

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Appendix

A The data

A.1 Data description and construction

This paper uses information primarily from three data sources, which I describe in this section: The Business Structure Database (Office for National Statistics (2017)), the Rating List and Summary Valuations compiled by the Valuation Office Agency and the Financial Analysis Made Easy (FAME) of the Bureau van Dijk.

Quoting the UK Data Service Catalogue description, "The Business Structure Database (BSD) is derived primarily from the Inter-Departmental Business Register (IDBR), which is a live register of data collected by HM Revenue and Customs via VAT and Pay As You Earn (PAYE) records. The IDBR data are complimented with data from ONS business surveys. If a business is liable for VAT and/or has at least one member of staff registered for the PAYE collection tax system, then the business will appear on the IDBR (and hence in the BSD). In 2004, it was estimated that the businesses listed on the IDBR accounted for 99 per cent of economic activity in the UK. Only very small businesses, such as self-employed, were not found on the IDBR."

The BSD is created by the ONS virtual Micro-data Laboratory (VML); every year, a snapshot of the IDBR is taken around April, and the captured point-in-time data are supplied to the VML by the following September. The reporting period is generally the financial year. For example, the 2000 BSD file is produced in September 2000, using data captured from the IDBR in April 2000. The data will typically reflect the financial year of April 1999 to March 2000. Employment information for the vast majority of firms, for instance, is updated on the IDBR using quarterly PAYE information. However, the ONS may, during this time, update the IDBR with data on companies from its own business surveys. I follow the literature, such as Anyadike-Danes et al. (2011), and define the BSD variables with respect to the named year of the snapshot. The data are divided into enterprises and local units. The enterprise is defined as "the smallest combination of legal units that is an organisational unit producing goods or services, which benefits from a certain degree of autonomy in decision-making, especially for the allocation of its current resources". A local unit is "an enterprise or part thereof (e.g.: a workshop, factory, warehouse, office, mine or depot)."; "(...) to qualify as a local unit, a business entity must only consist of one site at a mailing address". For each business, data are available on employment, turnover, foreign ownership, legal status, industrial activity based on Standard Industrial Classification (SIC), year of birth and death, as well as postcodes for both enterprises and local units. Turnover information is available only at the enterprise level. Within the IDBR, every local unit and enterprise is given its own, unique reference number when it enters onto the IDBR which remains unique to that business whilst it remains, in the same form, on the register. Given its confidential nature, the Business Structure Database can be accessed only through the UK Data Service Secure Lab.

Tax liabilities are calculated using information on Rating Lists and Summary Valuations, as provided by the Valuation Office Agency. The VOA compiles and maintains the rating list of rateable values for around 1.9 million non-domestic properties in England and Wales. About 80% of these properties have a summary valuation. I consider information drawn from the 2005 and 2010 rating lists, with summary valuations information for 2010. The data contains information on the adopted rateable value, the address of the property, date information on alteration to the rateable value and its effectiveness, the property category type and description, the size of the property measured in square meters, the adopted pounds per square meter rateable value and the valuation scheme reference number. Part of the tax data is live, which means that any physical change to the property after the revaluation will over-write the existing information. I try to account for this while matching the data by creating two comparable datasets. This will not be an issue in the empirical analysis, since the specific sample considered contains non-updated information at 2010 for all properties. For the tax data, I retain the properties that have non-missing rateable values before and after 2010. This excludes properties that were built, or closed, after the revaluation. For the BSD local unit data, I start by retaining local units in England and Wales, to be in line with the business rates. I then keep local units that did not change postcode sector around the revaluation,[51] and that are live between 2009 and 2011. I also exclude local units that die after 2012 without changing postcode, interpreting this as a property closure too. I break each side of the sample into two groups, depending on whether each full postcode unit has only one property (local unit) or more. I then proceed to match those sample groups. In some cases, one local unit is associated with more properties in the same postcode. Local units are defined as places where economic activity is carried out by one or more persons work; VOA properties, instead, do not require any employee. I therefore create a mapping between the SIC industry code of the local unit and the category type of the property, allowing for groups of properties that are likely to be part of the same local unit.[52] The mapping between industry codes and property types is also used for postcodes with multiple local units and multiple properties, or to check ex post the correctness of the matching.

[51] I allow for small changes in the postcode unit, since this allows me to match over postcode sector too at a later stage. This may be coding error, change in the coding of the last letter of a postcode, or genuine relocations ”next door”. In unreported results, I check that the estimated average MPH is unaffected when dropping these few occurrences.

[52] For example any property and its car park/ATMs/garages, or a school with its sport ground.

In order to allow for measurement error of postcode units, I repeat the same strategy at the postcode sector level, adding a small number of additional matches. The final sample consists of roughly 175,000 observations. The sample is then merged with firm-level information from the BSD, using the unique identifier that links local units and enterprises. There are 135,139 firms in the sample. I then exclude central government bodies and local authority establishments, establishments with 0 employees, properties with a rateable value of £0. To be in line with rental method for revaluation, as explained in section 2, I keep only the properties reporting a valuation scheme reference number. Moreover, I exclude all properties whose category - i.e.: property type - may be valued with methods other than the rental method. [53] I then exclude the properties incurring in material change of circumstances between 1 April 2010 and 2012. Indeed, firms have the possibility to reduce their tax bill by changing the features of the property and then reporting a material change of circumstances at the Valuation Office Agency.[54] This may imply a change in employment due to the complementarity with fixed assets and following a response to a change in the user cost of capital; since, instead, I am interested in the balance sheet channel of cash flow shocks, I exclude this possibility. In the data, it is not possible to observe directly whether a material change of circumstances took place. Nevertheless, I follow the Rating Manual, Volume 2, Section 5, Paragraph 6 and assume that any *effective date* beyond 2010 is deemed to be the date the circumstances arose that required the list to be altered. I also drop all properties incurring in an alteration to its pre-2010 rateable value taking place after 2010. This is typically the result of overdue resolution of appeals or retroactive changes to the tax bill. Finally, I drop the establishments that changed enterprise between 2009 and 2011, and the construction sector (UKSIC 41100-43999), given its special nature when it comes to a property tax. The sample now consists of 82,506 establishment-tax observations. The employment variable used in the analysis excludes business owners - thus measuring only the number of employed staff. To protect the results from the effect of the outliers, I trim the dependent variables at the 1st and 99th percentiles. I also drop the upper and lower 0.75 percent of the scaled tax shock. Results are robust to 1 percentile trimming of the tax shock.

When calculating the pound-for-pound MPH, I rescale the employment changes by an annual wage of £21,024. According to the Annual Survey of Hours and Earnings, in

[53] Fish farms and public religious worship halls may be exempted upon request to the local authority. The other valuation methods are: contractors' basis, revenue and expenditure method, fair maintainable receipts, agreed valuation, special treatment (e.g.: football stadia). The relevant information can be found in the Valuation Office Agency Rating Manual, Volume 5. I also exclude all the categories that may be valued through a national, rather than local, scheme.

