The Residential Collateral Channel

Saleem Bahaj Angus Foulis Gabor Pinter*

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Abstract

We present evidence on a new macroeconomic channel which we call the *Residential Collateral* Channel. Through this channel, an increase in real estate prices expands firm activity by enabling company directors to utilise their residential property as a source of funds for their business. This channel is a key determinant of investment and job creation, with a £1 increase in the combined residential collateral of a firm's directors estimated to increase the firm's investment by £0.02 and total wage costs by £0.03. To show this, we use a unique combination of UK datasets including firm-level accounting data matched with transaction-level house price data and loan-level residential mortgage data. The aggregate value of residential collateral held by company directors (around 70% of GDP) suggests that this channel has important macroeconomic effects. We complement this with further evidence on the *Corporate Collateral* Channel whereby an increase in real estate prices directly expands firm activity by enabling businesses to borrow more against their corporate real estate. An estimated general equilibrium model with collateral constrained firms is used to quantify the aggregate effects of both channels.

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Bahaj: saleem.bahaj@bankofengland.co.uk; BoE and CfM. Foulis: angus.foulis@bankofengland.co.uk; BoE and CfM. Pinter: gabor.pinter@bankofengland.co.uk, BoE and CfM. This paper contains the views of the authors and not necessarily those of the Bank of England, the MPC, the FPC or the PRC.

1 Introduction

Economic mechanisms that generate a causal link between residential property prices and the macroeconomy have been a focus of attention in the recent literature. Most of the analysis has centered on the behaviour of credit constrained households, who use real estate wealth to finance consumption. The literature has documented the quantitative importance of this channel using detailed microeconometric methods (Mian and Sufi, 2011) and structural macroeconomic models (Iacoviello, 2005).

In this paper, we argue that this picture is incomplete. The residential wealth owned by households is an important source of collateral to alleviate financing frictions faced by the corporate sector. Small and medium sized enterprises, who are responsible for and contribute to a meaningful share of economic activity and business cycle fluctuations, pledge the homes of their owners to finance their activity. The macroeconomic implications of this channel – which we refer to as the *Residential Collateral Channel* – have been hitherto untested.

Our contribution to the literature is to estimate the quantitative relevance of this mechanism. We do this by using a feature of firm-level data in the UK: the persons responsible for running a firm – known as *directors* – must declare their residential address to the public registrar. By matching this information to transaction level data on residential properties and administrative data on mortgages, we are able to obtain a time series of the value of each director's home and the equity contained within it. By taking these values to firm-level accounting data, we can show that for every £1 increase in the value of the residential property of a firm's directors the firm invests £0.02 more. The coefficient on home equity is the same.

The Residential Collateral Channel lies alongside but is separate to the widely studied *Corporate* Collateral Channel, whereby an increase in the value of commercial properties can enable increased corporate borrowing to fund investment and wages (e.g. Kiyotaki and Moore (1997), Chaney, Sraer, and Thesmar (2012), Liu, Wang, and Zha (2013)). However, we estimate that the value of residential real estate held by company directors (£1,100 Billion) is around 4 times larger than the value of commercial property held by owner-occupying firms (£280 Billion). Failure to account for the Residential Collateral Channel may therefore underestimate the macroeconomic relationships between real estate prices, credit and business cycle fluctuations.

To estimate the strength of the Residential Collateral Channel we rely on three sources of microdata. First, the central plank of our analysis is a firm-level dataset for the UK over the period 2002-2015. As a result of a comprehensive data collection process, we use archival data which provides extensive data coverage compared to the existing literature. The raw source of this data is the FAME database – the UK equivalent to ORBIS-AMADEUS –with snapshots of this database taken at 21 points in time. This database has two main advantages over administrative sources: first, comprehensive balance sheet information are available and second, most relevant to our study, information on who runs the firm – the directors – is available including their full residential addresses and dates of birth. Our second data source is the UK Land Registry database that covers the universe of residential real estate transactions since 1995. Via a textual algorithm, we are able to match directors' addresses to the relevant transactions allowing us to value the home of every matched firm director when he or she bought or sold it. The Land Registry also provides region specific repeat sales house price indices that we use to value directors' homes over time. Third, we make use of the administrative Product Sales Database (PSD) which contains detailed information on the universe of regulated mortgage contracts in the UK. We are able to match directors with mortgages to calculate the principal outstanding on their mortgage loans and hence we can calculate a time series of their home equity.

Our estimates rely on two primary sources of variation. First, directors live in homes of differing initial values (and loan-to-value). This implies that a given change in real estate prices translates into differential changes in borrowing capacity measured in £ terms. Second, around 45% of directors live in a region different from the location of their firm. This generates regional heterogeneity in the real estate price dynamics that an individual director faces depending on where they are located. Our key result is that fluctuations in this measure of total value of directors' real estate strongly correlates with firm activity. A £1 increase in this measure leads the average firm in our sample to invest £0.02 more but it also encourages the firm to spend an additional £0.03 on wages and a £400,000 increase leads the average firm to hire an additional worker. These effects appear stable across periods of real estate price increases and decreases and also are consistent across subsamples for the pre- and post- crisis period. However, intuitively, one group of firms who are insensitive to fluctuations in our Residential Collateral measure are the very largest firms in our sample.

These estimates may be confounded by four different sources of endogeneity. First, directors' property purchase is an endogenous choice that may be related to firm performance (e.g. the director buys a larger house because the firm is doing well). We address this concern by relying on the history of who has run the firms and where they have lived: we hold the properties and composition of directors constant at the start of sample and rely solely on changes in real estate prices to compute our collateral measure. The obtained results are virtually the same as our baseline. In fact, we are able to obtain our results assuming that directors have not changed or moved house in the past ten years.

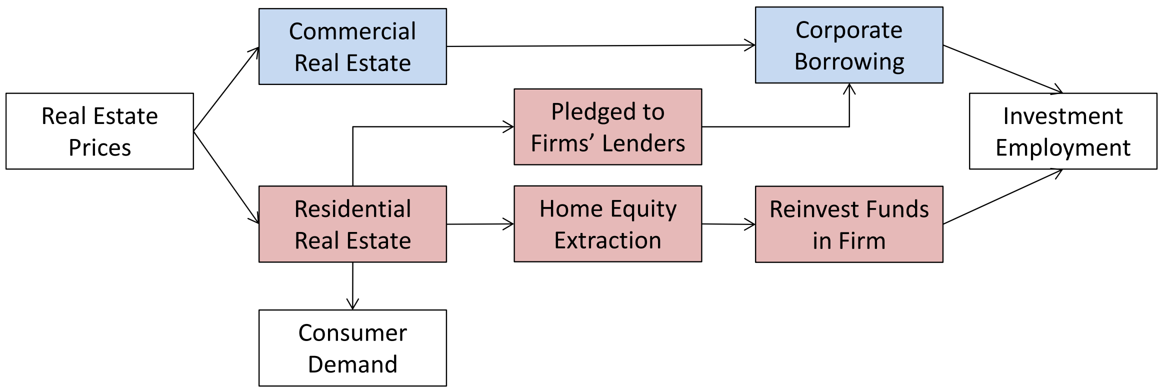
A second concern is that real estate prices may not operate through collateral constraints but our regressions are simply detecting how local economic conditions – correlated with real estate prices – are affecting our firms. Our regressions include region-time fixed effects that control for such linear effects of the local economy. However, if there are factors that cause heterogeneity across firms in their sensitivity to local economic conditions, and those factors are correlated with the types of properties that directors own, then this may confound our results. Therefore, we go further in showing (i) that firms operating in the manufacturing sector – that produce tradeable goods and hence are less sensitive to the local economy (Mian and Sufi, 2014) – are equally sensitive to our Residential Collateral measure, and (ii) that the results are similar even if we focus only on directors that live in a different region from their firms, so that house values are unaffected by local factors. A third linked concern is that firms are able to affect local real estate prices through their own activity. However, this latter test also reveals that this is not driving our results. Also, our sample is dominated by small and medium sized companies so this concern is likely to be less relevant to our analysis.

A fourth concern is that unobserved director heterogeneity may confound our estimates. When we hold the composition of directors fixed any time invariant director heterogeneity that may be correlated with where directors chose to locate themselves will be absorbed by a firm fixed effect. However, there is still the risk of a confounding factor if director-level heterogeneity leads to different sensitivities to real estate price fluctuations at the firm level. For example, if older directors conduct their business differently in response to changes in real estate prices as well as owning a systematically different type of housing, this could distort our results. Alternatively, highly skilled directors may own bigger homes and may also be better placed to take advantage of opportunities offered by expansions. We address this concern by saturating our model with a large number of director characteristics (age, gender, experience etc.) and interact them with real estate prices. Crucially, we can obtain a direct proxy for director skill by assessing the performance of *other* companies that the director is part of. This provides a more limited sample but we can exploit heterogeneity in the composition of directors across firms to get a sense of their quality.

An alternative mechanism to explain our results is that directors rebalance their portfolios towards investing in their firm following an increase in their real estate wealth. This could occur in the absence of collateral constraints. However, we have several reasons to justify our interpretation that the mechanism is due to collateral. First, as we will discuss in Section 3, there is substantial evidence, both anecdotally and in the corporate finance literature, that the personal wealth of directors is frequently pledged to support their firm's borrowing. Second, recent studies based on natural experiments have been able to isolate collateral effects from wealth effects and have demonstrated the importance of the former (DeFusco, 2017). Third, the literature assessing the strength and direction of such wealth effects is inconclusive (Brunnermeier and Nagel, 2008; Briggs, Cesarini, Lindqvist, and Östling, 2015; Chetty, Sandor, and Szeidl, 2017). Fourth, and most importantly, wealth effects imply that there should be different coefficients on the total value of directors' homes versus the total equity in their homes (Chetty, Sandor, and Szeidl, 2017). A collateral channel implies that the coefficients should be identical, and this is what we see in our empirical analysis.

In addition to our baseline estimates, we can also observe how changes in the value of directors' residential collateral influence the financing of their company. This can be through insider financing via director loans and equity issuance paid for by the directors extracting equity from their homes. Alternatively, directors can pledge their homes – in form of a personal guarantee – to secure corporate credit for their firm. A recent unpublished Bank of England survey of major lenders highlights the importance of both sources of collateral for firm activity, finding that 73% of lending to SMEs and mid-size corporates is secured on property with 29% of lending secured with a personal guarantee, typically with an explicit or implicit claim against their residential property. Whilst personal guarantees are more prevalent for smaller firms (33%), 25% of larger firms also use personal guarantees when borrowing, suggesting that the use of residential collateral is not confined to small firms.

Figure 1: Real Estate Collateral Channels



Our dataset and empirical strategy also allow us to estimate the Corporate Collateral Channel, using the observed level of real estate on the firm's own balance sheet, and run a horse race between the two channels. We find that a £1 increase in corporate collateral values leads firms to increase investment by around £0.08.[1] This is of comparable magnitude to the US evidence based on public firms (Chaney, Sraer, and Thesmar, 2012). The wage bill increases by £0.06.

At the individual firm level the Corporate Collateral Channel appears two-four times as strong as the Residential Collateral Channel. However, we estimate that the total value of residential real estate held by firm directors is around 4 times greater than the total value of owner-occupied corporate real estate. The macroeconomic consequence of a 1% change in real estate prices should therefore be similar. To show this we do a back-of-the-envelope calculation based on our microeconometric estimates that suggests that a 1% rise in real estate prices leads to a 0.11% rise in investment and 0.04% rise in total wage costs through the residential collateral channel, and a respective 0.11% and 0.02% rise for the corporate collateral channel.

Of course, such estimates omit general equilibrium feedback effects, thus to explore the macroeconomic implications of our channels we build a general equilibrium model featuring credit constrained entrepreneurs that extends Liu, Wang, and Zha (2013), and estimate the model with Bayesian methods using aggregate UK time series. We find that in response to a 1% land price shock, on impact, the combined effect of both channels leads to a rise of up to 1% on investment and 0.3% on total wages.

To sum up, the contribution of our paper can be illustrated by Figure 1. The literature so far mainly focused on consumer demand channels (bottom box) and the Corporate Collateral Channel (in blue). Our analysis makes important steps towards completing this picture by quantifying the Residential Collateral Channel (in red), thereby providing a fuller characterisation of the links

[1]Estimating this channel poses a new set of identification issues, which we address in a manner similar to Chaney, Sraer, and Thesmar (2012).

between house prices, credit markets and the real economy.

Related Literature This paper relates to at least two main strands of literature. On the one hand, seminal papers such as Kiyotaki and Moore (1997) and Bernanke, Gertler, and Gilchrist (1999) emphasise the role of financing constraints on firms in amplifying and propagating shocks to business investment and output. The recent contribution of Liu, Wang, and Zha (2013) shows that the amplification can be even larger in response to disturbances to the housing market. The microeconometric evidence provided by Gan (2007), Chaney, Sraer, and Thesmar (2012), Kleiner (2013), Cvijanovic (2014) and Chaney, Huang, Sraer, and Thesmar (2015) amongst confirms that movements in real estate prices have a significant effect on firms' capital structure and activity via the corporate collateral channel.

On the other hand, a number of theoretical papers such as Iacoviello (2005), Calza, Monacelli, and Stracca (2013), Eggertsson and Krugman (2012), Justiniano, Primiceri, and Tambalotti (2015), Midrigan and Philippon (2016), Favilukis, Ludvigson, and Nieuwerburgh (2017), Guerrieri and Lorenzoni (2017) emphasise the role of collateral constraints on households as an important mechanism for amplifying and propagating shocks. Many recent papers provided empirical evidence on the various aspects of the links between house prices, houshold consumption and borrowing behaviour – an incomplete list includes Hurst and Stafford (2004), Case, Quigley, and Shiller (2005), Campbell and Cocco (2007), Mian and Sufi (2011, 2014), Carroll, Otsuka, and Slacalek (2011), Calomiris, Longhofer, and Miles (2013), Cooper (2013), Stroebel and Vavra (2015), Cloyne, Ferreira, and Surico (2016), Jorda, Schularick, and Taylor (2016), Bhutta and Keys (2016), Agarwal and Qian (2017), DeFusco (2017) amongst others. Whilst these papers focus on consumption and related aggregate demand effects, other papers such as Hurst and Lusardi (2004), Robb and Robinson (2014), Adelino, Schoar, and Severino (2015), Corradin and Popov (2015) and Schmalz, Sraer, and Thesmar (2017) have explored the links between the household collateral channel and the creation of new companies. In contrast to this set of recent papers, we examine the role of household collateral in the financing of *existing* firms.

Our work touches on both literatures and thereby aims to provide a unified empirical framework to quantify the relative importance of both corporate collateral and the residential collateral of company directors for firm activity.

Structure of the Paper The remainder of the paper is structured as follows: Section 2 presents the construction of the data and summary statistics. Section 3 provides some background on the link between residential real estate of firm directors and corporate borrowing, Section 4 explains our methodology and regression design, Section 5 presents the main results and robustness checks, Section 6 presents a theoretical model which embeds both the corporate and residential collateral channels, Section 7 concludes.

2 Data

We use accounting data on firms from England, Wales, and Scotland covering the period 2002-2015, merged with transaction-level house price data and loan-level mortgage data.

2.1 Firm Data

Our firm level data for the UK is sourced from a large micro dataset of firms' financial accounts provided by Bureau van Dijk (BVD). This is a commercial database containing company filings at Companies House, which is a UK government agency acting as the registrar of companies in accordance with the Companies Acts of 1985 and 2006. The database contains information on approximately 4.8 million private and public companies, covering much of the corporate universe of the UK.[2]

BVD is a live database. This leads to several limitations. First, the company ownership structure is only accurate at the time of access and not for historical observations. Second, companies that die exit the database after four years. Third, the historical information based on past filed accounts has significantly more missing data than the most recent filings. To circumvent these issues, we use archived data sampled at a six monthly frequency to capture information when it was first published. This substantially improves data coverage, allows us to observe the birth and death of companies, and provides accurate information on the ownership structure of companies at the time the accounts were filed. As discussed in Kalemli-Ozcan, Sorensen, Villegas-Sanchez, Volosovych, and Yesiltas (2015), the use of archival information and careful treatment of the data is crucial to construct an accurate firm-level panel using data provided by BVD. In Appendix B, we discuss our procedure in great detail and the corresponding advantages it brings in terms of data coverage.

Firm Activity and Financing Our main dependent variable of interest is firm investment. To compute investment we calculate the annual change in the variable "Fixed Assets" less the variable "Depreciation", as a proxy for annual capital expenditure. We use cash, calculated as "Bank Deposits" less "Bank Overdrafts", and "Operating Profit" as control variables. We also examine how corporate and director collateral affect the firm's labour decisions, examining the impact of residential and corporate collateral on total labour costs (the variable "Remuneration") and employment (the variable "Number of Employees"). In addition, we examine the liability side of the firm balance sheet, including issued equity, director loans, and short and long-term external financing. All variables that enter our regressions are scaled using the past year's turnover as the scaling variable.[3] To prevent

[2] Unincorporated sole traders are not included in the dataset.

[3] Alternatively, we could have followed Chaney, Sraer, and Thesmar (2012) in using property plant and equipment as the scaling variable. However, unlike their dataset, ours is not limited to listed and relatively large companies, but includes a large number of small companies with potentially small amounts of fixed assets. The choice of turnover as a scaling variable is therefore better suited to our sample, and avoids placing too much weight on smaller companies with small holdings of fixed assets. One variable with different weighting is "Number of Employees". As "Number of

outliers distorting the results, all ratios are winsorised at the 1st and 99th percentile.

Sample Selection We focus on private limited and public quoted firms and follow the literature in excluding firms that operate in certain industries.[4] We also exclude companies that have a parent with an ownership stake greater than 50%. This is to ensure that the accounts used have the highest degree of consolidation possible, to prevent the double counting of subsidiaries and to ensure that the financial position of the company regarding the collateral it has available is correctly accounted for. For the purpose of empirical analysis, we drop observations which are missing data on the firm activity and financing variables, the control variables, and our measures of residential and corporate collateral, defined below. This leaves us with, in our most extensive sample, approximately 40,176 firm year observations covering 10,352 firms. The exact sample size for each specification is reported in the regression tables.

Land Holdings To measure corporate land holdings, we use the balance sheet item "Land and Buildings" from BVD. For the purposes of empirical analysis, a difficulty is that the firm's choice of changes in its holdings of Land and Buildings will be both serially correlated and endogenous to the environment that the firm is operating in, including information about the firm's future prospects that may not be directly observable in the data. Hence, the level of collateral at the start of the firm's accounting period may be endogenous to the firm's behaviour within the accounting period. This could either be because the firm has invested in Land and Buildings in anticipation of future growth or because investment decisions are serially correlated (for example, a firm that buys a new building one year, may be much less likely to buy a new building in the following year). To solve this potential endogeneity issue, we follow the literature (Benmelech and Bergman (2009), Chaney, Sraer, and Thesmar (2012)) and rely on fluctuations in the price of collateral rather than the quantity of collateral the firm employs (the intensive margin of collateral in the terminology of Benmelech and Bergman (2009)) to identify the corporate collateral channel. We estimate the value of firm collateral by fixing the book value of Land and Buildings, $L^B_{i,t}$, at its 2002 level and iterate forward using the regional price index. Specifically, the variable *Corporate Collateral,* for company i at time $t \geq 2002$ in region j is given by:

Employees" is a real variable we compute real turnover as the scaling variable by dividing nominal turnover by the UK consumer price index with 2005 as a base year. Estimates for the employment regression therefore correspond to 2005 prices.

[4] Specifically we exclude companies of the following types: "Economic European Interest Grouping", "Guarantee", "Industrial/Provident", "Limited Liability Partnership", "Not companies Act", "Other", "Royal Charter", "Unlimited", "Public Investment Trust", thereby ensuring that our sample contains only limited liability companies to which the Companies Act applies. In addition, we exclude from the sample firms operating in mining (UK 2003 Standard Industrial Classification [SIC] codes 1010-1450), utilities (UK 2003 sic codes 4011-4100), construction (UK 2003 sic codes 4511-4550), finance and insurance (UK 2003 sic codes 6511-6720), real estate (UK 2003 sic codes 7011-7032), and public administration (UK 2003 sic codes 7511-7530).

$$CorporateCollateral_{i,t} = L^B_{i,2002} \frac{L^P_{j,t}}{L^P_{j,2002}}, \quad (2.1)$$

where $L^P_{j,t}$ is the local house price index in region j at time t. As with the other variables, for the regressions corporate collateral is scaled by the lag of turnover. We select 2002 as it is the earliest year where we can conduct this exercise and preserve a sufficient number of observations. Our key identifying assumptions are then that $L^P_{i,2002}$ is uncorrelated with other factors that affect the sensitivity of firm behaviour to local real estate prices beyond the collateral channel and that regional property price variation is not caused by the individual firm's behaviour. We discuss both assumptions in detail below and show that our results are robust to different ways of calculating corporate land holdings including: (i) using a commercial real estate price index rather than a house price index and (ii) replacing the 2002 book value of Land and Buildings in (2.1) with the 2002 market value, calculated through a Last In, First Out (LIFO) recursive method.

2.2 Director Data

Company Directors Bureau van Dijk (BVD) also provide information on company directors. Under UK law, all registered companies, no matter how small, must have a director. Firms can themselves be directors, but every firm must have at least one director who is a natural person.[5] For many small firms, the director will also be the sole shareholder of the company. Under UK law, all company directors must provide information including their full name, their full date of birth, their nationality, their appointment and resignation dates as a director at the company. Directors are also required to report their residential address. This must be accurate, as it is used by Companies House if they need to contact a director.

Data on company directors is publicly available and compiled into usable form by BVD. As BVD is a live database, information on company directors is updated over time (because directors may change address, resign and new ones may get appointed). BVD thus holds information on who the company's directors are, and their current address, not who they were in the past, and their historical addresses. The archiving performed on old vintages of BVD data makes estimation of the residential collateral channel possible by providing historical information on who company directors were and where they lived at the time company accounts were filed.

Treatment of Company Directors We assumed that a director's initial, surname, and full date of birth are sufficient to uniquely identify them. Using this information a director can then be identified both across multiple companies at the same point in time, and across time, over different downloaded vintages of BVD data. Combining the director and firm data allows for the construction

[5] Company directors have a general legal duty to promote the success of the company to benefit of its shareholders, and perform other duties such as preparing annual accounts. See Part 10 of the Companies Act 2006 for details on the duties liabilities of comapny directors.

of several director characteristics that could determine both the value of a director's house and how they run their company. These can then be used as additional regression controls. Personal director data allows for the calculation of the director's age, gender, and nationality. The full archived director and firm data enables the calculation of various measure of *experience,* not just in their current role, but across previous roles held at other companies. We calculate a number of measures of experience including the number of different companies an individual has worked for, the total number of years of experience they have as a director, the number of their companies that have failed, and the number of different industries they have worked in. Finally, for individuals that hold directorships at multiple companies, proxies for director skill can be constructed based on the average credit score and asset growth at *other* companies they work for. Full details on the construction of director characteristics are given in Appendix C.

2.3 Real Estate Data

Our source of house price data for England and Wales is the Land Registry's Price Paid dataset, which covers the universe (over 20 million) of residential property transactions in England and Wales since 1995.[6] This data has several uses.

First, it is used by the Land Registry to construct monthly repeat sales house price indices for 172 regions in England and Wales.[7] Given the granularity and geographical coverage, in our baseline regression these regional house price series are used to proxy for the market price of commercial real estate in equation (2.1).[8]

Second, the Land Registry Price Paid dataset forms our source for computing the value of director's homes. As it covers the universe of residential property transactions in England and Wales since 1995, if a director's house has transacted in this period, these transaction prices will be recorded. The challenge is to match the addresses of individual company directors to this dataset. The addresses of company director's are recorded as an unstructured string of text in the BVD database, with the notable exception of the director's postcode which is also recorded in a separate field. We construct a textual analysis algorithm that searches the unstructured address strings for regular expressions that can be used to determine the director's house number/house name and (if applicable) flat number/flat name. These two bits of information coupled with the postcode are sufficient to uniquely identify a property in the UK. Given this information, we can match the director's address to the Land Registry. Our match rate is around 50%. For every matched address the Land Registry

[6] For a thorough description of this dataset see Bracke and Tenreyro (2016)

[7] The advantage of using the Land Registry dataset, compared to other popular UK house price indices such as Halifax and Nationwide, is that it (i) includes cash purchases, (ii) is not limited to applications for mortgages through a given financial institution, (iii) is not based on approved mortgage applications but on the price at completion of the transaction, and (iv) is available at far more disaggregated geographical regions.

[8] Of course, one limitation of using this as a proxy for changes in the market price of corporate real estate holdings in (2.1) is that it is based on residential rather than commercial real estate prices. Therefore, as an alternative measure, in our empirical analysis we also use the commercial real estate price index provided by the Investment Property Databank, which is based on commercial property valuations for a range of major cities.

dataset gives us the date of and price paid at every transaction involving that property since 1995. By combining this information with information from different vintages of BVD on the dates at which a director listed a matched property as their address, we are able to estimate the dates a director lived at a given property. The methodology used is explained in detail in Appendix D.

Finally, we augment the Price Paid dataset with further information from the Land Registry on whether the property was purchased with a mortgage. This is used, along with mortgage information, discussed next, to calculate the equity a director holds in their house.

The analogous dataset on property transactions for Scotland is provided by the Registers of Scotland (though it does not contain information on whether a property was purchased with a mortgage), and is also the basis for house price indices across 32 Scottish regions. Thus in all, we have house price data for 204 regions across England, Wales, and Scotland.

2.4 Mortgage Data

Administrative data on the universe of regulated residential mortgages are taken from the Product Sales Database (PSD) provided by the UK Financial Conduct Authority.[9] We use two mortgage datasets. First, data on the *flow* of mortgages (PSD 001), which covers all originated regulated residential mortgages since 2005 including mortgages for house purchase and refinancing.[10] Second, data on the *stock* of mortgages (PSD 007), which covers the outstanding stock of regulated residential mortgages at a point in time (we use H2 2015 as it's the first available vintage of this dataset). Crucially, both mortgage datasets include the full postcode of the property that the mortgage is secured against, as well as the full date of birth (including year) of the mortgagor. As these variables are also present for our company directors, we can match the two datasets, and observe residential mortgages taken out by company directors. With an average of 17 properties per postcode in the UK, the combination of full postcode and date of birth will have a low probability of mismatch between directors and mortgages.

The PSD flow data provides a wealth of loan-level information including the mortgage amount, property value, income of the borrower, interest rate charged, mortgage term and the purpose of the mortgage, whether for house purchase, or a remortgage, and indeed the reason for the remortgage. Using the information on the initial principal, interest rate, and mortgage term, a standard formula can be used to calculate the evolution of the mortgage principal over time. Combining this with the evolution of the regional house price index allows a director's home equity to be estimated over time. The PSD stock data can be used as a cross check against the estimated evolution of the mortgage principal, by providing one future point where it is known (H2 2015). We calculate the value of

[9] The FCA Product Sales Data include regulated mortgage contracts only, and therefore exclude other regulated home finance products such as home purchase plans and home reversions, and unregulated products such as second charge lending and buy-to-let mortgages.

[10] Refinancing is only recorded where there is an increase in mortgage principal, or there is no increase in principal but the refinancing occurs with a different mortgage provider.

a director's mortgage over time using two methods. The first method ("Passive") uses only initial information in the flow data. The second method ("Active") uses the initial information as well as all subsequent information, both from future remortgaging and the value in the stock. In this second version, future information is used to smooth the path of mortgage principal through time, between the known points. The estimation of mortgage principal is explained in detail in Appendix F.

2.5 Estimation of Director Home Value and Equity

Information from the property transaction database and administrative mortgage dataset are used to calculate both the value of director houses, and the equity they hold in it.

Residential Collateral A director's address matched to the transactions database will record the price the director paid for the house and/or the price they sold it for. We estimate the value of the property at intermediate dates using the purchase price and the local house price index. Where only the sale price is observed, we use the local house price index to calculate the value of their house prior to this date. The use of the purchase price is preferred as the estimated subsequent value of the director's house is then independent of their future behaviour. Where the address is not matched to the transactions database, for example because the house has not transacted since 1995,[11] it is still possible to obtain an estimate of the property's value if the director and their property are matched to the mortgage dataset. For example, if a director bought their house prior to 1995 but remortgaged it in 2007, we will have an estimate of its value at the remortgage date. The local house price index is then used to estimate the value of their house throughout the period they lived at their house.

For each matched director-property pair, we calculate the value of the house throughout the period they are estimated to have lived there. Through the use of archived data, we may observe multiple addresses listed by the same director. This could represent multiple properties that are owned at a given point in time, with each listed by the individual at different companies they are a director at, or it could represent multiple properties at different points in time, as the director moves house.[12] Through using transaction data to estimate the dates a director lived at a property, we are able to assign the property value to the director only during the dates they live there, avoiding double-counting property values when a director moves from one house to another. With this, for each director, we then calculate the total house value across all properties they are matched to at a given point in time.

For the firm level analysis, the variable *Residential Collateral* for firm i at time t is the estimated

[11] Manual checks on our matching algorithm revealed that in 86% of cases a failure to match a director's address was due to the address not having a recorded transaction in the Land Registry since 1995. The remaining 13% were due to a combination of errors in how the address was recorded (typos etc.) or the director recording a non-residential address.

[12] It could also be the same property listed multiple times but with a typo in one instance. Through using archived data such typos will not prevent the director's address being matched, if it is correctly recorded at another point in time or with another company.

market residential property value across all directors of the company, measured at the company accounting date t. As not all company directors will be matched in general, this is estimated as the average property value for matched directors at a point in time multiplied by the total number of company directors. As with the other variables, in the regression this is scaled by the lag of firm turnover.

Home Equity In the first instance, we use information from the PSD mortgage datasets to estimate the value of director home equity over time. Where the director's property is not matched to the PSD, but is matched to the Land Registry, and it indicates the property was bought without a mortgage, the director's home equity is simply calculated as the home value (i.e. 100% equity). As with director home value, we use any matched transaction dates to form an estimated window during which the director lives at the property, and only attribute the home equity to them during those dates, avoiding double-counting of home equity when a director moves house. For each director we then calculate the total home equity at the firm's accounting date, summing across multiple properties they are matched to.

One challenge with identifying the causal impact of director home equity on company activity is that home equity may be endogenous to firm financing. For example, if a director remortgages their property to extract home equity, and invests this in their firm, we will simultaneously observe a measured decrease in their home equity and an increase in the size of the firm's balance sheet, obscuring the relationship between the two.

To circumvent this issue we calculate a *passive* measure of home equity. This simply takes the first observed measure of home equity for the director's property and iterates it forward assuming no further changes to the mortgage status, and ignores information in the PSD stock data. For example, if the property is bought without a mortgage, the director has 100% home equity and passive equity evolves with the house value, ignoring any future remortgaging. For properties with mortgages, it is assumed that the mortgage principal evolves according to the initially observed mortgage interest rate, term, and principal, with future remortgaging ignored. The variable *Passive Equity* estimates the total value of this measure across all company directors, based on the average equity for each matched director and the total number of directors. The variable *Active Equity* instead uses all available information to calculate equity at the firm level, using information from subsequent mortgage activity and information in the PSD stock data. Both equity variables are scaled by the lag of firm turnover when included in the firm level regressions.

Ownership For the residential collateral channel to exist, a significant fraction of company directors must own the property they live at. We provide three pieces of evidence that suggests that vast majority of company owners do.

First, aggregate data suggests that company directors are very likely to own their house. The average age of a director in our sample is 52. The 2011 UK census shows that 88% of individuals with occupation "managers, directors, and senior officials", and located in the age group 50-64 own the property they live in.

Second, for England and Wales, the Land Registry Price Paid dataset does not contain information on who owns a property. However the Land Registry does record the title deeds to all residential properties and for a small fee these can be purchased for any address. From the latest BVD vintage, for firms that report information on the key variables used in the paper, we took a random sample of 100 directors living in England and Wales whose address could be matched to the Land Registry. From this sample we manually found that 90 of the 100 directors owned the property they lived at, and a further two appeared to be owned by family members of the director.

Third, for Scotland, the transaction database provided by Registers of Scotland *does* provide the name of all individuals buying and selling property. Using this data for director's addresses in Scotland that were matched to this transactions database, we automatically compared the surname of directors with the surname of the property owner, making no correction for typos, and found they matched in 83% of cases.

2.6 Summary Statistics

Firm Variables Table 1 presents summary statistics on variables of interest for our sample of firms. The median values of turnover and number of employees in the whole sample are about £11.5m and 98, respectively, which is much smaller than the corresponding mean values (£193m and 1100). This skew in the distribution suggests that our sample is dominated by small and medium-sized enterprises.[13] The median firm has 4 directors, with quite a tight distribution across firms, with the inter-quartile range running form 3 to 6 directors. The median firm also has assets worth around 63% of turnover. Turning to the main explanatory variables of interest, we note that the total value of residential collateral held by company directors is worth 22% of turnover for the median firm, around 3 times larger than the value of corporate collateral held, which is only worth around 7% of turnover. This suggests that residential property may be a material source of financing for the firms in our sample. The value of home equity held by company directors is also slightly larger than the total value of corporate collateral held.

Director Characteristics Table 2 presents summary statistics on the characteristics of the directors for our sample of firms. As the average company has 5 directors, there are around 5 times as many observations as in Table 1. The company directors are overwhelming male (84%), and from the UK (94%), and just over a third (35%) report for certain that they are shareholders at the company (note, we are unable to determine whether the remaining 65% are not shareholders or just have not reported that they are shareholders). The median company director is 52 years old, holds directorships in 2 companies at once, though has experience of 5 different firms, across 2 different

[13]In the UK, an SMEs is defined as a firm with less than 250 employees

industries. The median company director has also been involved in 1 company at its birth and 1 of the companies they have worked for have died.