[54] Material change of circumstances typically involve matters affecting the physical state or physical enjoyment of the hereditament and the category of occupation of hereditament (Rating Manual Volume 2 Section 5). While potentially still working through the balance sheet, the cash flow shock may depend on the marginal product of capital and driven by other reasons such as endogenous location choices.

Table 8: Descriptive statistics

	Mean	Std. Dev.	Median	Mean (>0)
$\Delta_{2009,10}T$ (% of $Sales_{2008}$)	– 0.05	0.7	-0.03	0.4
$\Delta_{2009,11}Emp$ (% of $Sales_{2008}$)	1.4	15	0	17
Emp_{2008}	103	2,054	5	
$Sales_{2008}$ (Th GBP)	17,364	541,400	250	

Note: Moments calculated from the sample of 63,242 observations in Table 1. Median values are averages around the median when there are less than 10 observations taking the median value.

April 2010 median gross weekly earnings for all employees were £404, which gives the rescaling wage if multiplied by 52 weeks. It seems sensible to consider both part-time and full-time employees when calculating the wage, especially given the very large number of small firms in the sample. Moreover, small firms typically pay lower wages and employ more part-time employees, as shown in the 2016 Annual Survey of Hours and Earnings; this may lead to overestimation of the pound-for-pound MPH.[55] On the other hand, it may underestimate the MPH since gross earnings slightly underplay firms' labour costs. Gross weekly earnings include regular pay - gross of income tax and employee National insurance contributions -, overtime pay and one-off bonuses, but exclude employer National insurance contributions, employer contributions to pensions schemes, benefits in kind, signing-on fees and stock options not paid through payroll.

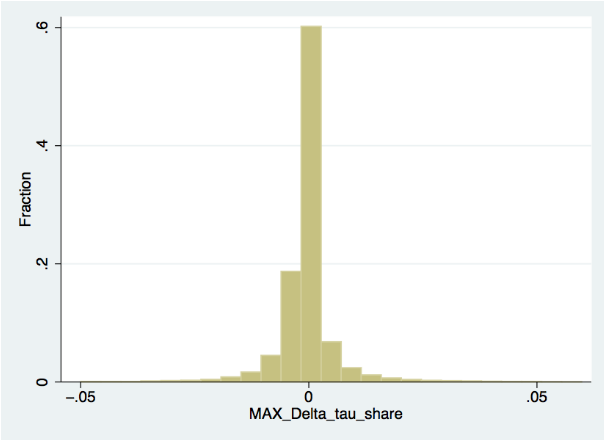
Table 8 shows the descriptive statistics for the sample used in Table 1, while Figure 13 the distribution of the scaled tax shocks.

A.2 Robustness to the average MPH

The analysis done in section 4 constructs tax shocks using tax liabilities calculated by the author. A few important comments are worth making, which will be the object of this section. The tax liability is calculated by multiplying the relevant rateable value by the multiplier. There are two main multipliers, one for Wales and one for England. I refer to section 2 for the description of how multipliers are updated every year. I then make a series of adjustments concerning the multipliers. The City of London authority charged an additional 0.4p for the properties in its area. Since the 1st April 2010, the Greater London Authority introduced a 2p additional levy on the multiplier, for rateable values over £55,000. Small properties, in England only, benefit from a lower multiplier, depending

[55] The median weekly earnings at micro firms (less than 10 employees) was 64% of the overall median in 2016. Part-time employees at those firms earned even less (35%). At the other extreme of the distribution, full-time employees at large firms earned 29% more than the overall median.

Figure 13: The distribution of tax shocks



Note: Distribution of $\Delta_{2009,10}T$ as of column III of Table 1.

on the rateable value of their property and the sum of all rateable values at the business.[56] The small business multiplier is automatically assumed, according to the rateable value of the property, since 2010 revaluation; the VOA then checks if the conditions of eligibility apply to the ratepayer. In the main analysis, I compute small business multipliers. Column I of Table 9 shows that the results are unchanged if I get rid of the small business multipliers when constructing the tax liabilities.

A number of reliefs are in place, which may affect the business rates liability. The small business rates relief is subject to the same conditions of the small business multiplier, but businesses need to explicitly apply for this to the relevant local authority. The dataset does not have the necessary information to take this into account, since businesses are not matched with all the properties they occupy and, moreover, there is no public information on whether the business rates relief has been granted. Restricting the analysis to the observations that are certainly not affected by the SBRR reduces the sample size by more than half but delivers similar results.

After the 2010 revaluation, a transitional relief was introduced in England only, aimed at phasing in sharp changes in the tax bills. The VOA set out the limits on the percentage

[56]To qualify for the small business multiplier, the ratepayer needed to fulfil the following criteria for the 2005 (2010) rating list: the ratepayer must occupy only one business in England or must occupy one property in England and other additional business properties, such that the main property has a rateable value less than £15,000 (£18,000) and £21,500 (£25,500) in London, each additional business property has a rateable value less than £2,200 (£2,600) and the combined value is less than the threshold.

Table 9: Robustness

	$\Delta_{2009,11}Emp$				$(\Delta_{2009,11}Emp - \Delta_{2006,08}Emp)$
	(I)	(II)	(III)	(IV)	(V)
$\Delta_{2009,10}T$	-0.38^{***}			-0.39^{***}	-0.54^{**}
	(0.13)			(0.11)	(0.21)
1st year relieved ΔT		-0.57^{***}			
		(0.18)			
5-year relieved ΔT			-0.10^{***}		
			(0.03)		
Observations	63,242	63,242	63,242	62,700	54,703
R^2	0.01	0.01	0.01	0.01	0.01

Note: Standard errors (in parentheses) are clustered at the postcode area level. *, ** and *** denote significance at the 10%, 5% and 1% level, respectively. Same notes and controls of column *III* of Table 1 apply.

by which the rates bill can increase or decrease every year.[57] The property is considered into the scheme until the true tax liability does not exceed the relieved tax bill. Column II shows the marginal propensity to hire calculated out of the first-year cash flow shock induced by the revaluation, after the transitional relief is considered. The coefficient is clearly larger than in the main analysis, because some firms know that they will face a larger tax shock in the future. In column III, I calculate the 5-year present value of tax shocks. This sums the relieved cumulative tax shocks for the following 5 years, with respect to the pre-revaluation tax liability.[58][59] The coefficient is still slightly larger than one fifth of the average MPH, suggesting that calculating the tax shocks before any relief effectively underestimates the MPH.

Excluding the financial and insurance activities (section K, UKSIC 2007 codes 64110-66300) and the public administration and defence (section O, UKSIC 2007 codes 84110 - 84300) does not affect the estimates, as shown in Column IV. The estimated MPH is unchanged if excluding also the real estate activities (section L, UKSIC 2007 codes 68100

[57] The scheme was originally devised to last 5 years. Limits to the reductions of tax bills were introduced to partly fund the scheme. Different limits apply for small and large properties, classified as such depending on their rateable value and whether they are in London. Year on year increases were limited to 5, 7.5, 10, 15 and 15 per cent for small properties, 12.5, 17.5, 20, 25 and 25 per cent for large properties. Decreases were limited to 20, 30, 35, 55 and 55 per cent for small properties and 4.6, 6.7, 7, 13 and 13 per cent for large properties.

[58] Note that this is meant to be a calculation made upon revaluation impact by a potential business. The ex-post actual sum of tax changes will be different, since business rates multipliers are adjusted every year in line with RPI.

[59] The present value as a share of firm sales has an average of -0.3%, 3.0% of standard deviation and is on average 1.5% conditional on being positive.

- 68320).

Finally, in column V I estimate the pound-for-pound sensitivity of the change in net hiring to a cash flow shock. In order to do so, I net the 2009-11 employment change with the 2006-08 employment change. The estimated coefficient is slightly larger than the benchmark, in line with the fact that there is a mild positive correlation between the revaluation and pre-2008 employment changes.

In unreported findings, I check that the results are robust to the anticipation of future choices along the extensive margin, such as establishment closures or material change of circumstances. 634 establishments in the sample are shut down in 2012: excluding these observations leaves the estimated average MPH unchanged. The MPH is even slightly greater at -0.42^{***} when excluding the establishments relocating in 2012. Finally, the coefficient is unchanged when excluding the material change of circumstances taking place in 2012.

A.3 Multiple establishments

The benchmark analysis pursued in this paper retains, for every firm i, the largest (in absolute value) establishment-level tax shock. This has the advantage of using explicitly the property-level and geographic controls to clean potentially endogenous and anticipated effects of the tax shock on employment. On the other hand, firms with multiple establishments will be likely to face an overall tax change that is different from than the one considered in the analysis. The direction of the bias is unclear ex ante, because it depends on the correlation between the different tax shocks faced by each firm i. In this section I show that, in practice, this issue does not affect the estimation of the MPH.

First, I show that, by restricting the sample to the firms with only one establishment between 2009 and 2011, as done in Column I of Table 10, the vast majority of observations is kept and the average MPH unchanged. In Column II I re-introduce multiple-establishment firms and estimate the MPH out of the overall tax shock at the firm level (i.e.: the sum across all establishments). This specification may introduce some noise since the property-level and geographical controls refer to the property associated with the largest firm-level tax shock. The estimated coefficient is very similar, suggesting that the bias introduced by looking only at the largest tax shock (in absolute value) for each firm does not systematically affect the estimation.

I then try to quantify the direction of the bias related with multiple establishments. At this stage, it is useful to recall that businesses have two ways to overturn a tax change: closing the establishment, or physically changing the property, incurring in a material

Table 10: Multiple-establishment firms

	$\Delta_{2009,11}Emp$		
	(I)	(II)	(III)
$\Delta_{2009,10}T$	-0.40^{***}		-0.41^{***}
	(0.11)		(0.11)
Total firm-level tax change		-0.38^{***}	
		(0.11)	
Single establishments only	✓		
Number of firms	55,121	63,242	63,242
R^2	0.01	0.01	0.01

Note: Same notes and controls of column III of Table 1 apply. Standard errors (in parentheses) are clustered at the postcode area level, except for column IV in which they are clustered at firm level. *, ** and *** denote significance at the 10%, 5% and 1% level, respectively.

change of circumstances. Both options are excluded by the sampling strategy.[60] Reshuffling workers across different establishments should not be caused by a tax shock, since it does not overturn any tax change, unless a physical change takes place. If the estimated MPH is really measuring the employment responses out of cash flow shocks, we would expect firms with multiple establishments, and whose total tax shock partly cancels out at the firm level, to respond less. The analysis performed in Table 1 may also be affected by another source of bias: for some firms in the sample it is not possible to match all the establishments with the associated tax change at the property level. I investigate both issues by augmenting specification (1) as follows. First, I add a dummy M that takes 1 if not all firm i establishments are matched with a tax entry. Second, a dummy O which takes 1 if the overall firm tax shock has a different sign than the largest shock $\Delta_{2009,10}T_{j,m}$. Only 0.1% of the firms in the sample have *overall offsetting shocks*. Finally, I interact both dummies with $\Delta_{2009,10}T_{j,m}$.

As shown in Column III, the average MPH is even slightly greater than the benchmark estimate. All the coefficients associated with the additional variables described above are insignificantly different from 0. Only firms with at least one establishment not matched with the property have, on average, a more positive employment growth. Most importantly, firms with offsetting shocks do not display a systematically different response to the tax change, providing an additional test for the presence of the cash flow channel which I try to quantify.

[60]Closures and material change of circumstances are ruled out until 2012. In Appendix A.2 I show that the coefficient is not affected by employment responses in anticipation of closures or physical changes taking place after 2012.

Table 11: The *averaged* matching

	$\Delta_{2009,11}Emp$	$\Delta_{2009,11}Log(Emp)$
	(I)	(II)
$\Delta_{2009,10}T$	-0.25^{*}	-0.57^{**}
	(0.15)	(0.27)
Number of groups	46,727	46,727
R^2	0.01	0.01

Note: Standard errors (in parentheses) are clustered at the postcode area level. *, ** and *** denote significance at the 10%, 5% and 1% level, respectively. Same notes and controls of column *III* of 1 apply.

A.4 The *averaged* matching

Mapping a industry SIC code into a category type works better the more precise the category type is. For instance, there is a perfect mapping between SIC 92000 and betting shops. In contrast, this matching strategy fails to deliver unique matches in situations in which generic property types like offices and shops are clustered in a very narrowly defined area.[61]

In order to deal with this issue, I create a separate sample of matches that contain the *average* information for groups of multiple local units and properties sharing the same postcode unit and industry / property type mapping.[62] I match 119,917 groups. To be in line with the results shown in section 4, I adopt the same sampling strategy. I adopt a very conservative approach and exclude any group for which: at least one establishment changed enterprise between 2009 and 2011, or reports zero employees, or is part of a central government body or local authority, or at least one property does not satisfy the sampling conditions explained in section 4. We are left with a bit more than a third of the original groups. Table 11 shows that the obtained estimates are smaller and less significant than the ones shown in Table 1, but not very different considered the large amount of noise and measurement error introduced by averaging at the group level. Moreover, in principle this strategy compares different properties occupied by the same firm.

A.5 Spatial differencing with matching

In this section I create pairs of firm-establishment-properties that share establishment, firm, property and geographic characteristics, and estimate their relative employment re-

[61]This may include a number of small shops in a train station, or offices at different floors of the same building.

[62]Details of the matching strategy are available upon request.

Table 12: Spatial differencing with matching

	$\Delta_d \Delta_{2009,11} Emp$			
	(Ia)	(Ib)	(IIa)	(IIb)
$\Delta_d \Delta_{2009,10} T$	-0.29^{**}	-0.28^{**}	-0.47^{***}	-0.47^{***}
	(0.11)	(0.12)	(0.16)	(0.17)
Paired by:				
Postcode area	✓	✓		
Postcode district			✓	✓
Industry sector	✓	✓	✓	✓
Property type	✓	✓	✓	✓
Different valuation schemes		✓		✓
Number of pairs	1,776,039	1,694,232	98,007	80,103
Number of firms	59,970	59,828	45,673	42,530
R^2	0.00	0.00	0.00	0.00

Note: Standard errors (in parentheses) are clustered at the firm level. Industry sector refers to the both firm and establishment sector. *, ** and *** denote significance at the 10%, 5% and 1% level, respectively.

sponse to relative tax shocks. One pair, for example, will consist of two ICT firms, each occupying an office, both located in the postcode district N1.