Table 1: Firm Summary Statistics

Variable	**Mean**	**Median**	**25%tile**	**75%tile**	**N**
Levels					
Turnover (£ 000s)	193065	11451	5103	30722	39247
No. Employees	1100	98	44	235	40176
No. Directors	5	4	3	6	37501
Ratios (to Turnover)					
Investment	-.13	.016	.0023	.056	40176
Remuneration	.56	.25	.14	.39	40176
Residential Collateral	2.2	.22	.089	.57	40176
Residential Equity	.66	.074	.023	.21	30804
Corporate Collateral	.45	.069	.0031	.22	40176
Cash	.37	.0016	-.045	.054	40176
Operating Profit	-.68	.028	.0044	.067	40176
Total Assets	2.6	.63	.41	1	40175
Issued Equity	.13	0	0	0	40176
Change in Directors Loans	-.0054	0	0	0	40176
Change in ST External Financing	.3	.0057	-.022	.04	40176
Change in LT External Financing	-.19	-.0028	-.017	.0068	40176

Note: The statistics are calculated using the sample of observations for the baseline regressions. This excludes firms who have an ownership stake greater than 50%, operate in certain industries, and report the main variables of interest for our regressions. Full details on sample selection are given in Section 2.1.

Table 2: Director Summary Statistics

Variable	**Mean**	**Median**	**25%tile**	**75%tile**	**N**
Fraction of Male Directors	84%				185911
Fraction of Non-UK Directors	5.9%				187551
Fraction of Directors Shareholders	35%				188135
Director Age	52	52	44	60	188058
Years of Experience	33	17	7.8	37	188095
Current Directorships	4.3	2	1	5	188095
No. of Directorships To Date	13	5	2	12	188095
Average Years Spent In Each Role	4	3.3	2	5.2	184673
No. Industries Worked In	3.5	2	1	5	188095
Companies With At Birth	2.1	1	0	2	188095
Companies That Have Died	3.2	1	0	2	188095

Note: The statistics are calculated for all the directors in the sample of observations used for the baseline regressions. This excludes firms who have an ownership stake greater than 50%, operate in certain industries, and report the main variables of interest for our regressions. Full details on sample selection are given in Section 2.1.

3 Residential Collateral and Corporate Borrowing

The main contribution of our paper is to highlight the quantitatively important role played by the residential property of firm directors in linking house price dynamics with firm borrowing, investment and job creation. Given this Residential Collateral Channel, it is instructive to first provide some legal and historical background as well as some anecdotal evidence on how the wealth held in directors' residential properties can support corporate borrowing and business activity.

A personal guarantee of a company director is the key concept which enables the personal property of directors to be used as collateral to secure the loans of the director's firm. By signing a guarantee when obtaining a business loan, the director promises that the company will fulfill its debt obligation, or if failing so, the director will personally be liable for the company's debt. In effect, a personal guarantee provides a means to pierce the corporate veil and break limited liability.

A large fraction of SME loans in the UK are secured by a personal guarantee. Note however that the prevalence of personal guarantees is wide-spread across the world. Appendix G provides cross-country evidence on the use of guarantees as security for business loans. This form of security also has a long history, which in the UK dates back to the development of the modern corporate structure by the late 19th century. Appendix G shows that by 1910-1914, with the rise of limited companies as the predominant form of legal personality, guarantees became the most common security taken by commercial banks when granting a business loans. Appendix G also provides additional anecdotal evidence on the importance of guarantees, with examples involving one of the Presidents of the United States as well. This background information aims to highlight that guarantees have a long history, and in fact some argue that they are "as old as the pyramids" (Andrews and Millett, 2011). Indeed, the corporate finance literature has long recognised the importance of personal property and guarantees as source of collateral in the business loan market (Berger and Udell 1995; Avery, Bostic, and Samolyk 1998; Jimenez and Saurina 2004; Brick and Palia 2007; Davydenko and Franks 2008; Ono and Uesugi 2009). Our paper highlights the macroeconomic implications of this phenomenon.

Legal Background A personal guarantee is a contract whereby one person (the guarantor) promises to be answerable for a liability of another (the principal debtor) to a third person (the creditor) (pp. 901 of Ellinger, Lomnicka, and Hare (2011)).[14] A personal guarantee is thus subject to the general laws that govern contracts. Furthermore a contract of guarantee needs to be evidenced in writing as required under section 4 of the Statute of Frauds 1677.

Banks have a preference for secured guarantees. Security can come in the form of a cash deposit, but it typically comes in the form of a fixed charge over the property of the guarantor: "*A guarantee*

[14] Banks often use the term indemnity and guarantee synonymously yet there are important differences between the two. A personal guarantee is a secondary liability. This means that the guarantor is only liable to the extent that the principal debtor is liable. Moreover, a guarantor is only liable once the debtor has defaulted. However, an indemnity is a primary liability. It is effectively a promise by 'one party to keep the other party harmless against loss.' (pp. 903 of Ellinger, Lomnicka, and Hare (2011)) It is independent of the debtor's liability or default.

may simply be a personal undertaking by the guarantor, but such promise is often secured by a further charge on property owned by the guarantor" (pp. 903 of Ellinger, Lomnicka, and Hare (2011)). Any property given as security, which may include the home of the company director, may be repossessed by the bank if repayments are not kept. Even if a director's house does not explicitly secure a personal guarantee, it can still implicitly back it. This is because if a director fails to fulfill a personal guarantee, the creditor can obtain a court order to seize their house.

To prevent the spouse/partner of the guarantor (company director) from making any future claim asserting undue influence by the guarantor, the guarantor's spouse/partner is required to seek independent legal advice before a guarantee can be offered (Royal Bank of Scotland versus Etridge (No 2), 2011). Firm directors' bank guarantees are usually joint and several. This means that any director is obliged to pay the whole debt and may then sue his co-partners or co-directors for a contribution. *"All of this makes something of a mockery of limited liability so far as directors of private companies are concerned.*" (pp. 80 Riches and Allen (2009)).

Recent Evidence for the UK This subsection provides additional empirical evidence on the prevalence on personal guarantees and residential property as security for business finance in the UK. The first data source is the Surveys of SME Finances that were conducted among 2,500 SMEs (defined as firms with up to 250 employees) in the private sector in the UK. We combine the 2001-2004 and 2005-2008 waves together. The data were projected by size (number of employees) within sector and by region to the total number of SMEs in the UK in scope of the study. The data were weighted up to the population of UK enterprises within the scope of the survey in terms of size and sector: 3,625,415 (2004 wave) and 4,430,825 (2008 wave) enterprises in total. The second data source is the Bank of England's 2015 survey of UK SME and Mid-Corporate Lending by the five major UK banks. This survey covered lending from the five major UK banks to businesses borrowing at least £250k, and whose annual revenue was no more than £500million.

Panel a of Table 3 summarises the results from Surveys of SME Finances based on the answers to the question "*What security was used to get this (business) loan?*" There are main messages conveyed by the panel. First, residential collateral is about as important as corporate collateral when used to obtain a business loan: almost half the respondents use either or both types of collateral when obtaining external finance. Second, the use of corporate collateral is more prevalent amongst larger firms, whereas the use of residential collateral is more frequent amongst smaller firms: the median employment is 28 (16) amongst responding firms that do (do not) use corporate collateral, whereas the median employment is 13 (27) amongst responding firms that do (do not) use residential collateral. This can be explained by the fact that smaller firms have little accessible corporate collateral (as they typically do not own commercial real estate), and the main source of real estate collateral is the personal property of the firm director. As shown in Section 2, our dataset is dominated by SMEs, with the median firm in our sample owning much less commercial real estate than the combined value of residential real estate owned by the median firm's directors.

Table 3: Survey Evidence on the Type of Security Used when Obtaining a Business Loan in the UK

	Corporate Collateral	Residential Collateral
yes in %	43%	45%
no in %	57%	55%
yes - median employment	28	13
no - median employment	16	27

(a) Results from Surveys of Businesses

	Loan Secured on Property	Loan Secured By Personal Guarantee
	(1)	(2)
0-1 Employees	86%	12%
2-49 Employees	80%	33%
50-249 Employees	54%	31%
250+ Employees	50%	25%
All Firms	73%	29%

(b) Results from Surveys of Lenders

Notes for Panel A: the values are calculated based on the answers to the question 'What security was used to get this (business) loan?' in the UK Survey of SME Finances (2004 and 2008 waves). In the survey there 13 possible types of securities mentioned. These are: 1. stock or debtor; 2. equipment and vehicle; 3. business security; 4. business property; 5. personal property; 6. mixed property (e.g. flat above shop); 7. other personal assets; 8. floating charge; 9. directors' personal guarantee; 10. other reserves; 11. life insurance policy; 12. other; 13. do not know. We classify business property as corporate collateral and classify personal property, mixed property and personal guarantee as residential collateral. Grouping personal guarantees (that typically involve a fixed charge on personal property) and personal property together is motivated by the following fact: only about 26% of the represented firms in survey are limited liability companies, and about 65% of the represented firms are sole proprietorships to which the Companies Act do not apply. Sole proprietors are the business, the owner and the director. They are by law personally liable for their debt. Thus a director of a sole proprietorship cannot offer a personal guarantee himself but they can secure a loan directly with their personal property.
Notes for Panel B: The panel presents the results of the Bank of England's 2015 survey of UK SME and Mid-Corporate Lending by the five major UK banks. This survey covered lending from the five major UK banks to businesses borrowing at least £250k, and whose annual revenue was no more than £500million. To facilitate comparison with our regression results, we exclude lending to businesses in Mining and Quarrying, Construction, Financial and Insurance Activities, and Commercial Real Estate. Column (1) shows the fraction of business loans (weighted by number) that were secured on property, broken down by the size of business being lent to. Column (2) shows the fraction of business loans (weighted by number) that were secured by a personal guarantee, also broken down by the size of business being lent to.

Panel b of Table 3 summarises the results from survey of lenders. The findings confirm that property and personal guarantees are the types of security that banks seek when granting business loans not only to small and medium sized companies but also to large companies.

4 Methodology

Our baseline regression estimates the impact of *Residential Collateral* on firm investment. For firm i, operating in region j, in industry l, at date t, we estimate the following regression:

$$INV_{i,t} = \alpha_i + \delta_{j,t} + \mu_{l,t} + \eta \times ResidentialCollateral_{i,t} + \beta \times CorporateCollateral_{i,t} + \gamma \times controls_{i,t} + \epsilon_{i,t} \tag{4.1}$$

where $INV_{i,t}$ is firm investment, $ResidentialCollateral_{i,t}$ is the total value of residential real estate held by the company directors, as described in Section 2.5, and $CorporateCollateral_{i,t}$ is the value of commercial real estate owned by companies, as calculated by equation 2.1. The term α_i is a firm fixed effect, controlling for the firm's average investment rate, $\delta_{j,t}$ is a region-time fixed effect, which aims to capture aggregate as well as region-specific business cycle fluctuations, and $\mu_{l,t}$ is an industry-time fixed effect.

As is standard in firm-level investment regressions (e.g. Chaney, Sraer, and Thesmar (2012)), we include cash on hand, calculated as "Bank Deposits" less "Bank Overdrafts" at the start of the accounting period, as a control variable. A proxy for Tobin's Q, such as the firm book-to-market ratio, is also typically included as a control variable, however we cannot do this as our dataset includes many private as well as public firms. Instead, similar to Chaney, Huang, Sraer, and Thesmar (2015), we include 2-digit industry x time fixed effects to capture changes in investment opportunities for industries. In addition, we include the variable "Operating Profit" lagged one period as a further control. As discussed, all variables enter the regression as a ratio to the the lag of firm "Turnover".

A potential endogenity problem related to regression model 4.1 is that real estate prices and therefore residential and corporate collateral values could be correlated with investment opportunities, e.g. because an increase in local real estate prices fuels local consumption (Mian and Sufi (2011)). The inclusion of region-time fixed effects, $\delta_{j,t}$, will deal with this problem, so long as firms within a given region respond similarly to changes in local demand. The standard errors in (4.1) are clustered at the firm-region level.

5 Main Results

5.1 The Residential Collateral Channel: Main Results

Table 4 reports our estimates for various specifications of equation 4.1. The third column in the table presents our baseline. The coefficient of 0.0207 on residential collateral suggests that a £1 rise in the total value of the residential real estate holdings of a firm's directors increases the firm's investment by around 2.1p. Equivalently, the coefficient on corporate collateral suggests that every £1 increase in the value of the firm's own real estate holdings causes a 8.4p increase in investment (for comparison, Chaney, Sraer, and Thesmar (2012) report a figure of 6p). At the micro-level, this implies that the corporate collateral channel is about 4 times stronger for investment than the residential collateral channel. However, as discussed in the introduction, the total value of director collateral in the economy as whole is 4 times larger than that of real estate collateral held by owner-occupying corporates, suggesting the investment effects in aggregate from an increase in real estate prices from the two channels are of similar magnitude.

The estimates are robust to perturbations in the specification. Columns (1), (2) and (4) in Table 4 show that the 2p coefficient on residential collateral is, for the most part, unaffected by altering the control set or the degree of fixed effect saturation. Indeed, column (4) shows estimates when we include a comprehensive set of controls to capture other potential firm level characteristics that govern the firm's sensitivity to local real estate prices. In particular, firm characteristics such as

Table 4: Firm Investment and the Collateral Channels

	Investment						
	Director Collateral Alone	With Firm Controls	Baseline	Add. Firm Controls	Firm Collateral Alone	Non-Land-Building Investment	Maximal Sample
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Residential Collateral	0.0272***	0.0214***	0.0207***	0.0200***		0.0134***	0.0034***
	(0.004)	(0.004)	(0.005)	(0.005)		(0.003)	(0.000)
Corporate Collateral		0.0903***	0.0843***	0.0843***	0.1051***	0.0447***	
		(0.015)	(0.013)	(0.013)	(0.013)	(0.008)	
Cash Ratio		0.1402***	0.1415***	0.1357***	0.1479***	0.0774***	
		(0.026)	(0.027)	(0.027)	(0.027)	(0.014)	
Profit Margin		0.1028***	0.0916***	0.0876***	0.0470*	0.0633***	
		(0.026)	(0.027)	(0.027)	(0.027)	(0.017)	
N	37501	37501	37291	36887	37291	35480	6142146
Adjusted R^2	0.23	0.25	0.26	0.26	0.26	0.27	0.15
Add. Firm Controls	No	No	No	Yes	No	No	No
Region-time FE	No	No	Yes	Yes	Yes	Yes	Yes
Industry-time FE	No	No	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Firm region clustered standard errors in parentheses

$^{\star}p < 0.10, ^{\star\star}p < 0.05, ^{\star\star\star}p < 0.01.$

Notes: The table reports the link between residential collateral, corporate collateral, and firm investment. The dependent variable, Investment, is defined as the change in fixed assets less depreciation. Director Collateral is the total value of residential property held by current directors of the firm, estimated as the average property value for current directors whose address is matched, multiplied by the number of current directors. Firm Collateral is the 2002 book value of firm Land and Buildings iterated forward using the regional house price index. Cash and Profits enter with a lag. All variables, except in column (8) are scaled by the lag of firm turnover and winsorised at the 1% and 99% levels. Standard errors, clustered by firm region, in parentheses. The sample covers reporting UK firms over the period 2002-2015. Columns (1) and (2) present the results of regressions including only a firm fixed effect, with, and without, additional controls. All other regressions also include region-time and (2 digit) industry-time fixed effects. Column (3) presents the baseline results. Column (4) augments the baseline regression with firm characteristics in 2002 (quintiles for age, size, and profitability) interacted with real-estate prices. Column (5) presents the baseline regression omitting director collateral. Column (6) estimates the baseline specification with investment, excluding investment in land and buildings, replacing investment as the dependent variable. Column (7) estimates the link between investment and residential collateral on the maximum possible sample size. Specifically, it regresses the change in total assets on Residential Collateral, with both variables weighted by the lag of total assets rather than firm turnover.

age, size and profitability may affect a firm's decision to own real estate as well as influence their sensitivity to shocks to real estate prices. We therefore follow Chaney, Sraer, and Thesmar (2012) and divide firms into groups based on which quintile of age, size, and profitability they were in at the base year of 2002, when we fix the quantity of Land and Buildings held.[15] We then include in our baseline regression 4.1 the interaction of these quintile variables with the level of real estate prices in the firm's region.[16] This has little affect on the results.

Comparing column (5) with column (3) in Table 4 one can see that once the residential collateral

[15]Table 10 in Appendix A presents results from a linear probability model (in column (1)) confirming that larger and older firms are more likely to own Land and Buildings in 2002, though there is no clear relationship with profitability. Column (2) also presents some evidence that larger and older firms own more Land and Buildings in 2002.

[16]We thus estimate the following regression for firm i, operating in region j, in industry l, at date t:

of company directors is accounted for, the impact of the corporate collateral channel is somewhat diminished, with the estimated impact on investment from a £1 increase in the value of the firm's real estate falling from 10.5p to around 8.4p. However, the two coefficients are still within two standard errors of one another. This implies that existing estimates in the literature on the strength of the corporate channel are unlikely to be suffering from bias due to the omission of residential collateral from their specifications. This is unsurprising when one considers that two collateral measures for a firm are not particularly collinear. The average within-firm correlation between the two series is low , in part because many firms do not own corporate real estate and because directors often do not live in the same region as their firm.[17]

Some firms may invest in property for speculative purposes when prices rise. This may explain the sensitivity between investment and both collateral measures. To address this we rerun our investment equation for investment excluding investment in land and buildings in column (6) of Table 4. As can be seen, corporate collateral (and residential collateral) both still influence investment in other forms of fixed assets suggesting non-speculative motives are at work. Furthermore, as we discuss in section 5.4, firms also hire more workers in response to an increase in both measures of collateral. Again, this is evidence of non-speculative motives.

These results are all conditional on a particular sample of firms who report the necessary information for us to compute our dependent variables and controls. Since reporting requirements vary by firm size and firms can still voluntary choose to report information we do not have a representative random sample. Furthermore, we have not used the information that is available for millions of firms. To address this, in column (7) of Table 4 we estimate a specification which gives us the largest possible sample. Specifically, we make use of the fact that the variable Total Assets is near universally reported in our database. Our dependent variable is the change in Total Assets (as opposed to the change in Fixed Assets plus Depreciation), and we scale all variables by lagged Total Assets rather than Turnover. We also drop all other controls except our measure of residential collateral (which is also well reported as all firms must declare who its directors are and provide an address). This leaves us with a sample with 6.1 million observations and a point estimate of 0.33p for the Residential Collateral Channel. That this estimate is still highly significant is encouraging. However, in doing this exercise we are adding to the sample a large number of very small entities who may not have much abilitity, desire or need to grow. This may explain the smaller coefficient. This can be seen if we compare some summary statistics between the two samples. The median firm in our baseline

$$\begin{aligned} INV_{i,t} =& \alpha_i + \delta_{j,t} + \mu_{l,t} + \eta \times ResidentialCollateral_{i,t} + \beta \times CorporateCollateral_{i,t} + \gamma \times controls_{i,t} \\ &+ \sum_k \kappa_k X_k^i \times L_{j,t}^P + \varepsilon_{i,t} \end{aligned} \tag{5.1}$$

where X_k^i gives firm $i's$ quintile in 2002 in the distribution of firms ordered by variable $k \in (size, age, profitability)$, and κ_k the related coefficient. $L_{j,t}^P$ is the house price index in region j at time t.

[17]Out of the directors in the full sample, more than 45% of them live in a region different from where their firms are located.

sample has £7.2 million in assets and median asset growth is around 3% per year. In contrast, in the expanded sample the median firm has £50,000 of assets and median asset growth is zero.

5.2 Identification

So far we have presented results giving a causal interpretation to the coefficients on residential collateral and in doing so we are assuming that the pool of real estate available to a firm's directors is independent of the firm's own performance and other confounding factors that govern either the firms behaviour or its sensitivity to real estate prices. In Table 5, we present alternative specifications designed to address concerns over the causality of our estimates.

One obvious concern is that an improvement in firm prospects may encourage the firm's directors to purchase larger homes (or, alternatively, the firm to appoint new directors, possibly with larger homes, adding to the firm's total residential collateral). Our approach to dealing with this is similar to how we treat the endogeneity of Corporate Collateral, i.e. fix the composition of directors and where they live at a certain point in time and iterate the value of those properties forward using the regional house price index. Using our panel data on who was a director of the firm, and where they lived in the past, we can calculate the market value of property held by company directors *as if* there had been no change in the composition of company directors, or their houses, for a given period of time (3,5,10 years in the regressions below), with the only change coming from movements in the local house price index. Columns (2), (3) and (4) in Table 5 present results when we use these alternative measures. The results when we fix for 3 and 5 years are within a standard error of the baseline specification. The results when we fix for 10 years are stronger but less precise. Furthermore, by definition, the sample has shifted towards older firms with at least 10 years of history so the coefficient estimates are not completely comparable.

Column (5) in Table 5 presents results when we instead compute Residential Collateral in a near equivalent way to Corporate Collateral by fixing who the directors were and where they lived at the start of the sample in 2002 and then iterating forward using the regional house price index. This is an alternative way of addressing concerns regarding the reverse causality between firm performance and decisions of directors. Furthermore, since the composition of directors is now fixed throughout the sample any time invariant omitted heterogeneity at the director level (e.g. skill) that may be correlated with the types of properties that directors own is absorbed by the firm fixed effect. The coefficient of interest is unaffected.

There is still the potential for omitted variation at the director-level that both determines the sensitivity of the firm to real estate prices and is correlated with the type of property the director inhabits. For example, it could be that firms with older directors are more conservative in the face of local business cycle (and hence real estate price) fluctuations. Or that more skillful directors are better able to take advantage of the opportunities presented by expansions, and also own more expensive houses. As described in Section 2.2, our dataset contains a rich a set of information about directors

Table 5: Residential Collateral: Identification

	Investment									
		3 Year Director Fix	5 Year Director Fix	10 Year Director Fix	2002 Director Fix	Dir. Controls All Dir.	Dir. Controls Multi-Firm	Director Different Regions	Tradables Firms	Director Known S.holder
	Baseline (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Residential Collateral	0.0207***	0.0154***	0.0222***	0.0387**	0.0272***	0.0201***	0.0198***	0.0396***	0.0351***	0.0180**
	(0.005)	(0.005)	(0.005)	(0.015)	(0.006)	(0.005)	(0.007)	(0.015)	(0.011)	(0.008)
Corporate Collateral	0.0843***	0.0968***	0.0894***	0.0691**	0.0814***	0.0842***	0.0952***	0.0967***	0.0933***	0.0998***
	(0.013)	(0.015)	(0.016)	(0.027)	(0.015)	(0.013)	(0.020)	(0.023)	(0.035)	(0.020)
Cash Ratio	0.1415***	0.1576***	0.1389***	0.1498***	0.1435***	0.1358***	0.1056***	0.1220***	0.1390***	0.1425***
	(0.027)	(0.027)	(0.032)	(0.041)	(0.028)	(0.026)	(0.039)	(0.040)	(0.029)	(0.035)
Profit Margin	0.0916***	0.0591**	0.0666*	0.0433	0.0772***	0.0870***	0.0621	0.0358	0.1413***	0.0433
	(0.027)	(0.029)	(0.034)	(0.064)	(0.026)	(0.027)	(0.044)	(0.040)	(0.038)	(0.035)
N	37291	32339	27596	10845	33540	36853	20971	16075	10728	21464
Adjusted R^2	0.26	0.27	0.28	0.34	0.26	0.26	0.26	0.23	0.25	0.32
Director Controls	No	No	No	No	No	Yes	Yes	No	No	No
Add. Firm Controls	No	No	No	No	No	Yes	Yes	No	Yes	No
Region-time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Firm region clustered standard errors in parentheses

$^{\star}p < 0.10, ^{\star\star}p < 0.05, ^{\star\star\star}p < 0.01$.

Notes: The table reports the link between residential collateral, corporate collateral, and firm investment. The dependent variable, Investment, is defined as the change in fixed assets less depreciation. Residential Collateral is the total value of residential property held by current directors of the firm, estimated as the average property value for current directors whose address is matched, multiplied by the number of current directors. Corporate Collateral is the 2002 book value of firm Land and Buildings iterated forward using the regional house price index. Cash and Profits enter with a lag. All variables are scaled by the lag of firm turnover and winsorised at the 1% and 99% levels. Standard errors, clustered by firm region, in parentheses. The sample covers reporting UK firms over the period 2002-2015. All regressions include firm, region-time and (2 digit) industry-time fixed effects. Column (1) presents the baseline results. Columns (2)-(4) fix the composition of directors, and the houses they own, at the firm as they were 3,5,10 years ago, respectively. Changes in the value of residential collateral since this date are calculated using changes in the relevant local real estate price indices since that date. Column (5) fixes the composition of directors and their houses in 2002. Column (6) augments the baseline regression with a number of director characteristics (discussed in detail in the Appendix) averaged at the firm level, and also interacts them with the level of real estate prices. Firm characteristics in 2002 (quintiles for age, size, and profitability) interacted with real-estate prices are also included. To column (6), column (7) adds director controls that can be calculated for individuals who are directors of multiple companies. Specifically, it adds as director controls the average credit score and total asset growth at *other* companies they are a director of. In column (8) Director Collateral is measured as the total value of residential property held by current directors of the firm that live in a different region to their firm (restricted to firms whose trading addresses are all in one region). Column (9) presents the results of the baseline regression for manufacturing firms. In column (10) Director Collateral is measured as the total value of residential property held by current directors of the firm who are also shareholders of the firm.

beyond just where they live, including their age, gender, nationality, and a number of measures of experience, including the number of directorships held, their experience across industries, and their total years as a director. To account for these director characteristics in our regressions, we average the characteristics at the firm level and place firms into 5 quintiles based on where they sit in the distribution of firms for each measure in each year. Column (6) in Table 5 presents the results of including these quintiles, and their interaction with local house prices in the firm's region, in the baseline regressions. There is very little change from the baseline regression.[18] To try and control for director skill, we exploit the fact that many directors hold directorships at more than one company at a time. For this subset of directors we are able to calculate two proxies for their skill, based on the average growth rate in total assets and average credit score at the *other* companies they are a director of. Column (7) in Table 5 also includes these additional director characteristics in the same manner with little change to the baseline results.

Despite this, it could still be the case that we are failing to properly control for the local demand effects of changes in real estate prices when assessing the Residential Collateral Channel. The baseline regression includes region-time fixed effects, however these will be insufficient to control for local demand effects of changes in real estate prices if these affect firms in the same region in a heterogeneous way. Two further pieces of analysis can be used to address this. In column (8) of Table 5 we show results when Residential Collateral is computed only for directors who live in different regions from their firms, such that the local real estate price for the region the firm operates in does not enter our collateral measure. This actually strengthens the coefficient estimate. Similarly if we look at firms who operate in the manufacturing sector, where output is tradable and local demand effects should be irrelevant, we also see a stronger relationship with Residential Collateral.

A final concern is that, despite our sample being made up primarily of SMEs, some directors could be just be agents of the owners of the firm rather than shareholders in their own right. These directors may be much less willing to invest increases in their real estate wealth in a firm that they run but do not own. Our dataset contains a variable indicating whether a director is a shareholder. However, this variable is not universally reported and it is unclear if a missing value indicates a negative response or not.[19] On average around 35% of directors report being a shareholder of their firm. In column (10) of Table 5, we re-estimate our baseline specification with a version of Residential Collateral computed using only those directors who report for certain that they are a shareholder of a company. This returns a very similar coefficient on Residential Collateral.

There are additional identification challenges that arise regarding the Corporate Collateral Channel. However, since these are all issues raised in Chaney, Sraer, and Thesmar (2012), we can address them by simply repeating their analysis on our sample. We discuss the specifics and the results in detail in Appendix A. For sake of brevity, in the main text we only reassure readers that our estimates

[18]The additional firm controls, as used in column (5) of Table 4 are also included.

[19]In earlier vintages of the Bureau van Dijk, the shareholder flag was either recorded as yes or missing. In more recent vintages it is recorded as yes, no or missing. This adds to the ambiguity.

are robust to these perturbations.

5.3 Firm Financing

We now turn to how firms finance the increase in investment documented above. Residential Collateral can affect the available funding for the firm either through the of granting a claim on the director's house to guarantee a loan to the firm,[20] or via the director extracting equity from their house to inject of the funds directly into the firm in the form of insider debt financing (director loans) or new equity. To explore the channels through which increases in the value of real estate are converted into firm funding we estimate the effects of the residential and corporate collateral channels on changes in specific parts of the liabilities side of firm's balance sheets. Specifically, we rerun our specification with four liability measures as left hand side variables: (i) the change in issued equity capital; (ii) the change in director loan liabilities; (iii) the change in short term external debt liabilities;[21] (iv) The change in long term external debt financing.[22]

The results are presented in Table 6. As for the corporate collateral channel, the impact of increased firm collateral has the largest and most significant effect on measures of external debt financing: a £1 increase in corporate collateral increases long-term debt by about 2.5p. Short-term external debt increases by an additional 3p. As would be expected, firm collateral has no impact on our measures of insider finance; neither director loans nor issued equity respond.

As for the residential collateral channel, an increase in the residential collateral of the average company director has a significant effect on both equity issuance and short-term debt, with a more material impact on the latter: a £1 increase in the market value of the directors' homes increases net equity and short-term corporate debt issuance by about 0.1p and 1.1p, respectively. The point estimate on long-term external borrowing suggests a 0.2p increase for every £1 increase in the value of the average director's house. This effect is not statistically significant; however, the size of the investment response to residential collateral, on the asset side of the balance sheet, suggests that this mechanism is present. Note also that it is common to use personal guarantees to support credit lines and overdraft facilities which explains why it is primarily short term financing that responds.

Summing across these four estimates, the firm increases its liabilities by an additional 1.5p for every £1 increase in residential collateral. This is less than the 2p increase in fixed assets, leaving 0.5p unaccounted for. However, if one repeats our baseline analysis using total asset growth rather than investment in fixed assets as a dependent variable one achieves a coefficient estimate of 1.5p (not shown), in line with the increase in liabilities. This suggests that other portions of the asset side of the balance sheet adjust downward; for example, cash holdings.

[20] Note that some guarantees will not be captured by observing whether a director remortgages or not. In some instances, directors may be able to borrow against the value of their house without taking on a formal charge.

[21] This is defined as the sum of the change in short term debt, overdrafts and trade credit less the change in short term director loans. Short term loans is supposed to refer to maturities less than a year but there may be some discrepancies across firms.

[22] This is defined as the change in long term debt less the change in long term director loans.

Table 6: Firm Financing and Collateral

	Financing			
	Issued Equity	Director Loans	ST External Financing	LT External Financing
	(1)	(2)	(3)	(4)
Residential Collateral	0.0012***	-0.0005	0.0107***	0.0018
	(0.000)	(0.000)	(0.003)	(0.003)
Corporate Collateral	0.0003	-0.0014	0.0299***	0.0260**
	(0.001)	(0.001)	(0.009)	(0.011)
N	37291	37291	37291	37291
Adjusted R^2	0.26	-0.01	0.02	0.04
Region-time FE	Yes	Yes	Yes	Yes
Industry-time FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes

Firm region clustered standard errors in parentheses

$^{\star}p < 0.10, ^{\star\star}p < 0.05, ^{\star\star\star}p < 0.01$.

Notes: The table reports the empirical link between residential collateral, corporate collateral, and firm financing. ST External Financing is short-term debt and overdrafts plus trade credit less short-term director loans. LT External Financing is long-term debt less long-term director loans. Residential Collateral is the total value of residential property held by current directors of the firm, estimated as the average property value for current directors whose address is matched, multiplied by the number of current directors. Corporate Collateral is the 2002 book value of firm Land and Buildings iterated forward using the regional house price index. All variables are scaled by the lag of firm turnover and winsorised at the 1% and 99% levels. Standard errors, clustered by firm region, in parentheses. The sample covers reporting UK firms over the period 2002-2015. All models control for firm fixed effects, region-time, and (2 digit) industry-time fixed effects.

The small size of the coefficient estimate on equity issuance coupled with the lack of meaningful response from director loans suggests that direct cash injections from directors is the less important marginal source of finance unlocked via residential collateral.[23] The mechanism at work is not, for the most part, one where directors remortgage their property to extract funds which they provide to their firms. Instead, the estimate related to increased short-term debt is consistent with the residential collateral channel operating through increasingly valuable personal guarantees from company directors that expands the corporate borrowing capacity of the firm. There are two main reasons why this method of funding may be more prevalent. First, a personal guarantee extends the company's tax shield to the director. Second, the use of personal guarantees can offset informational frictions in the credit market. The guarantee can both act as a signal of quality and align the incentives due to the loss of limited liability. Therefore, it may be that firm enjoys better borrowing terms if the director offers a guarantee.

5.4 Labour Market Implications

The increases in the value of collateral can also have implications for a firm's use of labour inputs as well as physical capital. Since Residential Collateral primarily seems to unlock short-term funding it may provide the working capital for the firm to hire new workers. To test this we alter our left

[23] Our estimates are for existing firms. The sensitivity of the initial liability structure of new start-ups to the housing wealth of their directors may be quite different.

hand side variable and consider two separate labour inputs: (i) the firm's total Remuneration paid to employees; and (ii) the Number of Employees. As per our other specifications, we scale both variables by the lag of the firm's Turnover. However, since Number of Employees is a real variable we convert Turnover into real terms using the UK CPI when re-scaling.