While being conceptually similar to the benchmark equation estimated in 4, this specification is tighter in that it retains only the firms that can be associated with at least another firm in a pair. Moreover, it allows me to investigate the importance of belonging to different valuation schemes as a source of the variation in tax changes.

For each pair, I compute the difference in any continuous variable between the two observations in the pair. I denote as Δ_d the difference operator. Categorical controls used in the matching strategy (e.g.: industry dummies) will drop from the specification when applying the operatore Δ_d. I then estimate the differenced specification below:

$$\Delta_d \Delta_{2009,11} E_{i,j,k,m} = \alpha + \beta \Delta_d \Delta_{2009,10} T_j + \Delta_d \gamma x_{i,2008} + \Delta_d \theta z_{j,2008} + \Delta_d \varepsilon_{i,j,k,m} \qquad (13)$$

I consider two different levels of matching tightness when creating the pairs. In column Ia of Table 12 I match observations with respect to the firm and establishment industry sector, the property type (i.e.: whether the property is an office, a shop or a warehouse/factory) and the postcode area. 59,970 firms are matched, which means that roughly 5% of the original sample is dropped. The coefficient is still very significant but lower than the one estimated in Table 1. Column Ib uses the same matching strategy but restricts the sample to pairs in which the two paired observations belong to different valuation schemes. The average MPH is unaffected, suggesting that the variation between valuation schemes is an important driver of the estimated MPH.

Column IIa considers a tighter matching strategy at the postcode district level. One pair in this sample, for example, will consist of two ICT firms, each occupying an office, both located in the postcode district N1. The MPH becomes larger while remaining very significant. By looking at narrower geographical areas we are more likely to control for confounding local demand. The direction of the bias suggests that local demand shocks underplay the MPH by affecting the tax change and employment growth in the same direction. Even in this case the results are robust to the exclusion of pairs belonging to the same valuation scheme.

A.6 Spatial differencing with matching: km distance

In this section I follow the same approach as in section A.5, but I create pairs of establishment-properties that are located within a certain distance, rather than sharing the same postcode area or postcode district. This approach has the advantage of comparing observations that are located nearby but across a postcode area border; on the other hand, it skews the geographical distribution of the sample. As shown in the first three columns, the coefficient becomes larger and more significant as the distance narrows down, which is assuring for the identification strategy. Moreover, as shown by column IV of Table 13, the variation is mainly driven by properties belonging to different valuation schemes. As the distance is further reduced to 1km, however, the coefficient becomes statistically insignificant, although is around the same magnitude of the coefficient in the previous column.

As we narrow down the distance between the two sides of a pair, the geographical composition of the sample becomes dramatically skewed towards areas of high business property density. For instance, the share of observations in the postcode districts W1B-W1W (more central part of West London) goes from 4.8% to 11% and to 36% when the distance is 10, 5 and 1 km respectively. Most importantly, the same is not true for the spatial differencing with matching constructed with postcode geographic controls. The share of observations in the same area is 1.5% in the sample in Table 12, 2.7% when we built pairs sharing the same postcode area and 4.3% with postcode district.

A.7 Balance sheet data

The balance sheet data used in section 4.3 and for the calibration of the model is taken from FAME (Financial Analysis Made Easy), a database compiled by the Bureau van Dijk. Brav (2009) provide detailed and extensive explanation of the FAME dataset and

Table 13: Spatial differencing (km) with matching

	$\Delta_d\Delta_{2009,11}Emp$				
Distance	$\leq$ 20km	$\leq$ 10km	$\leq$ 5km	$\leq$ 5km	$\leq$ 1km
	(I)	(II)	(III)	(IV)	(V)
$\Delta_d\Delta_{2009,10}T$	-0.25^{**}	-0.32^{**}	-0.33^{**}	-0.35^{**}	-0.32
	(0.12)	(0.14)	(0.15)	(0.16)	(0.28)
Different valuation schemes				✓	
Number of pairs	3,269,611	1,247,587	491,777	455,208	67,011
Number of firms	58,734	55,729	49,600	48,038	28,591
R^2	0.00	0.00	0.00	0.00	0.00

Note: Standard errors (in parentheses) are clustered at the firm level. In all specifications, pairs are created when sharing property type, firm and establishment sector, besides the geographical distance. *, ** and *** denote significance at the 10%, 5% and 1% level, respectively.

the legal framework for incorporation at the Companies House. In this appendix I will refer only to the features of the data that specifically refer to the analysis pursued in this paper. A sample of around 1.5 million FAME firms was matched to the Business Structure Database by the UK data service, anonymising the company registration numbers issued by the Companies House upon registration of the firm. The matching rate was quite high, at 83%. For around 3% of the cases, one BSD firm is associated with more FAME firms; this will happen whenever a demographic change involves reincorporation at the Companies House, but no change in the enterprise definition within the Business Structure Database. Among duplicates, I retain the observations with the longest history of balance sheet data and the largest value for turnover and total assets in 2008, under the assumption that this should allow to pick the consolidated balance sheet of an enterprise group. I then retain the firms reporting a non-missing value for total assets either in 2007 or 2008. In line with Brav (2009), I exclude the following company types: Guarantee, Limited Liability Partnership, Not Companies Act, Other, Public Investment Trust, and Unlimited. For reliability of the balance sheet entries, I also exclude the firms classified by the BSD as sole proprietorships or partnerships in 2008.

Around half of the BSD-VOA sample is matched with balance sheet information from FAME. The vast majority of unmatched firms are set up as legal entitites that do not have to report financial information at the Companies House. 96% of the firms in the sample are not quoted. Table 14 shows some descriptive statistics for the sample.

Depending on the following inclusion criteria, firms need to disclose financial information at different levels of granularity. As of 2017, companies are classified as small if

Table 14: FAME subsample: descriptive statistics

	Mean	Std. Dev.	Median	Mean (>0)
$\Delta_{2009,10}T$ (% of $Sales_{2008}$)	– 0.02	0.67	-0.04	0.37
$\Delta_{2009,11}Emp$ (% of $Sales_{2008}$)	1.3	14	0	15
$I_{2009-11}$ (% of $Sales_{2008}$)	1.6	18		12
$\Delta_{2009,11}Debt$ (% of $Sales_{2008}$)	2.1	25		15
$\Delta_{2009,11}NetDebt$ (% of $Sales_{2008}$)	0.9	28		17
Emp_{2008}	214	3,187	6	
$Sales_{2008}$ (Th GBP)	34,397	689,200	410	
$TotalAssets_{2008}$ (Th GBP)	44,717	1,593,099	222	

Note: Moments calculated from the sample of 24,646 observations in Table 4. Median values are averages around the median when there are less than 10 observations taking the median value.

they fulfil two of the following criteria for two consecutive years: annual turnover equal to £6.5 million or less, balance sheet total must not exceed £3.26 million and average number of employees must be 50 or lower. Small companies need to submit an abridged balance sheet and no profit and loss account.[63] The vast majority - around 80% - of the firms in the matched sample fit into this bin. Following the Small Company regulations (SI 2008), an abridged balance sheet consists of the items labelled with a letter or a Roman number in the balance sheet format set out in the regulation. This will guide the variables definition in this paper.