Table 7: Firm Employment and Wages

	Total Remuneration		Employment	
	Director Collateral	Baseline	Director Collateral	Baseline
	(1)	(2)	(3)	(4)
Residential Collateral	0.0456***	0.0295***	0.0030***	0.0024***
	(0.003)	(0.003)	(0.000)	(0.000)
Corporate Collateral		0.0588***		0.0034***
		(0.010)		(0.001)
Cash Ratio		0.0308***		0.0009
		(0.011)		(0.001)
Profit Margin		-0.1829***		-0.0053***
		(0.016)		(0.001)
N	37501	37291	37501	37291
Adjusted R^2	0.84	0.85	0.88	0.89
Region-time FE	No	Yes	No	Yes
Industry-time FE	No	Yes	No	Yes
Firm FE	Yes	Yes	Yes	Yes

Firm region clustered standard errors in parentheses

$^{\star}p < 0.10, ^{\star\star}p < 0.05, ^{\star\star\star}p < 0.01.$

Notes: The table reports the link between residential collateral, corporate collateral, and two employment variables. Total Wages is the remuneration paid by the firm, whilst Employment is the number of employees the firm has. Director Collateral is the total value of residential property held by current directors of the firm, estimated as the average property value for current directors whose address is matched, multiplied by the number of current directors. Firm Collateral is the 2002 book value of firm Land and Buildings iterated forward using the regional house price index. Cash and Profits enter with a lag. All variables are scaled by the lag of firm turnover and winsorised at the 1% and 99% levels. Standard errors, clustered by firm region, in parentheses. The sample covers reporting UK firms over the period 2002-2015. Columns (1), (3) regress each of the employment variables on Director Collateral and a firm fixed effect alone. The regressions in Columns (2), (4) also include firm controls, region-time and (2 digit) industry-time fixed effects.

Table 7 reports the estimates with and without controls for the effect of collateral on labour market outcomes. A £1 rise in the total value of the residential real estate holdings of a firm's directors increases the firm's total wage bill by around 3p. The equivalent figure for Corporate Collateral is 6p. The employment estimate (0.0024) can be interpreted as an increase of £400,000 (in 2005 prices) in the total residential holdings of a firm's directors resulting in the hiring of approximately one additional worker. The equivalent figure is an increase of £300,000 of Corporate Collateral required to hire an extra worker. For labour inputs the gap between the two channels is therefore smaller. Additional identification tests for the labour market variables are provided in Tables 12 and 13 in Appendix A, with little impact on the results.

Recall that £1 of additional Corporate Collateral generated four times as much investment as £1 of additional Residential Collateral, whereas the increase in the wage bill is only twice as large.

We can only speculate on the reasons behind this. However, one explanation is that investment is disproportionately conducted by large firms which may be more reliant on Corporate Collateral. In contrast, smaller firms are responsible for a greater share of employment.

The two channels also have different implications for the marginal worker. Combining the estimated strength of the channels on total wages and employment allows us to estimate the wage paid to the marginal worker hired when collateral values increase. For instance, £400,000 of additional Residential Collateral will imply that the firm hires one more worker and pays around an additional £12,000 in wages (using the coefficient estimate of 0.0295). For corporate collateral, the analogous calculation estimates that the marginal worker is paid around £20,000, which is close to the median wage per employee rate paid by the firms in our sample. There are several interpretations for this difference. First, workers hired using the funds from increased director collateral may be of lower quality/wage, or hired on a part-time basis. Alternatively, there may be a greater lag between changes in director collateral values and the hiring of a worker, which would result in the wage appearing to be lower as the worker will only be paid for part of the firm's accounting year.

5.5 Sample Splits

Having established the quantitative importance of the collateral channels on average, we now turn to how the channels vary through time and across firms. To explore whether there are asymmetric effects of the two channels, we include in the baseline regression the interaction of firm collateral and a dummy that takes value 1 when house price growth in the firm's region is negative and 0 when it is positive.[24] Column (2) in Table 8 shows there is no obvious asymmetry in the impact of the Residential and Corporate Collateral Channels on investment. We also consider how our results vary if we split the sample into the pre- and post-crisis period (before and after 2007). Inspecting Columns (3) and (4) one sees that the Residential Collateral Channel is approximately the same across the two subsamples. In contrast, the Corporate Collateral Channel has weakened in the post crisis period.

We also consider how the strength of both channels varies with firm size, in columns (5) and (6) we present results conditional on firms being in two different subsamples. We consider small firms (using the UK definition of less than 50 employees) in column (5) and medium and large firms (greater than 50 employess) in column (6). The coefficients suggests that Corporate Collateral has a smaller impact on the investment decisions of small firms (7.3p vs 10.2p per £1 increase); however, the estimates are not statistically significant from one another. Intriguingly, though, the residential collateral channel appears to have a bigger impact on relatively larger firms.

There are several explanations for this counter-intuitive finding. It may be simply that larger firms are more sensitive to the value of their director's residential collateral. This seems unlikely but as described in Section 3, personal guarantees are still commonplace for larger firms. More importantly, however, is that the investment behaviour of small firms, and the ratio of Residential

[24] Just over 20% of our firm-year observations occur when the regional house price is falling.

Table 8: Investment: Sample Splits

	Investment						
	Baseline	HPI Asymmetry	Pre-Crisis	Post-Crisis	Small Firms	Medium/ Large	Largest Firms
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Residential Collateral	0.0207***	0.0207***	0.0214**	0.0270***	0.0165***	0.0651***	-0.2765
	(0.005)	(0.005)	(0.008)	(0.009)	(0.005)	(0.009)	(1.597)
Corporate Collateral	0.0843***	0.0823***	0.1160***	0.0532***	0.0730***	0.1018***	0.2392*
	(0.013)	(0.014)	(0.031)	(0.020)	(0.027)	(0.015)	(0.127)
Residential Collateral×HPI fall		0.0000					
		(0.000)					
Corporate Collateral×HPI fall		0.0008					
		(0.001)					
Cash Ratio	0.1415***	0.1402***	0.2194***	0.1096***	0.1045**	0.1595***	0.2054*
	(0.027)	(0.027)	(0.057)	(0.036)	(0.040)	(0.034)	(0.117)
Profit Margin	0.0916***	0.0927***	0.0891*	0.0730*	0.0788	0.1073***	0.5130***
	(0.027)	(0.027)	(0.048)	(0.041)	(0.056)	(0.035)	(0.165)
N	37291	37291	15232	20511	8607	27271	806
Adjusted R^2	0.26	0.26	0.33	0.29	0.24	0.29	0.31
Time FE	No	No	No	No	No	No	Yes
Region-time FE	Yes	Yes	Yes	Yes	Yes	Yes	No
Industry-time FE	Yes	Yes	Yes	Yes	Yes	Yes	No
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Firm region clustered standard errors in parentheses

$^{*}p < 0.10, ^{**}p < 0.05, ^{***}p < 0.01$.

Notes: The table reports the link between residential collateral, corporate collateral, and firm investment. The dependent variable, Investment, is defined as the change in fixed assets less depreciation. Director Collateral is the total value of residential property held by current directors of the firm, estimated as the average property value for current directors whose address is matched, multiplied by the number of current directors. Firm Collateral is the 2002 book value of firm Land and Buildings iterated forward using the regional house price index. Cash and Profits enter with a lag. All variables are scaled by the lag of firm turnover and winsorised at the 1% and 99% levels. Standard errors, clustered by firm region, in parentheses. The sample covers reporting UK firms over the period 2002-2015. All regressions except (9) include firm, region-time and (2 digit) industry-time fixed effects. Column (1) presents the baseline results. Column (2) is for the sub-sample where house prices have risen in the last year in firm's region, whilst Column (3) is the sub-sample where prices have fallen. Column (4) estimates the baseline regression for the period 2002-2006 whilst column (5) estimates for the period 2007-2015. Column (6) estimates the baseline regression for manufacturing firms. Column (7) estimates the baseline regression for *small* firms: those with 0-49 employees. Column (8) estimates the baseline regression for firms with 50 and more employees. Column (9) displays the results for firms for which the ratio of Director Collateral to Total Assets is less than 1%. This specification includes time and firm fixed effects only.

Collateral to investment, is very different for small firms. If we convert our coefficient into an elasticity rather than a £ per £ estimate small firms are more sensitive. To see this, note that we estimate a model equivalent to I=αR, where I is the £ value of investment and R is the £ value of Residential Collateral. The point estimate of α is about 3.95 times larger for medium/large than small firms (0.0651/0.0165). We can convert our estimate into an elasticity by using the expression $\frac{\Delta I}{I}=\alpha\frac{R}{I}\frac{\Delta R}{R}$. The median Residential Collateral to Investment ratio (R/I) is 5.23 times larger for small than medium/large firms (18.269/3.49). Thus, an estimated elasticity for the two groups is 30% larger for small than medium/large firms. This suggests that small firms are more sensitive to a 1% rise in the value of their Residential Collateral than large firms

As a final test, we examine whether director collateral affects the behaviour of the very largest of firms where the value Residential Collateral should be small compared to the size of the balance sheet. Specifically, in column (7) of Table 8, we limit our sample to the 114 firms in our sample who employ more than 10,000 people. As one would expect, for such firms, Residential Collateral does not have a statistically significant impact on firm behaviour, furthermore the sign is counter intuitive. However, the Corporate Collateral channel is stronger for these firms.

5.6 Director Equity

Our measure of Residential Collateral is the total value of the housing occupied by a firm's directors. However, this ignores that residential property is typically leveraged on purchase, and differences in encumberance may alter our results.[25] As discussed in Section 2, we use a mixture of housing transaction data and administrative mortgage data to estimate the equity company directors hold in their house over time.

While we can observe the mortgage behaviour of directors, these are still endogenous choices. A particular concern would be if the director remortgages their property to inject funds into the firm. This will generate negative comovement between Residential Equity and Firm Activity. As outlined in Section 2, our approach is to generate a *Passive* series for the equity a director holds in their house, based on our first observation of their home equity, and abstracting from any subsequent changes made, for example, refinancing. We contrast this an alternative *Active* measure where all remortgaging behaviour is included in the calculation of the loan principle. We provide further details on the construction of these series in Appendix F.

Table 9 presents regression results in which Residential Collateral is replaced by Residential Equity (both Passive and Active) as an explanatory variable. The near identical coefficients on the total value of the homes of firm directors versus the the total equity in the houses of firm directors underpins why we consider the key mechanism at work to be a collateral channel. If our estimates where simply due to a portfolio rebalancing effect from an increase in housing wealth, then

[25]The same argument applies to Corporate Collateral, however, we cannot observe the degree to which firms have borrowed against their property so are forced to abstract from this.

Table 9: Director Home Equity

	Investment					
	Active Equity Sample			Passive Equity Sample		
		Home Equity			Home Equity	
	Baseline	Active Alone	Active	Baseline	Active	Passive
	(1)	(2)	(3)	(4)	(5)	(6)
Residential Collateral	0.0247***			0.0444***		
	(0.005)			(0.009)		
Residential Equity (Active)		0.0523***	0.0274**		0.0527**	
		(0.012)	(0.011)		(0.022)	
Residential Equity (Passive)						0.0420**
						(0.018)
Corporate Collateral	0.0928***		0.1081***	0.0621***	0.0805***	0.0841***
	(0.017)		(0.016)	(0.021)	(0.021)	(0.021)
Cash Ratio	0.1410***		0.1438***	0.1487***	0.1539***	0.1559***
	(0.032)		(0.033)	(0.034)	(0.036)	(0.036)
Profit Margin	0.0969***		0.0626*	0.0921**	0.0526	0.0445
	(0.031)		(0.032)	(0.045)	(0.048)	(0.047)
N	28499	28767	28499	16966	16966	16966
Adjusted R^2	0.26	0.23	0.26	0.30	0.29	0.29
Region-time FE	Yes	No	Yes	Yes	Yes	Yes
Industry-time FE	Yes	No	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes

Firm region clustered standard errors in parentheses

$^{*}p < 0.10, ^{**}p < 0.05, ^{***}p < 0.01.$

Notes: The table reports the link between residential collateral, corporate collateral, and firm investment. The dependent variable, Investment, is defined as the change in fixed assets less depreciation. Director Collateral is the total value of residential property held by current directors of the firm, estimated as the average property value for current directors whose address is matched, multiplied by the number of current directors. Director Home Equity is the total value of residential equity held by current directors of the firm, estimated as the average residential equity for current directors for matched directors, multiplied by the number of current directors. Firm Collateral is the 2002 book value of firm Land and Buildings iterated forward using the regional house price index. Cash and Profits enter with a lag. All variables are scaled by the lag of firm turnover and winsorised at the 1% and 99% levels. Standard errors, clustered by firm region, in parentheses. The sample covers reporting UK firms over the period 2002-2015. All regressions include firm fixed effects. Column (1) presents the baseline results. Two measures of director home equity are calculated: *Active,* and *Passive.* The *Active* measure updates estimates of a director's home equity if they subsequently remortgage their property, whilst the *Passive* measure does not and is based on the evolution of their home equity based on their initially observed equity/mortgage terms. Column (2) regresses Investment on Active Home Equity alone, with Column (3) including firm controls, region-time, and (2 digit) industry-time fixed effects. Columns (4)-(6) are for the reduced sample for which Passive Home Equity is non-missing. Column (4) repeats the baseline regression, with (5) and (6) replacing Director Collateral with Active and Passive Home Equity respectively, with both regressions including firm controls and region-time, (2 digit) industry-time fixed effects.

accounting for the amount of equity in the home should make a difference to our estimates. A 1% increase in house prices has different consequences for the wealth of a director depending on the size of the mortgage, holding house value fixed. Thus, we would expect to see different coefficients on our Residential Collateral measure versus our Residential Equity measure if wealth effects where at work. In contrast, if collateral constraints are at work, then the distinction between housing value and housing equity is less important. If the director owns a £100,000 home a 1% increase in house prices generates an additional £1000 of pledgeable net worth regardless of the current equity in the home. Hence, the fact that our regressions are revealing that a £1 increase in Residential Equity has the same effect as a £1 increase in Residential Collateral suggests it is a collateral channel at work.

6 Macroeconomic Consequences

In this section we illustrate the macroeconomic implications of our firm-level estimates of the residential collateral channel, and how they compare to the corporate collateral channel.

6.1 Back-Of-The-Envelope-Calculation

Our first pass is to perform a simple back-of-the-envelope calculation combining the firm-level estimates with aggregate numbers for total firm investment and wages, and director and commercial collateral. We estimate that in 2012 the total value of residential property held by company directors is around £1,100 Billion,[26] with the value of commercial property held by non-CRE companies around 4 times smaller at £280 Billion (IPF, 2014). The baseline regression estimates find that a £1 increase in residential collateral increases investment by 2.1p and total wages by 3.0p. Similarly, a £1 increase in corporate collateral increases investment by 8.4p and total wages by 5.9p. Aggregate UK investment at this time was £220 Billion, whilst total wages were £870 Billion. Combining these numbers implies that a 1% increase in real estate prices increases investment by 0.11% and total wages by 0.04% through the residential collateral channel, and 0.11% and 0.02% respectively through the corporate collateral channel. Of course, such a calculation omits general equilibrium feedback effects. These are explored next in an estimated DSGE model.

6.2 Insights From A Theoretical Model

To measure the relative strength of the residential and corporate collateral channels and to explore potential feedback effects that the partial equilibrium regression design of the previous sections could

[26] To show this, we use the following formula $V = n_{D,2012} \times p_{H,2012} \times \frac{\bar{p}_D}{\bar{p}_{ALL}}$, where V is the total value of residential director collateral in 2012, $n_{D,2012} \approx 4,692,000$ is the number of unique company directors (that are not companies) in 2012, $p_{H,2012} \approx £160,000$ is the average house price in England and Wales in 2012, $\bar{p}_D \approx £244,000$ is the average transaction price of houses bought by directors in our sample, and $\bar{p}_{ALL} \approx £162,000$ is the average price of all transactions throughout the whole sample. This gives an estimate of $V \approx £1.13 trillion$.

not account for, this section extends the general equilibrium model of Liu, Wang, and Zha (2013) by incorporating both collateral channels.

The model builds on Kiyotaki and Moore (1997) and features two types of agents: a patient household who is the supplier of funds and an impatient entrepreneur whose borrowing capacity is constrained by the market value of physical assets it owns. The entrepreneur produces output using physical capital, commercial land and labour input supplied by the household. An additional key feature of our model is the introduction of an unproductive asset to the entrepreneurial sector: residential land. The entrepreneur derives utility flow from holding residential land, and it can also be used as collateral, thereby capturing the residential collateral channel.

The model is log-linearised to fit six UK time series over 1975Q3-2015Q1 with Bayesian methods: real house prices, the inverse of the relative price of investment, real per capita consumption, real per capita investment, real per capita lending to non-financial corporations and per capita hours worked. The full description of the model and details about the estimation and calibration are presented in Section H of the Appendix.

Credit Constraint A key feature of the model is the assumption that the entrepreneur's optimisation problem is subject to an endogenous credit constraint. This takes the following form:

$$B_t \leq \theta \mathbb{E}_t \left[q_{l,t+1} \left(L_{c,t} + \omega L_{r,t} \right) + q_{k,t+1} K_t \right], \tag{6.1}$$

where B_t is the real value of debt issued by the entrepreneur, θ is the loan-to-value ratio (LTV), $q_{l,t}$ is the market price of land, $L_{c,t}$ is entrepreneurial commercial land, $L_{r,t}$ is entrepreneurial residential land, $q_{k,t}$ is the relative price of investment in consumption units and K_t is physical capital. The parameter ω measures how collateralisable residential land is relative to commercial land. We argue that the parameter ω is a reduced-form way of controlling for the strength of the residential collateral channel in business cycle analysis.

The Impact of Housing Demand Shocks Households in our model are also owners of land, $L_{h,t}$, and they derive utility from such land holdings. The utility flow is subject to stochastic disturbances referred to as housing demand shocks. This shock features prominently in Liu, Wang, and Zha (2013) and can explain about one third of US business cycle fluctuations via the following mechanism: (i) a housing demand shock that raises the household's marginal utility of land increases household demand for land and therefore land prices; (ii) higher land prices increases the entrepreneur's net worth, triggering competing demand for land between the two sectors that drives up the land price further; (iii) increased net worth expands the entrepreneur's capacity to borrow more to finance investment and production; (iv) the expansion adds to household wealth and raises land prices further, thereby generating further ripple effects. The collateral channel amplifies and propagates the housing shock, leading to dynamic expansions of investment, hours, and output.

We build on this mechanism by introducing entrepreneurial residential land. To quantify the relative importance of the residential collateral channel, we solve and simulate the model under different values of ω in the credit constraint 6.1. Our main goal is to see whether increasing the value of ω (and thereby increasing the collateralisability of residential real estate owned by the entrepreneur) would change the dynamic propagation of housing shocks to the macroeconomy. This exercise can be interpreted as a way of assessing the importance of the residential collateral channel. It is important to note that, while changing ω, we keep the steady-state level of corporate debt fixed.[27]

For this exercise, we use a combination of calibrated and estimated parameters to fit the model to UK data. An important aspect of our calibration is the assumption that 20% of total residential land is owned by the entrepreneur in steady state. This introduces a non-trivial source of residential collateral for the production sector. We argue that this is a conservative estimate of the total residential collateral held by company directors. We estimate that the value of the homes of company directors in 2012 was about £1,100 Billion. Together with the estimate for the total value of UK residential properties being £4,600 Billion (IPF, 2014), this suggests that around 25% of the residential housing stock by value is owned by company directors.[28]

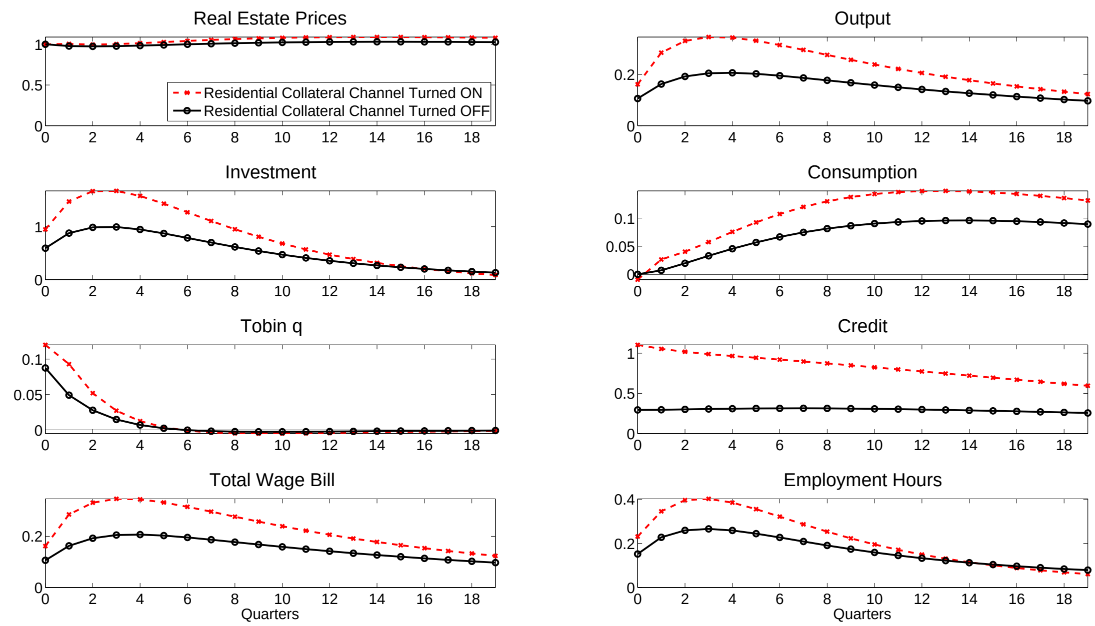
To explore how important the residential collateral channel may be in affecting macroeconomic fluctuations, we first analyse the effects of the housing demand shock *with* and *without* the residential collateral channel. To perform this exercise, Figure 2 shows the impulse response functions for the baseline ($\omega = 1$) and for the model without the residential collateral channel ($\omega = 0$). In the baseline, depicted by the red crossed lines, a shock which increases house prices by 1% on impact has a 0.3-0.4% peak effect on output, the total wage bill and employment, and it has a 1% and 1.5% peak impact on corporate credit and investment, respectively. In the counterfactual economy, the impact of the housing shock drops substantially. In fact, the black circled lines in Figure 2 show that a housing shock of the same magnitude has about a *40%* smaller effect on all macroeconomic variables relative to the baseline.

A key conclusion from this simple exercise is to illustrate that the partial equilibrium effect estimated in the previous section may play an important role in understanding macroeconomic fluctuations as well. The model of Liu, Wang, and Zha (2013) focuses on the role of productive (commercial) land as collateral and ignores the role of residential land as a source of collateral for producers. Though unproductive, residential land may be a quantitatively important source of collateral for producers. Ignoring the residential collateral channel may therefore underestimate the macroeconomic relationships between real estate prices, credit and business cycle fluctuations.

[27]This means that when we set $\omega = 0$, then the credit constraint 6.1 becomes $B_t \leq \theta \mathbb{E}_t \left[q_{l,t+1} \left(L_{c,t} + \Phi \right) + q_{k,t+1} K_t \right]$, where the level of Φ is set to equal the steady-state of $\omega \bar{L}_r$ in the baseline model. In essence, some fraction of the endogenous credit constraint become exogenous in order to ensure that the steady-state level of B is unchanged across models.

[28]This is a main conceptual departure from the model of Liu, Wang, and Zha (2013), where residential land is owned entirely by the household.

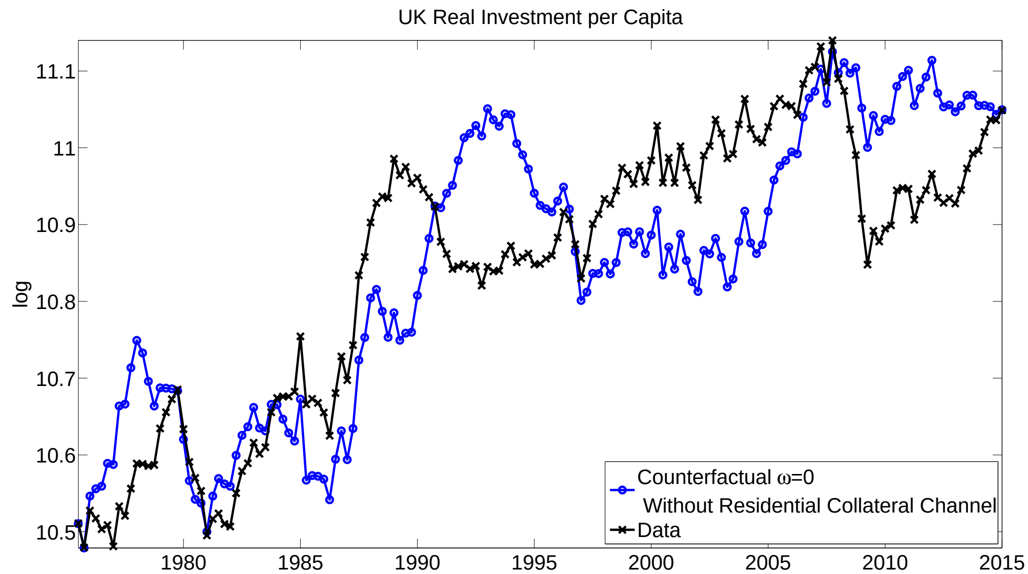
Figure 2: The Impact of a Housing Demand Shock in the DSGE Model: The Role of the Residential Collateral Channel



Notes: The impulse responses are normalised to raise the real estate price by 1% on impact. The effects are measured in %-deviations from the steady-state. The posterior modes of the estimated parameters are used to compute the impulses.

The UK Business Cycle and the Residential Collateral Channel To shed light on the historical importance of the residential collateral channel over the last four decades of UK business cycles, we use our estimated model to compute the counterfactual path of investment that would have realised if the residential collateral channel had been absent. To perform this counterfactual exercise we proceed in three steps. First, we estimate the model and store the estimated series of structural shocks. Second, we change ω from the baseline 1 to 0, thereby shutting down the residential collateral channel, and compute policy functions for this new model. Third, we combine the estimated structural shocks from step 1 with the new policy functions in step 2 to compute the counterfactual path of the variables of interest. By doing so, we ask: how would the propagation of all structural shocks (including that of the housing shock) to investment have changed if the collateral value of residential land held by entrepreneurs had been zero? Figure 3 shows the counterfactual (circled blue line) path of investment along with the actual (black line) path in the data. The result suggests that the residential collateral channel played a major role in the fall of investment in the early 1990s as well as during the Great Recession. Conversely, the channel had a sizeable positive contribution to the economic expansion during the housing boom of the late 1980s and early 2000s.

Figure 3: The Importance of the Residential Collateral Channel over the UK Business Cycle



Note: The counterfactual path of the investment is conditional on using all estimated structural shocks before changing $\omega = 1$ to $\omega = 0$. The units of both paths are in natural logarithm.

7 Conclusion

The global housing boom of the 2000s and the Great Recession that followed demonstrated striking correlations between real estate prices and economic activity. To explain these phenomena, the literature has mainly focused on mechanisms operating through household balance sheets and consumer demand as well as on mechanisms operating through corporate balance sheets and firm activity. Our paper highlights an additional, previously unexplored, channel which links household balance sheets with firm activity via the residential real estate collateral of company directors. We have shown that a £1 increase in the total value of directors' residential real estate leads the directors' firm to increase investment by around £0.02 and to spend £0.03 more on wages. We have also corroborated the corporate collateral channel and found that a £1 increase in the value of a firm's corporate real estate leads the firm to increase investment by around £0.08 and to spend £0.06 more on wages.

To our knowledge the results on the residential collateral channel have no analogue elsewhere in the literature and our findings are wholly novel. Our evidence on the corporate collateral channel complements other studies in the literature, most notably Chaney, Sraer, and Thesmar (2012), and we obtain similar estimates with an alternative data set. Nonetheless, we correct several deficiencies in the existing literature by using a dataset that is not restricted to large listed firms and can accurately pin down the region where a company is located rather than relying on the HQ location. We showed that a simple general equilibrium model with credit constraints can embed both collateral channels, and we argued that the residential collateral channel can play an important role in propagating house price shocks to the wider economy.

In terms of the policy implications of the analysis, the link between asset prices and activity has led to calls for macroprudential policy targeted at the housing market to limit the extent of property price cycles. This would, it is argued, reduce the severity of recessions. However, the direction of causation between property prices and the economy must be determined to evaluate the effectiveness of such policies. This paper highlights two such channels, quantifying the causal impact of a change in property prices on firm activity, acting through a relaxation of residential and corporate collateral constraints. Moreover, by separately identifying the impact of both channels, operating through the residential real estate of firm directors and commercial real estate held by firms, our paper informs the policy debate on the macroprudential regulation of both real estate markets. Our results suggest that a reduction in the volatility of real estate prices would reduce economic volatility.

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A Additional Regressions

A.1 Determinants of Property Ownership in 2002

Table 10: Determinants of Property Ownership in 2002

Commercial Property			
		Ownership	Value
		(1)	(2)
Assets	2nd quintile	0.2139***	0.1412***
		(0.034)	(0.055)
	3rd quintile	0.3339***	0.0822
		(0.035)	(0.057)
	4th quintile	0.4759***	0.1575***
		(0.035)	(0.057)
	5th quintile	0.5546***	0.3295***
		(0.036)	(0.058)
Margins	2nd quintile	0.0358	0.1100**
		(0.035)	(0.056)
	3rd quintile	0.0436	0.0927*
		(0.034)	(0.056)
	4th quintile	0.0325	-0.0246
		(0.035)	(0.056)
	5th quintile	-0.0297	-0.1066*
		(0.034)	(0.055)
Age	2nd quintile	0.0949***	0.0538
		(0.033)	(0.054)
	3rd quintile	0.1289***	0.0339
		(0.034)	(0.055)
	4th quintile	0.1444***	0.1070*
		(0.034)	(0.055)
	5th quintile	0.2363***	0.1248**
		(0.036)	(0.057)
	N	1735	1735
	Adjusted R^2	0.27	0.22
	Region FE	Yes	Yes
	Industry FE	Yes	Yes

Standard errors in parentheses

$^{\star}p < 0.10, ^{\star\star}p < 0.05, ^{\star\star\star}p < 0.01$.

Notes: The table reports the link between firm characteristics and property ownership, as well as its value, in 2002. Firms are placed into 5 quintiles based on the size of Total Assets in 2002. Similarly, 5 quintiles are formed for firm age in 2002 and the ratio of Operating Profits to Total Assets. Both regressions include region and industry fixed effects. The dependent variable in column (1) is a dummy variable taking value 1 when the firm's value of Land and Buildings is positive in 2002. The dependent variable in column (2) is the book value of Land and Buildings in 2002.

A.2 Firm Identification

Table 11 presents additional results to address concerns regarding the exogeneity and measurement of Corporate Collateral.

Table 11: Firm Collateral: Identification

	Investment					
	Baseline	IV HPI	CRE	Single Region Firms	2002 Market Value Land	1 Year Book Value Fix
	(1)	(2)	(3)	(4)	(5)	(6)
Residential Collateral	0.0207***	0.0182***	0.0194***	0.0224***	0.0184***	0.0368***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.004)	(0.004)
Corporate Collateral	0.0843***	0.0805***	0.1232***	0.0702***	0.0838***	-0.0031
	(0.013)	(0.013)	(0.024)	(0.017)	(0.031)	(0.013)
Cash Ratio	0.1415***	0.1424***	0.0871**	0.1459***	0.1639***	0.1520***
	(0.027)	(0.029)	(0.043)	(0.032)	(0.044)	(0.019)
Profit Margin	0.0916***	0.0790***	0.0868**	0.0560	0.0777**	0.0560**
	(0.027)	(0.028)	(0.038)	(0.035)	(0.037)	(0.023)
N	37291	33872	18098	23934	14393	57696
Adjusted R^2	0.26	0.27	0.26	0.24	0.22	0.28
Region-time FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry-time FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes

Firm region clustered standard errors in parentheses

$^{\star}p < 0.10, ^{\star\star}p < 0.05, ^{\star\star\star}p < 0.01$.

Notes: The table reports the link between director collateral, corporate collateral, and firm investment. The dependent variable, Investment, is defined as the change in fixed assets less depreciation. Director Collateral is the total value of residential property held by current directors of the firm, estimated as the average property value for current directors whose address is matched, multiplied by the number of current directors. Firm Collateral is the 2002 book value of firm Land and Buildings iterated forward using the regional house price index. Cash and Profits enter with a lag. All variables are scaled by the lag of firm turnover and winsorised at the 1% and 99% levels. Standard errors, clustered by firm region, in parentheses. The sample covers reporting UK firms over the period 2002-2015. All regressions include firm, region-time and (2 digit) industry-time fixed effects. Column (1) presents the baseline results. Columns (2), (3) calculate Firm Collateral by iterating forward the 2002 book value of Land and Buildings using the instrumented house price index, and commercial real estate price index, respectively. Column (4) restricts the baseline regression to firms whose trading addresses are all contained in one region. Column (5) calculates Firm Collateral using the market, rather than book, value of Land and Buildings in 2002. This is calculated using a *LIFO* recursion, with the market value of land in the base year taken from the value of Land and Buildings when the firm was first incorporated. Column (6) calculates Firm Collateral using the one-year lagged book value of Land and Buildings, iterated forward using the regional house price index.