With regard to investment, CAPEX is not part of the compulsory reporting for the vast majority of firms. For these reasons, I use information from the asset side of the balance sheets. Firms can choose whether to report Fixed Assets (item B) or its three components (Intangible assets, tangible assets and investments). Missing values for fixed assets imply that no line for this category was reported in the original accounts documents. Given the reporting requirements, I interpret a missing entry for fixed assets as a 0, for non-missing observations of total assets in the same year.[64] In column *I* of Table 15 I show the response to the tax shocks when investment is calculated using only the non-missing information on fixed assets. Not imputing a zero entry clearly reduces the sub-sample but does not affect the coefficient much. Column II defines, instead, investment as the difference in tangible assets plus depreciation.

I define debt as current liabilities plus long-term debt. The use of current liabilities instead of short-term debt in current liabilities is motivated by the fact that the latter is not

[63]Note that the BSD, reporting information on sales for all enterprises, takes care of this shortcoming.

[64]A non-missing observation for total assets implies that a balance sheet had been compiled. Inspecting the original accounts documents, it seems that firms do not report fixed assets in their balance sheet when not owning any, rather than explicitly adding a line in the accounts with £0.

Table 15: FAME robustness

	$\widetilde{I}_{2009-11}$	$I^{tang}_{2009-11}$	$I_{2008-11}$	$\Delta_{2008,11}Debt$	$\Delta_{2008,11}NetDebt$	$I_{2006-08}$	$\Delta_{2009,11}Emp$
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)
$\Delta_{2009,10}T$	-0.26	-0.14	-0.22	-0.42	-0.51	-0.41	-0.37^{**}
	(0.29)	(0.24)	(0.36)	(0.41)	(0.46)	(0.31)	(0.19)
Observations	23,227	22,797	24,686	24,659	24,659	21,246	23,532
R^2	0.02	0.02	0.01	0.01	0.01	0.03	0.02

Note: Standard errors (in parentheses) are clustered at the postcode area level. Controls are the same as in Table 4. *, ** and *** denote significance at the 10%, 5% and 1% level, respectively.

part of the compulsory items in the abridged balance sheet. It should be borne in mind that this might overestimate firms' stock of debt.[65] Net debt is defined as debt minus *Bank deposits*, which is the FAME definition for cash at bank and in hand.

The reporting month for the balance sheet data is not the same for all firms, and range from July to end of year. This may imply that the dependent variables are computed with respect to a reference value that is already affected by the news of a future tax shock.[66] To account for this, I repeat the same analysis as in Table 4, but over the period 2008-11, as shown in columns *III-V*.

In Column VI I run a placebo test which shows that past investment does not respond to future tax changes. In case of reverse causality, we might expect to find a positive coefficient indicating that part of the tax change is due to firms' investment – in their property – before the revaluation. In contrast, the estimated coefficient is negative and insignificantly different from 0.

Finally, FAME data also allow me to control for firms' capital intensity directly, which I define as firm fixed assets as a ratio of firm sales in 2008. First, this controls for possible confounding factors related to real estate intensity, on top of the industry dummies included in the main regressions. Second, it implicitly and partly controls for the ownership status, since renters will typically have a lower stock of fixed assets. This analysis is further expanded in section A.8. As shown in column VII, the MPH coefficient is not affected.

[65] Current liabilities are typically made of Bank Loans and overdrafts, trade creditors and other creditors. The latter term includes debt in corporation tax, dividends, social securities and VAT, besides accruals and deferred income.

[66] Draft revaluations were published on 30 September 2009. Firms reporting their 2009 balance sheet for the period 1 January - 31 December may already account for the revaluation in the 2009 values.

Table 16: Renters and owners

	$\Delta_{2009,11}Emp$		
	(I)	(II)	(III)
$\Delta_{2009,10}T$ x renters	-0.41^{*}	-0.41^{***}	-0.46^{**}
	(0.22)	(0.19)	(0.20)
$\Delta_{2009,10}T$ x owners	-0.40	-0.36	0.03
	(0.25)	(0.42)	(0.48)
Renters	-0.005^{**}	-0.009^{***}	-0.008^{***}
	(0.002)	(0.002)	(0.002)
Observations	24,646	24,646	24,646
R^2	0.02	0.02	0.02

Note: Standard errors (in parentheses) are clustered at the postcode area level. Controls are the same as in Table 4. *, ** and *** denote significance at the 10%, 5% and 1% level, respectively.

A.8 Renters and owners

Although the business rates are paid by the occupiers of the property, it may be argued that, at least in the long-run, some of the tax incidence will be borne by property owners.[67] In addition, there are other possible reasons for which renters and owners may respond differently to the revaluation. First, if the value of the property correlates with the estimated rateable value, this could impact the owners through the collateral channel presented by Chaney et al. (2012) among others. Second, given the correlation between estimated rateable values and the self-reported business rents used when creating the valuation schemes, renters may be better able to anticipate the revaluation; note, however, that any deviation from their expectations will be likely to cause sharper responses, exactly in form of unexpected changes. Finally, renters may be more sensitive to the shock if this also comes together with a change in the rent they pay, thus resulting in a underestimation of the effective cash flow shock at the firm.

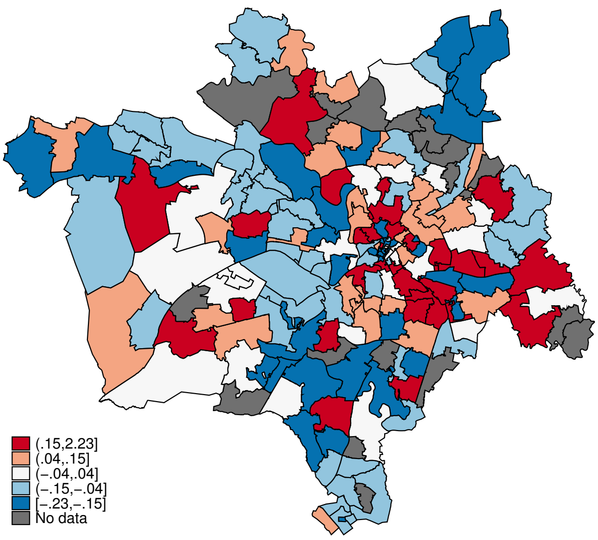
In order to investigate whether there are systematic differences between renters and owners in terms of MPH, I follow Chaney et al. (2012) and group firms according to the fixed assets they own. Balance sheet reporting requirements, as explained previously, make this analysis drastically more difficult than with Compustat data using by Chaney and co-authors. I consider two definitions of renters. In the first column of Table 16, I classify as renters those properties whose fixed assets in both 2007 and 2008 were less than £6,000. This cutoff is chosen so that around a fourth of observations are defined as renters. A uniform cutoff, besides arbitrary, is also probably not a good indicator of the

[67] For an analysis on this issue see Bond et al. (1996) and a 2015 report by Regeneris consulting.

ownership status of a property. Another alternative is to look at the price to rent ratio, or, conversely, at the rental yields. Bracke (2015) finds an average ratio of 19 for a matched dataset of residential properties in central London. The CBRE UK all sector average prime yields averaged around 5% in 2007, thus implying a ratio of price to annual rent of around 20. In column *II* and *III* I experiment with two cutoffs: a price-rent ratio of 15 and 5 respectively, where the ratio is computed by dividing firm fixed assets by the rateable value.[68] The implied share of renters is 42% and 61% respectively.