A potential concern with our identification strategy for the corporate collateral channel is that certain firms could be important enough in their local area to affect local real estate prices through their behaviour. As many of the firms in our dataset are not large, this may unlikely. Nevertheless, to address this we present our results following the IV strategy adopted by Mian and Sufi (2011) and Chaney, Sraer, and Thesmar (2012) among others. Specifically, we instrument local authority level house prices by interacting local geographical constraints on housing supply with aggregate shifts in the interest rate on 2-year 75%-LTV mortgages.[29] When mortgage rates fall, the demand

[29] This was the most standard mortgage product in the UK during our sample.

for real estate rises. If local housing supply is very elastic, the increased demand will translate mostly into more construction rather than higher prices. If local housing supply is very inelastic on the other hand, the increased demand will translate mostly into higher prices rather than more construction. Our measure of local housing supply constraints is the share of all developable land that was developed in 1990. The data are from Hilber and Vermeulen (2016) who originally derived the measure from the Land Cover Map of Great Britain using satellite images, allocating land to 25 cover types on a 25 meter grid.[30] We thus estimate, for region j, at date t, the following first-stage regression to predict house prices:

$$L^P_{j,t} = b_{0j} + b_{1t} + b_2 \times elasticity_j \times i_t + u_{jt}, \tag{A.1}$$

where $elasticity_j$ measures constraints on land supply at the local authority level. The term i_t is the nationwide mortgage rate at monthly frequency, b_{0j} is a region fixed effect, and b_{1t} captures macroeconomic fluctuations in real estate prices. Region specific shocks to real estate prices, some of which are potentially due to the behaviour of the firm, are contained in u_{jt}. Since u_{jt} contains the terms we wish to abstract, we can generate a instrumented house price index using the fitted values from A.1. We can then instead use the predicted house price series to compute firm collateral values. The results from re-estimating the regression the instrumented are very similar to our baseline results. These estimates are presented in column (2) of Table 11.

Another criticism of our estimated results for the corporate collateral channel is the use of residential house prices to proxy changes in the market value of firm collateral. We therefore re-estimate the baseline regression using commercial real estate prices to compute firm collateral. The data on CRE prices comes from the Investment Property Databank, however, as this is only available for a range of major UK cities (as opposed to local authority level), we lose around 50% of the observations compared to the baseline estimates in Table 4. The results, presented in column (2) of Table 11, show similar estimates of both the corporate and residential collateral channels, suggesting that the use of residential real estate prices is not a bad proxy.

We also assume that the appropriate price index with which to value a firms real estate is the index for the region where its registered office is located. This may be problematic if the firm has several far flung locations or has an office in a location separate from where its main activities take place. We do, however, see in our dataset the addresses of all locations where the firm has operations ("Trading Addresses"). Column (4) in table 4 presents results where we focus attention on firms the operate in a single region only.

The book value of Land and Buildings in 2002 may also be a poor proxy for the market value. To address this, we impute market values from the book values by adopting the recursion method used in Hayashi and Inoue (1991), Hoshi and Kashyap (1990) and Gan (2007) amongst others, which

[30] The data covers England (excluding 22 local authorities in Wales), so we include only 150 local authorities in our IV regressions.

treats the valuation of land in a "last in, first out" (LIFO) fashion. The recursion can be written as follows:

$$\begin{aligned}\tilde{L}^Y_{i,j,t} &= \begin{cases}\tilde{L}^Y_{i,j,t-1}\frac{L^P_{j,t}}{L^P_{j,t-1}} + dB_{i,j,t} & if\ dB_{i,j,t} \geq 0\\ L^Y_{i,j,t-1}\frac{L^P_{j,t}}{L^P_{j,t-1}} + dB_{i,j,t}\frac{L^P_{j,t}}{L^B_{i,j,t-1}} & if\ dB_{i,j,t} < 0\end{cases}\\ L^B_{i,j,t} &= \begin{cases}L^P_{j,t} & if\ dB_{i,j,t} \geq 0\\ L^B_{i,j,t-1} & if\ dB_{i,j,t} < 0,\end{cases}\end{aligned} \tag{A.2}$$

where $L^Y_{i,j,t}$ is the market value of land owned by firm i in region j at time t, $L^P_{j,t}$ is the market price of land in region j, $L^B_{i,j,t}$ is the price at which land was last bought by firm i, and $dB_{i,j,t} = B_{i,j,t} - B_{i,j,t-1}$ is the change in the book value of land, $B_{i,j,t}$, owned by firm i.

To implement this method one needs to make an assumption regarding the market value of land in the base year, $L^Y_{i,j,0}$. We take as the base year the first recorded value of land and buildings within three years of incorporation, at which time we assume that the market value and book value of land and buildings are the same. Additionally, whenever the book value of land and buildings is zero, we infer that the market value is also zero.

Given, a time series for $\tilde{L}^Y_{i,j,t}$, we then recompute our Corporate Collateral measure by fixing land holdings at the market value in 2002, $\tilde{L}^Y_{i,j,2002}$, and iterating forward using the regional price index. Column (5) of Table 11 shows that we obtain near identical results by doing this.

We also test the extent to which our choice to fix the initial stock of collateral as opposed to letting it vary may influence our results. To do this we redefine collateral as:

$$Corporate\,Collateral_{i,j,t} = L^Y_{i,j,t-1}\frac{L^P_{j,t}}{L^P_{j,t-1}},$$

where $L^Y_{i,j,t-1}$ is the previous year's book value of Land and Buildings reported by the firm. This means that investment decisions in previous years now affect our collateral measure (although, for obvious reasons, we do not include investment in the current period). Column (6) of Table 11 presents the regression estimates when corporate collateral is redefined in this fashion. The coefficients on both the labour variables and investment are diminished, particularly for investment. One explanation for the particularly diminished results for investment is that investment in Land and Buildings has a negative serial correlation: if a firm bought a building in the previous period it is unlikely to invest in the current period, which would bias down the coefficient estimate.[31] This finding illustrates our reasoning behind the use of our baseline collateral measure. Importantly for the robustness of our main result: the coefficient on Residential Collateral is insensitive to changes in the definition of Corporate Collateral.

[31] Indeed, if one looks at investment excluding Land and Buildings the coefficients is not effected by this redefinition of Corporate Collateral.

A.3 Identification for Labour Market Variables

Table 12: Residential Collateral and Total Wages: Identification

	Total Wages									
		3 Year	5 Year	10 Year	2002	Dir. Controls		Director		Director
		Director	Director	Director	Director	All	Multi-	Different	Tradables	Known
	Baseline	Fix	Fix	Fix	Fix	Dir.	Firm	Regions	Firms	S.holder
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Residential Collateral	0.0295***	0.0243***	0.0237***	0.0755***	0.0377***	0.0290***	0.0260***	0.0760***	0.0605***	0.0404***
	(0.003)	(0.004)	(0.005)	(0.018)	(0.005)	(0.003)	(0.005)	(0.013)	(0.006)	(0.005)
Corporate Collateral	0.0588***	0.0683***	0.0708***	0.0948***	0.0570***	0.0595***	0.0575***	0.0576***	0.1666***	0.0626***
	(0.010)	(0.010)	(0.009)	(0.015)	(0.011)	(0.010)	(0.011)	(0.021)	(0.024)	(0.011)
Cash Ratio	0.0308***	0.0271**	0.0232*	-0.0147	0.0410***	0.0275**	0.0189	0.0443**	0.0205	0.0068
	(0.011)	(0.012)	(0.013)	(0.019)	(0.012)	(0.011)	(0.014)	(0.022)	(0.015)	(0.018)
Profit Margin	-0.1829***	-0.1809***	-0.1763***	-0.1334***	-0.1946***	-0.1840***	-0.2189***	-0.2040***	-0.1413***	-0.1867***
	(0.016)	(0.016)	(0.022)	(0.032)	(0.018)	(0.016)	(0.023)	(0.027)	(0.024)	(0.025)
N	37291	32339	27596	10845	33540	36853	20971	16075	10728	21464
Adjusted R^2	0.85	0.87	0.88	0.91	0.85	0.85	0.88	0.83	0.82	0.87
Director Controls	No	No	No	No	No	Yes	Yes	No	No	No
Add. Firm Controls	No	No	No	No	No	Yes	Yes	No	No	No
Region-time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Firm region clustered standard errors in parentheses

${}^{*}p < 0.10, {}^{**}p < 0.05, {}^{***}p < 0.01$.

Notes: The table reports the link between residential collateral, corporate collateral, and the firm's total wages. The dependent variable, Total Wages, is remuneration. Residential Collateral is the total value of residential property held by current directors of the firm, estimated as the average property value for current directors whose address is matched, multiplied by the number of current directors. Corporate Collateral is the 2002 book value of firm Land and Buildings iterated forward using the regional house price index. Cash and Profits enter with a lag. All variables are scaled by the lag of firm turnover and winsorised at the 1% and 99% levels. Standard errors, clustered by firm region, in parentheses. The sample covers reporting UK firms over the period 2002-2015. All regressions include firm, region-time and (2 digit) industry-time fixed effects. Column (1) presents the baseline results. Columns (2)-(4) fix the composition of directors, and the houses they own, at the firm as they were 3,5,10 years ago, respectively. Changes in the value of residential collateral since this date are calculated using changes in the relevant local real estate price indices since that date. Column (5) fixes the composition of directors and their houses in 2002. Column (6) augments the baseline regression with a number of director characteristics (discussed in detail in the Appendix) averaged at the firm level, and also interacts them with the level of real estate prices. Firm characteristics in 2002 (quintiles for age, size, and profitability) interacted with real-estate prices are also included. To column (6), column (7) adds director controls that can be calculated for individuals who are directors of multiple companies. Specifically, it adds as director controls the average credit score and total asset growth at *other* companies they are a director of. In column (8) Director Collateral is measured as the total value of residential property held by current directors of the firm that live in a different region to their firm (restricted to firms whose trading addresses are all in one region). Column (9) presents the results of the baseline regression for manufacturing firms. In column (10) Director Collateral is measured as the total value of residential property held by current directors of the firm who are also shareholders of the firm.

Table 13: Residential Collateral and Employment: Identification

	Employment									
		3 Year	5 Year	10 Year	2002	Dir. Controls		Director		Director
		Director	Director	Director	Director	All	Multi-	Different	Tradables	Known
	Baseline	Fix	Fix	Fix	Fix	Dir.	Firm	Regions	Firms	S.holder
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Residential Collateral	0.0024***	0.0021***	0.0021***	0.0048***	0.0033***	0.0024***	0.0019***	0.0044***	0.0032***	0.0033***
	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)
Corporate Collateral	0.0034***	0.0040***	0.0044***	0.0058***	0.0029***	0.0034***	0.0035***	0.0033***	0.0085***	0.0047***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)
Cash Ratio	0.0009	-0.0000	-0.0007	-0.0026*	0.0011	0.0007	-0.0008	0.0010	-0.0003	-0.0015
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Profit Margin	-0.0053***	-0.0053***	-0.0051***	-0.0052***	-0.0057***	-0.0055***	-0.0053***	-0.0060***	-0.0036***	-0.0081***
	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.002)
N	37291	32339	27596	10845	33540	36853	20971	16075	10728	21464
Adjusted R^2	0.89	0.90	0.91	0.94	0.89	0.89	0.92	0.89	0.86	0.91
Director Controls	No	No	No	No	No	Yes	Yes	No	No	No
Add. Firm Controls	No	No	No	No	No	Yes	Yes	No	No	No
Region-time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Firm region clustered standard errors in parentheses

$^{\star}p < 0.10, ^{\star\star}p < 0.05, ^{\star\star\star}p < 0.01.$

Notes: The table reports the link between residential collateral, corporate collateral, and the firm's employment. The dependent variable, Employment, is the number of employees of the firm. Residential Collateral is the total value of residential property held by current directors of the firm, estimated as the average property value for current directors whose address is matched, multiplied by the number of current directors. Corporate Collateral is the 2002 book value of firm Land and Buildings iterated forward using the regional house price index. Cash and Profits enter with a lag. All variables are scaled by the lag of firm turnover and winsorised at the 1% and 99% levels. Standard errors, clustered by firm region, in parentheses. The sample covers reporting UK firms over the period 2002-2015. All regressions include firm, region-time and (2 digit) industry-time fixed effects. Column (1) presents the baseline results. Columns (2)-(4) fix the composition of directors, and the houses they own, at the firm as they were 3,5,10 years ago, respectively. Changes in the value of residential collateral since this date are calculated using changes in the relevant local real estate price indices since that date. Column (5) fixes the composition of directors and their houses in 2002. Column (6) augments the baseline regression with a number of director characteristics (discussed in detail in the Appendix) averaged at the firm level, and also interacts them with the level of real estate prices. Firm characteristics in 2002 (quintiles for age, size, and profitability) interacted with real-estate prices are also included. To column (6), column (7) adds director controls that can be calculated for individuals who are directors of multiple companies. Specifically, it adds as director controls the average credit score and total asset growth at *other* companies they are a director of. In column (8) Director Collateral is measured as the total value of residential property held by current directors of the firm that live in a different region to their firm (restricted to firms whose trading addresses are all in one region). Column (9) presents the results of the baseline regression for manufacturing firms. In column (10) Director Collateral is measured as the total value of residential property held by current directors of the firm who are also shareholders of the firm.

B UK Accounting Data

B.1 Company Reporting Rules in the United Kingdom

The statutory reporting requirements for companies registered in the United Kingdom are mainly governed by the Companies Act 2006 and prior to that the Companies Act 1985. The last provisions of the Company's Act 2006 came into force in 1st October 2009. This means that firms in the United Kingdom operated varying reporting standards during our sample period, the most relevant change in standards for our purposes is the treatment of director's addresses which is discussed in detail below. The Act covers private and public limited companies. Other types of companies, for instance Partnerships or LLPs, are covered by separate legislation but have their own reporting standards and still must file accounts at the registrar. As described below, these are omitted from our analysis to ensure a consistent legal basis for the type of firm under consideration.

Companies House is the Registrar of companies in the United Kingdom. The agency has the responsibility for examining and storing all the statutory information that companies in the United Kingdom are required to supply. Companies House also has the responsibility to make the filed information public; however, there are exceptions to what a company (or individuals that run or exert significant control over a company) have to make publicly available. While Companies House filings often go hand with a companies tax returns (annual accounts can be filed jointly with a tax return), this information held by the Registrar is not directly used for the purposes of calculating corporation tax. Tax returns by companies are dealt with separately by Her Majesty's Revenue and Customs, the United Kingdom Tax Authority.

Reporting Requirements. At the end of the a company's financial year a company must prepare a set of statutory annual accounts that they file with Companies House. These include a version of the firm's balance sheet and profit and loss account. All limited company's are required to report in some way or another to Companies House. However, reporting requirements, particularly over the annual accounts, vary by firm size (see part 1 of the Companies House guide for additional details).[32]

Companies House must also be informed of the firms' name, registered office, share capital and charges against the company's assets for the purposes of securing a loan. Companies must also maintain, inter-alia, a register of directors (including the director's usual residential address). If any of these details change the company must inform Company's House by via an event driven filing. Key for our purposes is the information on director's usual residential addresses. One of the last provisions to be implemented in the Company's Act 2006, on the 1st October 2009, allowed company directors the right to only publicly disclose a service address rather than a usual residential address (although directors are still required to report their residential address to Companies House).

[32] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/533350/GP2_Life_of_a_company_Part_ver0.1-6.pdf

Time Lags. Companies have 21 months from incorporation to file their first set of accounts with Companies House. Subsequent annual accounts must be filed within 9 months of the company's financial year end for private companies and 6 months of the company's financial year end for public companies. Companies can amend the accounts retrospectively to fix errors and present data revisions. Companies can also amend the end of their accounting year (but not retroactively), which can lead to irregular accounting windows of different lengths than a year. However, companies must file accounts every 18 months.

Event driven Companies House filings have shorter time lags. For instance, all appointments, changes to personal details and cessations of a company's directors should be reported to Companies House within 14 days of the changes being made.

B.2 BvD's Collection and Coverage of Firms in the United Kingdom

Companies House is the original source of our data but our direct source is Bureau van Dijk (BvD) who aggregate the data and provides a workable interface to access it. For the United Kingdom and the Republic of Ireland, BvD provides firm-level data through a product called FAME (Financial Analysis Made Easy). This is distinct from the more commonly used Amadeus and Orbis products provided by BvD which cover firms at the European and Global level respectively (although UK firms form a subset in both data sets).

BvD does not source its data from Companies House directly. In between Companies House and BvD is another data provider, Jordans, with whom we have no direct contact. Jordans serve as the direct source for BvD. In the FAME user guide, BvD describes the logistics of the data collection procedure as follows:

Once accounts are filed at Companies House they are processed and checked, put onto microfiche and made available to the public. Companies House aim for a turnaround time of 7-14 days, however this will increase at peak times (October).

Jordans collect data from Companies House daily and transfer it from microfiche to their database with a turnaround time of 3-5 days. This may take longer at peak times of the year (October) and also if figures appear to be incorrect and need to be rechecked with Companies House.

Bureau van Dijk collect data from Jordans on a weekly basis and create the appropriate search indexes to link with the FAME search software. These indexes are then tested and published to the internet server within 48 hours of receiving the data.