B Additional maps

Figure 14: Business rates revaluation: Most frequent growth rate in tax liability for large offices in Manchester



Notes: Maps plot postcode sectors (e.g.: M1 1). Sample of offices in postcode area M, whose size is above the 75th of offices distribution (i.e.: 178 m^2). Properties undergoing material change of circumstances before 2012 are excluded, as well as properties without a valuation scheme and whose 2005 rating list has been altered after 2010. For each property, I compute the percentage growth rate in the tax liability due to the revaluation, rounded at the integer. The map shows the mode of this quantity at the postcode sector.

C Derivation of the financial friction

This section derives the enforcement constraint shown in equation 4. As mentioned in section 5.1, exiting firms are forbidden to borrow, so I will focus on firms that have already learnt they will survive to the next period. The decision to default arises after the realization of revenues, but before repaying the intra-period loan. At this stage, the firm has total liabilities $l_t + b_{t+1}$. The firm also holds liquidity given by its revenues minus

[68] A cutoff of 5 is aimed at including potentially high-yielding properties, like industrials or London-based. This, however, implies a yield of 20%, hence a very conservative approach.

all the payments that were not financed through the intra-period loan. Hence, we can see from the budget constraint that firm liquidity is equal to the intra-period loan l_t. Since the liquidity can be easily diverted, the only asset available for liquidation by the lender is physical capital k_{t+1}.

Let us assume that there are two different creditors, and that the inter-period creditor is senior to the intra-period creditor. If the firm defaults, the lender acquires the right to liquidate the firm's capital. The recovery value of firm's capital, however, could be k_{t+1} or 0. At the moment of contracting the loan, neither the lender nor the firm know the recovery value. With probability ϕ, the collateral has full value by the end of the period. With probability $1-\phi$, it has no value at the end of the period, but full value at the beginning of the following period. Whether collateral has value at the end of period t is only discovered if liquidation is triggered at that point. If the intra-period creditor triggers liquidation and k_{t+1} has no value in period t, then she gets nothing. The collateral will have again full value at the beginning of the next period, and $k_{t+1} \geq b_{t+1}$ ensures that the inter-period creditor gets the loan back. If k_{t+1} has instead full value, the interperiod creditor is senior and gets b_{t+1}, so the intra-period creditor gets $k_{t+1} - b_{t+1}$.

In order to derive the renegotiation outcome, I follow Jermann and Quadrini (2012) and assume that the firm has all the bargaining power in the renegotiation and the lender gets only the threat value. A defaulting firm can offer $\phi\,(k_{t+1} - b_{t+1})$ to the intra-period lender in order to dissuade her from triggering liquidation. In this case both lenders are indifferent between liquidating the firm or not.

From the borrower perspective, enforcement requires that the value of not defaulting is not smaller than the expected value of defaulting:

$$\frac{1}{1+r}\sum_{i=1}^{N_z}\pi^z_{ji}V_0(k_{t+1},b_{t+1},z_{i,t+1}) \geq l_t + \frac{1}{1+r}\sum_{i=1}^{N_z}\pi^z_{ji}V_0(k_{t+1},b_{t+1},z_{i,t+1}) - \phi(k_{t+1}-b_{t+1}) \tag{14}$$

from which we derive: $l_t \leq \phi(k_{t+1} - b_{t+1})$.

D Numerical method and calibration

The model is solved with value function iteration. The AR(1) process for the log of idiosyncratic productivity is discretized using Tauchen and Hussey (1991) method over 7 grid points. Following Khan and Thomas (2013) , I specify the value function over $V(k, \frac{b}{k}, z)$; using $\frac{b}{k}$ allows me to restrict the knot points to the feasible set. For capital, I use a convex grid of 60 points; the convexity enables me to define the capital endowment of entrants precisely. The quantitative results are unchanged if using 80 grid points. I use also 60 points for the net leverage ratio. The majority of firms in the simulations borrow or have a mildly negative net leverage ratio; hence, I define the grid as being concave when b is negative, and linear otherwise. This also accounts for the potential kink introduced around zero leverage by the tax on interest rate.

The marginal propensity to hire is computed as explained in section 5.2. In order to identify whether a firm has $\mu_t > 0$ and $\xi_t > 0$, I proceed as follows. For the first Lagrange multiplier, I compute the slackness of the collateral constraint; labor decisions is defined in the numerical solution such that there is exactly no slack if the constraint is binding. To assess whether the non-negativity of dividends binds, I use the envelope condition and define $\xi_t = \frac{V_k(k_t, \frac{b_t}{k_t}, z_{j,t})}{\nu z_{j,t} k_t^{\nu-1}(n^*)^{\alpha} + 1 - \delta_k - R(b_t)\frac{b_t}{k_t}}$, where n^* is the optimal choice of labour, and $V_k(k_t, \frac{b_t}{k_t}, z_{j,t})$ is the derivative of the value function with respect to capital, calculated numerically using the numerical solution of the model.

At the calibration stage, the following moments are computed using the invariant distribution $\lambda^*(S)$ obtained using (13). Given the assumption that exiting firms do not produce, the labour share is equal to $\frac{\int_S n^*(k,b,z)\lambda(d[k \text{ X } b \text{ X } z_j])}{\int_S y^*(k,b,z)\lambda(d[k \text{ X } b \text{ X } z_j])}$.

Following Khan and Thomas (2013) , aggregate investment is computed as $\int_S [(1-\pi^e)(k^*(k,b,z) - (1-\delta_k)) + \pi^e(k_0 - (1-\delta_k)k)]\, \lambda^*(d[k \text{ x } b \text{ x } z])$.

The average MPH is computed restricting the stationary distribution to non-exiting firms only.

The remaining empirical moments are computed as follows. I consider the BSD-VOA-FAME sample used in Table 4. The net leverage ratio is computed as the ratio between the firm-level average net debt in 2007 and 2008 and the firm-level average total assets between 2007 and 2008. Using one of the two years only gives very similar results. The net leverage ratios are winsorized between -1 and 1. The log of TFP is estimated for each firm i as follows: $log\,(TFP_{i,t}) = log\,(Sales_{i,t}) - \alpha log\,(Employees_{i,t}) - \nu log\,(FixedAssets_{i,t-1})$ where α and ν are the calibrated values in the model. Fixed assets are chosen to be one period in advance to be in line with the model, since in the data they are recorded at the end of the year. This implies that the TFP growth can be computed only between 2007 and 2008 and between 2008 and 2009, since balance sheet data start in 2006. Using contemporaneous fixed assets changes the autocorrelation marginally, to -0.21.

The standard deviation of employment and sales growth rates are computed with the larger BSD-VOA sample, used to estimate the MPH in Table 1. The reported moments refer to growth rates between 2005 and 2006, for a set of firms that remain alive throughout 2012. Using the FAME-BSD-VOA sample delivers very similar values for the reported moments.

In the model, I draw a sample of 200,000 firms from the invariant distribution, and simulate it for 50 periods, discarding the first 40 periods. I retain the firms that are alive for all the last 10 periods, to be in line with the data sample from which the targeted moments will be calculated. Two biases may arise: aging and selection. Both the model and the data suffer from the aging bias: as we go on over time in the sample, surviving firms are older and thus the moments will be affected.[69] To overcome this issue, I compute the cross-sectional moments in the first year of the sample. Selection bias, defined as the surviving firms being ex ante - in the first year of the sample - different from the whole sample may exist in the data, while it is not present in the model given the random nature of exit.

The share of net savers is defined as the fraction of firms in the restricted simulated panel that have negative end-of-period net debt (i.e.: $b_{t+1} < 0$).[70] In the same way, net leverage ratios used to compute the moments are end-of-period. They are defined as net debt b over total assets, which is given by k plus financial savings $|b < 0|$. Growth rates are also computed using the sample of surviving firms. This introduces a slight aging bias, since they must be calculated for firms of at least 2 years of age. Similarly, autocorrelations introduce a minimum age of 4 years.

To be in line with the empirical counterpart, Figures 4a and 4b consider last period size and net leverage ratios. Consider the simulated panel of surviving firms used to compute the moments in Table 7. Figure 4a shows the correlation between the MPH in the second year of the panel and labour n chosen in the first year. Net leverage ratios in figure 4a are the beginning-of-period 2 values - hence chosen in period 1. Looking at the second year of the panel introduces a slight aging bias, since firms are restricted to be at least 2 years of age. Nevertheless, the average MPH is only mildly affected (0.378). Moreover, this strategy has the advantage that the correlations are not affected by the normalization on the pre-determined debt for new entrants.

E Equity issuance and balance sheet propensities

This section extends the model to allow for equity issuance, although subject to a cost. First, I show that, for large enough costs, the properties of the MPH are preserved. Second, this corroborates the reliability of the analytical MPH used in the main analysis.[71] Third, this allows me to estimate the model counterpart of investment and debt propensities to cash flow estimated in the data.

[69] Note, however, that standard deviation of growth rates remains fairly constant over time in the data sample.

[70] Note that this share is slightly different if calculated using the beginning-of-period stock of debt and the invariant distribution, given the normalization $b_t = 0$ for entrants.

[71] The accuracy of the analytical MPH has been also checked by comparing it with the numerical counterpart evaluated out of changes to b. At stationary distribution, the resulting average MPH is 0.39 as found for the analytical counterpart.

I proceed as follows. I solve the model for 10 levels of a lump-sum tax τ, equal to 10% of each decile of the output stationary distribution for a model with $\tau = 0$. Then I simulate a panel of 200,000 firms, drawn from the invariant distribution at $\tau = 0$. After 50 years, I hit each firm with an unexpected change in τ; the size of the shock is firm-specific and is chosen to be 10% of their sales 2 years before.[72] The shock is assumed to be permanent. For each firm, I define a treatment path, which feeds in the tax shock, and a control path, which keeps $\tau = 0$. This allows me to define firm-level responses for a given path of idiosyncratic productivity z. Propensities are calculated at the firm-level as the difference between the treatment and the control variable, divided by the size of the shock.

I consider two equity issuance cost functions. The benchmark follows Bond and Söderbom (2013), defining the cost as convex and such that the marginal cost is increasing in issued equity relative to the firm's stock of capital:

$$\Xi(d_t) = 1(d_t < 0)\left(\frac{\vartheta}{2}\right)\left(\frac{d_t}{k_t}\right)^2 k_t \tag{15}$$

In the last column of Table 17 I also explore the possibility of a linear cost, as in Michaels et al. (2016): $\Xi(d_t) = \eta |d_t| 1(d_t < 0)$.

I follow the corporate finance literature and re-write the recursive problem so that firms maximise the present discounted expected value of after-fee dividends:

$$V(k_t, b_t, z_{j,t}) = \max_{d_t, k_{t+1}, b_{t+1}, n_t} \left\{ d_t - \Xi(d_t) + \frac{1}{1+r} \sum_{i=1}^{N_z} \pi^z_{ji} V_0(k_{t+1}, b_{t+1}, z_{i,t+1}) \right\}$$

subject to constraints 5-8. Table 17 shows the average propensities with different equity issuance costs.[73] In the first column, I consider a very large cost to mimic an economy that approaches the case explored in the main text in which equity issuance is forbidden. The parameters for the following two columns are taken from Bond and Söderbom (2013), and Michaels et al. (2016)) for the last. MPI denotes the average change in capital following a cash flow shock, while MPB in debt.

First, we notice that the average MPH is lower than when equity issuance is forbidden. This is mainly due to the extensive margin: even in presence of large and convex equity issuance costs, many firms have been able to save themselves out of the constraint by pursuing small equity issuances in the past, and using them to finance capital investment.

[72] This approach makes the analysis more similar to the data, compared to a uniform lump-sum shock for all firms. Firms keep treating the shock as lump-sum, although its size effectively depends on past sales.

[73] Average of the firm-level responses on the first year of the tax shock. Sample of firms that did not exit between 2 years before the shock - that defines the scaling sales - and the year of the shock.

Table 17: Propensities with equity issuance

	$\vartheta = 50$	$\vartheta = 4$	$\vartheta = 1$	$\eta = 0.05$
MPH	0.31	0.19	0.10	0.02
MPI	1.47	0.80	0.34	0.34
MPB	0.76	0.38	0.20	0.29
Equity issuers	65%	72%	72%	45%
Median equity payout	1.9%	8.6%	11%	25%
Positive MPH	64%	40%	19%	12%
Corr(MPH,size)	-0.28	-0.06	0.04	0.04
Corr(MPH,leverage)	0.62	0.38	0.18	0.02

Notes: Equity payout is defined as a fraction of output. Leverage is the beginning-of-period net leverage ratio, computed as explained in the main text.

The possibility to issue equity, however, also lowers the firm-level MPHs. Indeed, the new firm-level MPH is lower than the analytical counterpart without equity issuance the more (negative) dividends absorb the cash flow shock.

The share of firms issuing equity is quite large, but most of them issue a very small amount of equity. This is apparent with a convex issuance cost that disincentivize large issuances. The large share of equity issuers is also related to the fact that there is no tax incentive on debt, but only a disincentive on savings.[74]

Even with large equity issuance costs, the correlations between MPH and size and net leverage ratios are milder than in the benchmark model. Even when the equity cost is a function of the payout ratio, small firms may be so disrupted that they prefer to issue more equity and lower their employment response. The same reasoning applies to leveraged firms; first, they are constrained in inter-temporal borrowing so equity issuance may be their only option. Second, they may issue equity to finance capital investment and, in the following periods, be in a better position to both pay the tax - through larger wealth - and borrow more - through additional collateral.

Finally, we can use the specification with $\vartheta = 4$ to investigate further the firm-level responses of capital and debt. Productive and constrained firms typically cut capital following a negative cash flow shock; by keeping the debt to capital ratio constant, they also decrease their stock of debt. Less productive firms, especially when small, may have enough room to increase their leverage ratio further. Since the shock is permanent, they may have the incentive to hang on for the first period and finance - either through equity issuance, or inter-temporal debt - capital expenditures, which in the following periods

[74] A tax benefit on debt of the same size as the tax on savings lowers the share of equity issuers to 67% when $\vartheta = 4$, while leaving unaffected the median equity payout and the MPH and increasing the MPB.

expands their wealth and ability to pay the tax. For this reason, 11% of firms display a negative MPI when $\vartheta = 4$, and this share increases to 12% when $\vartheta = 1$.

F Sensitivity of aggregate employment to ϕ

With a slight abuse of notation, I sort the firms in the economy by their constraint status and define $\underline{c}$ as the cutoff below which all firms are constrained. Considering a measure 1 of firms, aggregate employment is:

$$N = \int_0^{\underline{c}} n_i^c di + \int_{\underline{c}}^1 n_i^u di \tag{16}$$

Then by the means of the Leibniz rule we get:

$$\frac{\partial N}{\partial \phi} = \int_0^{\underline{c}} \frac{\partial n_i^c}{\partial \phi} di + \int_{\underline{c}}^1 \frac{\partial n_i^u}{\partial \phi} di + \frac{\partial \underline{c}}{\partial \phi} \left[n^c(\underline{c}) - n^u(\underline{c}) \right] \tag{17}$$

The economy can be classified in three groups: already constrained firms with a positive MPH, firms becoming constrained due to the change in ϕ and unconstrained firms with a zero MPH. For the last group, the derivative of employment with respect to ϕ is 0. For the first group, we can exploit the binding financial constraints. I differentiate the combined non-negativity of dividends and collateral constraint, when both binding, to get: $MPL\frac{\partial n}{\partial \phi} - \frac{\partial n}{\partial \phi} - \frac{\partial n}{\partial \phi}\frac{1}{\phi} + \frac{n}{\phi^2} = 0$. This implies:

$$\frac{\partial n_i}{\partial \phi} = \frac{n_i}{\phi^2} MPH_i \tag{18}$$

In order to present more clearly the link between MPH moments and the response of aggregate employment to a credit tightening, let me now abstract from the effect of changes in ϕ on the share of constrained firms. By doing so, the response of aggregate employment is approximately given by:

$$\frac{\partial N}{\partial \phi} \approx \int \frac{n_i}{\phi^2} MPH_i di \tag{19}$$

This object can be decomposed as follows, in the spirit of the Olley and Pakes (1996) decomposition:

$$\int \frac{n_i}{\phi^2} MPH_i di = \frac{1}{\phi^2} \left[E(MPH)E(n) + \int (n_i - E(n))(MPH_i - E(MPH))\, di \right] \tag{20}$$

which can be rewritten as equation 12.

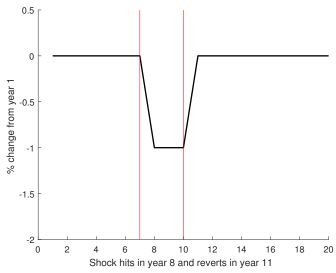
G Aggregate TFP shocks and the MPH

This section works along the lines of 7.2 but for an aggregate TFP shock. Figure 15 shows the response of aggregate capital, net debt, labour, output and endogenous TFP to an unanticipated 1% drop in aggregate exogenous TFP, lasting 3 years. Aggregate exogenous TFP is defined as A in the new firm-level production function $y_t = Az_{j,t}k_t^{\nu}n_t^{\alpha}$; in steady state, A is 1. Solid lines refer to the economies with the financial frictions, while dashed lines to the economies' counterparts without. When there are no financial frictions, the average MPH is 0.

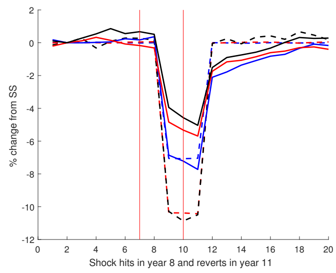
In the blue economy, the average MPH is 0.07, in the red economy is 0.23 while the black economy depicts the benchmark case with MPH equal to 0.39.

Introducing exogenous exit to an otherwise frictionless economy implies a much stronger response of aggregate capital, labour and output. Financial frictions, however, dampen all responses, and more so the higher the average MPH of the economy. Moreover, the gap opens up as the crisis goes by. At trough, labour has fallen by 15% less in the low-MPH economy than its frictionless counterpart, while the dampening is 10 times larger, at 146%, for the high-MPH economy. Finally, the propagation of the shock, measured in terms of years required for output to recover to the pre-crisis episode, is shorter the larger the MPH of the economy.

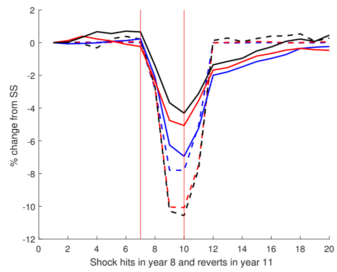
Figure 15: Aggregate responses to a TFP shock: different MPH



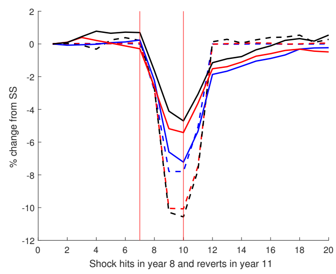
(a) Aggregate exogenous TFP



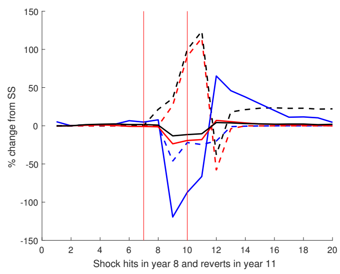
(b) Aggregate Capital



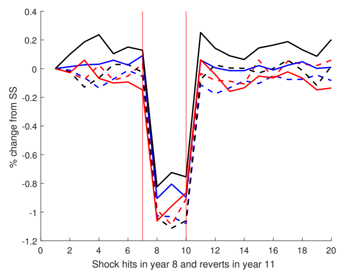
(c) Aggregate Employment



(d) Aggregate Output



(e) Aggregate Net debt



(f) Aggregate endogenous TFP

Notes: Aggregate capital and net debt are computed using the beginning-of-period k_t and b_t respectively. Endogenous TFP is the Solow Residual obtained from $log(Y_t) - \alpha log(N_t) - \nu log(K_t)$. All variables are plotted in % deviation from year 1. The model is solved twice for two different values of exogenous TFP. Then the economy is simulated for 100 years over a panel of 200,000 firms. The initial conditions are drawn from the invariant distribution at the steady state level of exogenous TFP. This stays constant for 50 years, drops to the lower value for 3 years and then reverts back.