In theory, this time frame would imply that most live companies in the Bureau van Dijk database would have their latest accounts filed within the past year (9 months after the firm's financial year plus one-two month's processing time) but lags of two years are not uncommon. Given that lags can occur at four different stages (the filing stage and the three processing stages that follow), we have not been able to determine the root cause of this.

There are four sub-databases in FAME (A,B,C and D) which are ordered by the size of the company as determined by different thresholds in their accounts (e.g. balance sheet size). We have access to and use data from all four databases to achieve the widest possible coverage.

There is conflicting information regarding how long inactive companies remain in the FAME database. When the Bank of England contacted BvD regarding this issue, BvD's claim was that Jordans (their data provider) would only keep inactive companies in the database for five years, so those firms would be lost from the source material. However, BvD would then (on a quarterly cycle) re-upload the missing companies from their own archives ensuring that no data lost from FAME or their other products. However, this claim may not be accurate. From inspecting different vintages of the FAME data set it was that firms did exit the database. For instance, almost 50% of firms in the database in January 2005 were not present 10 years later. Furthermore, some 3 million companies left the database between 2013 and 2014.

B.3 Treatment of the BvD UK Accounting Data

B.3.1 The Sample of BvD Discs Used

The Bank of England received DVDs and later Blu-Ray discs from BvD on a monthly basis. These discs contained a snapshot of the FAME database for UK firms during the month in question. We refer to these discs as different vintages of the database. From month to month, the database is updated both as companies filed new annual accounts and as companies conducted event driven filings with Company's House (such as form CH01 which is used to notify Companies House of a change in the details of a company's directors). However, for the majority of firms there is no change from one month to the next as no new filings take place.

Our general principle was to sample these discs at a six monthly frequency. We did not pursue a higher frequency as the cost in terms of the amount of time needed to process each disc and the capacity required to store the information was excessive given how little additional information would be gained. The recorded information for an individual company does not change so frequently as to require multiple observations within a six month period. In principle, since accounts are typically filed on an annual basis, we could have also sampled the discs annually and still have guaranteed that for any given company, all the annual accounts filed over our sample period would have appeared as the most recent observation in at least one of the sampled discs. However, we chose biannual sampling for two reasons. First, companies can occasionally have irregular filing periods, if a firm changes its financial year end date, and file twice within a year. Second, as described above, director's and other company information can change outside of accounting periods. These are so-called event driven filings, for example if a director moves house. By sampling discs at a biannual frequency we are less likely to have event driven filings causing a deviation between the non-accounting information accurate as of when the disc was produced and the accounting information that is accurate as of the account filing date.

Over the course of the past decade some of the Bank of England's discs have been lost or become damaged so we are not able to pick the same months in every year to conduct our sampling. We chose the last available monthly disc in each half of the year - i.e. June and December are our preferred discs for any given year. If either June or December were not available we substitute in May or November etc. If no disc was available in a half year (for instance, if there are no discs available between January and June) we would use the next available disc in the following half of the year. The complete list of discs used is below:

January 2005, December 2005, June 2006, December 2006, May 2007, December 2007, June 2008, December 2008, May 2009, December 2009, June 2010, September 2010, September 2011, December 2011, April 2012, November 2012, August 2013, December 2013, June 2014, September 2014, August 2015.

B.3.2 Download Strategy

We focus on companies that have either a registered office or primary trading address in England, Wales or Scotland. We exclude Northern Ireland from our sample as the Province lacks some of the necessary property price data. Our downloads were conducted in regional blocks within each disc and we extracted data for both active and inactive companies. All the data we use is denominated in GBP. The discs have an inbuilt panel structure in the sense that it is possible to download up to 10 years of historical observations for a firm in each vintage of the database. We exploited this by downloading the most recent observation for each firm and two years of lags for discs in the middle of our sample. For the first disc (January 2005) in the sample we downloaded five years of lag data (ten years in the case of Land and Buildings data) to add additional historical coverage. For the final disc, August 2015, we downloaded the full 10 years of data in order to evaluate the benefits of using the archive discs versus a single snapshot of the database.

B.4 Merging the Discs into a Firm Panel

Each company is the UK is assigned a unique Company's House Registration Number (CRN) upon formation which stays with the company throughout its lifetime. The CRN may change if Companies House chooses to adopt a new numbering format (see Section 1066 of the Companies Act 2006). Fortunately this did not happen over our sample period thus we use the CRN as an identifier to determine the same firms across different vintages of FAME. This allows us to build a firm level panel using information across all vintages.

Beyond expanding the time coverage of the data, forming the firm panel has three benefits over using 10 lags of downloaded data. First, the combined data across vintages contains information on companies who were alive historically but died and are no longer present in the final disc, guarding against survivorship bias. Second, the combined data improves coverage for the companies still present in the final disc, with historical observations sometimes lost from the database between vintages.[33] Third, our approach allows the observation of event-driven variables such as *company status* (whether the company is live, dormant, dissolved etc) when they were first reported, which is important as these variables can change independently of the company accounts. In the case of company status this is particularly important, enabling a more accurate measure of the date when a company dies, as discussed further below.

The benefits the panel structure brings over a single download with 10 lags of data in terms of firm coverage and reporting of variables is set out following the explanation of the firm panel construction. Information held on company directors across all the discs is separately combined to form a panel of director characteristics, as discussed in Appendix C. The firm and director panels are then merged for the regression analysis.

B.4.1 Treatment of the First Disc

In the first disc (January 2005), we used the additional lagged accounting information as historical observations of the firm accounts. The dates of historical accounts are generated using the *statement date* of the latest set of accounts and the *number of months* covered by the accounting period (12 months in the vast majority of cases), both are variables reported in FAME. For young firms, this process can generate purported accounting periods before the firm was born. To correct for this, all historically generated observations where the *incorporation date* is after the statement date are dropped.

As discussed above, information on company directors can change outside of accounting periods, for example if a new director is appointed to the company or if they move house. To determine which of the directors present at the company in January 2005 were present in the company at the time of the historical accounts, we use the director's earliest *appointment date* across all roles they currently hold in the company (for example, they could be a director and company secretary). Directors are retained for all historical accounts whose statement date is before the director's appointment date. To account for directors who may have moved house since the time of the historical accounts and January 2005, we use information on the transaction dates of the addresses listed with BvD, through merging to the property transactions databases of the Land Registry (for England and Wales) and Registrars of Scotland (for Scotland), as discussed in detail in Appendices D and D. Information on the director's address is taken to be correct historically for historical accounts whose statement date is after the most recent transaction of the director's property prior to January 2005, at which date it is inferred that they bought their house.

B.4.2 Treatment of Multiple Observations on the Same Firm Accounts

With company data downloaded from BvD at a biannual frequency, the same set of company accounts frequently appear in multiple different BvD discs (up to a maximum of 21 observations on the same

[33] For reasons that are unclear, again the information from BvD suggests this should not happen.

Table 14: Treatment of Duplicate Accounts:

Variables *Only* Revised When Missing				
Firm	BvD disc	Account Date	Variable X	Variable Y
1	A	31/03/2006	x_A	
1	B	31/03/2006	x_B	y_B
1	C	31/03/2006	x_C	y_C

Resolved Accounts				
Firm	BvD disc	Account Date	Variable X	Variable Y
1	n.a.	31/03/2006	x_A	y_B

accounts). The next step in the formation of the firm panel is to treat these multiple observations on the same set of accounts. At this point the data set is restricted to companies that report the statement date of their accounts, allowing a given set of company accounts to be uniquely identified using the CRN and statement date. The treatment of data is broken up into three groups:

Variables Never Revised by Later Data. As discussed above, information on directors is event-driven, and can change outside of firm accounting periods. To ensure accuracy, for all director variables we retain information from the earliest disc where the accounts are filed. In particular, this process omits information on directors appointed after the disc when the accounts were first published. Multiple trading addresses listed by the firm are treated in the same manner.

Variables Only Revised by Later Data When Initially Missing. A small number of other variables such as the *company status* and the *primary sic code* (the primary industry to which the company belongs) can be changed independently of the firm accounts but take a unique value per firm at a given point in time, and are less likely to change over time. For these variables information is used from the earliest disc in which the accounts appear. However, in contrast to director information, as these variables are less likely to change over time, the initial observations on a variable are replaced with subsequent observations if it is initially missing. Table 14 provides a stylised example of this for variables with and without missing data. This treatment also covers lagged accounting information held on the discs.

Variables Always Revised by Later Data Unless Subsequently Missing. The remaining data are accounting variables such as *land and buildings* and *number of employees* that are specific to the accounting period in question. Companies revise their historical accounts over time and using the panel structure such revisions are captured. The general principle is to use the latest data on the company's accounting period for these variables, capturing improvements made to the accounts from subsequently filed revisions. Sometimes these data revisions are only filed for the variables that have changed, which can result in missing values on non-revised variables in later discs. To circumvent

Table 15: Treatment of Duplicate Accounts:

Variables Revised *Unless* Missing

Firm	BvD disc	Account Date	Variable W	Variable Z
1	A	31/03/2006	w_A	z_A
1	B	31/03/2006	w_B	z_B
1	C	31/03/2006	w_C	

Resolved Accounts

Firm	BvD disc	Account Date	Variable X	Variable Y
1	n.a.	31/03/2006	w_C	z_B

this problem, the latest non-missing data is taken for this group of variables. Table 15 provides an example of this, for variables with and without missing data. As with the prior group of variables the treatment here is also applied to lagged accounting information.

B.4.3 Treatment of Downloaded Lagged Accounting Information.

Following the data harmonisation in the prior step, for each company statement date there is a unique observation for every variable. This includes the current value of accounting variables at each statement date, as well as two years of lagged accounts. The next step combines this lagged accounting data with data from previous accounts, to incorporate revised accounting data. The first step is to identify and treat missing accounts.

Identifying and Treating Missing Accounts. The firm data is set to panel form using the company CRN and *statement date* of accounts. Before harmonising lagged accounting data with previous accounts it is determined if any firm account observations are missing. Using the *statement date* and *number of months* variables (length of the accounting period) it is determined if successive accounts are the correct number of months apart. Prior to treatment, 97.8% of company observations have no accounts missing, with 1.8% having one set of accounts missing and 0.1% having two accounts missing. Accounts are generated where missing accounts are identified (up to four missing accounts), with the statement date set as the *statement date* of the subsequent accounts less the *number of months* in the accounting period associated with that statement date (taking the last day of the month in question). For the generated accounts, variables without lagged accounting data are assumed to take the same value as at the first statement date after the missing accounts. Following this treatment, 99.81% of company observations have no accounts missing. As with the treatment for the first disc, observations on company directors appointed after the *statement date* for the generate accounts are removed. Variables with lagged accounting data are treated for the missing accounts in the same way as for the rest of the data set, as discussed next.

Table 16: Treatment of Lagged Accounting Information

Firm	Account Date	No. Months	Variable X, Current	Variable X, Lag 1	Variable X, Lag 2
1	31/03/2006	12	$x_{C,2006}$	$x_{L1,2006}$	$x_{L2,2006}$
1	31/03/2007	12	$x_{C,2007}$	$x_{L1,2007}$	$x_{L2,2007}$
1	31/03/2008	12	$x_{C,2008}$	$x_{L1,2008}$	$x_{L2,2008}$
1	31/03/2009	12	$x_{C,2009}$	$x_{L1,2009}$	

Resolved Accounts

Firm	Account Date	No. Months	Variable X, Current	Variable X, Lag 1	Variable X, Lag 2
1	31/03/2006	12	$x_{L2,2008}$	n.a.	n.a.
1	31/03/2007	12	$x_{L1,2008}$	n.a.	n.a.
1	31/03/2008	12	$x_{L1,2009}$	n.a.	n.a.
1	31/03/2009	12	$x_{C,2009}$	n.a.	n.a.

Harmonisation of Accounting Data. As accounting data can be revised, the general principle for treating it is to use the latest available non-missing data.[34] A stylised set of accounts are presented in Table 16. When there are no accounts missing for a firm and accounting data has not been revised, the diagonal entries in the table will be the same. Thus, for example, the current value of variable x in the 2006 accounts will be the same as the first lag of x in the 2007 accounts, which will in turn be the same as the second lag of x in the 2008 accounts: $x_{C,2006} = x_{L1,2007} = x_{L2,2008}$. Where accounting revisions occur these values will differ.

Consider the 2006 accounts in Table 16. No accounts are missed for the subsequent two accounts between the 2006 accounts and the two that follow (with the time between accounts equal to the number of months covered by each of the accounts that follow) so the current data, $x_{C,2006}$, and the elements running down the diagonal of the table, $x_{L1,2007}$ and $x_{L2,2008}$ refer to the same accounting variable over the same time period. In the first instance, the twice lagged accounts from two periods ahead are used to update variable x as this is non-missing. Thus, in the resolved accounts shown below (for 2007, 2008 only), the value is $x_{L2,2008}$ (which may or may not differ from $x_{C,2006}$). Contrast this with the 2007 accounts. In this case, the twice lagged accounts from two periods ahead has a missing value for x. In this case, the latest available non-missing data is the lagged accounts from one period ahead, and so the resolved value for x in the 2007 accounts is $x_{L1,2008}$. With all accounting variables treated in this way the first and second lags in the accounts are dropped, leaving only the current value of x at the accounting date, as shown in the resolved accounts.

B.4.4 Firm Birth and Death

Building the firm panel also allows for accurate calculation of firm birth and death dates.

[34]One exception is the *QuiScore* (a credit score for the firm) which can change outside of the filing of the firm's accounts. For this variable the earliest non-missing value is taken.

Firm birth date. The firm's birth date is given by the variable *incorporation date*. This is seldom absent, but where it is, it can be imputed using its value across different vintages of BvD discs, given that it's value doesn't change over time. The use of the panel can increase data coverage for this variable, compared to relying upon a single download of the data.

Firm death date. The advantages of the firm panel are particularly pronounced for the date at which the firm dies, due to two main disadvantages from using a single download. First, a single download only shows the current *company status*, not lagged information on it. Thus, it can reveal that a company has been dissolved, but not *when* they were dissolved. Second, as discussed in the next section, there is a significant survivorship bias in the data with many companies that die exiting the database over time. Thus, when using a single download of the data, a significant number of companies who previously died will be omitted, with no way of knowing when they died, or were even last present in the database. Using the panel of firm information the death date of a firm can be calculated in two ways:

- *Disc death date.* This variable records the date of the first disc where *company status* is "dissolved". This variable is calculated using all company observations, not just those for which the *statement date* of the accounts is present. This allows for *company status* to be updated, and recorded in the data set, even though, once dissolved, there may be no *statement date* associated with the updated accounts.

- *Statement death date.* This variable records the date of the first set of accounts where *company status* is "dissolved" for the company, and, necessarily, is calculated only for the firms where *statement date* is present. Due to the lags in reporting accounts, the *statement death date* is typically earlier than the *disc death date.* It is important to note that *statement death date* is calculated *before* duplicate observations of the same set of accounts across different discs are processed. As discussed above, as it is an event-driven variable, the earliest non-missing value for *company status* is taken where multiple observations on the same set of accounts are present, to ensure that its value is observed as close as possible to the period covered by the accounts. If a company is live the first time they file their accounts for a given year, but subsequently die and file no more accounts, but BvD update the company status to reflect the death, the treatment process will record the company as live for that set of accounts, as they were when they were first filed. Calculating *statement death date* prior to performing this treatment ensures that it is observed both that the company was live the first time the accounts were published, and that they subsequently died.

B.4.5 Enhancement of Data Coverage Through Using the Firm Panel

The final constructed firm panel, comprised of companies with non-missing statement dates, contains 28.9 million firm-account observations, with 4.8 million distinct firms. The constructed firm panel has significant advantages over a single download of data.

- First, and most straightforwardly, with a maximum of 10 sets of accounts being accessible from a given disc, by using multiple historical discs, a greater time period can be covered.

- Second, even within the time period covered by the 10 lagged accounts, the panel brings significant benefits in terms of coverage of the accounting information firms report. To demonstrate this, 10 accounts were downloaded for each company from the August 2015 disc for *total assets,* a particularly well-reported variable, and compared to the same variable over the same set of 10 accounts using the data as created from the firm panel using all 21 discs. The proportion of observations for which *total assets* are missing from each data set is shown in Figure 4. Using the full panel, *total assets* is consistently well-reported, as shown in red, with data missing for only around 3% of firm observations throughout the sample. Data downloaded only from the 2015 disc has similar coverage of *total assets* for the first five accounts, before dropping off substantially, with around a third of observations missing this data by the final lagged accounts.

- Third, the panel has significantly greater coverage of firms themselves. Figure 5 displays the proportion of companies present in each accounting year in the panel that are still present in the August 2015 disc. Only 55% of the companies that filed accounts in 2000 are still present in the August 2015 disc. Note, this is not the requirement that the company *accounts* from 2000 are present in the 2015 disc, only that information on the *company* itself is still present. The difference in asset reporting in Figure 4 is driven largely by firms exiting the database before the 2015 disc. Indeed, 94% of the firm observations where *total assets* is reported in the full panel but not from the 2015 discs have a *statement death date* prior to 2015.

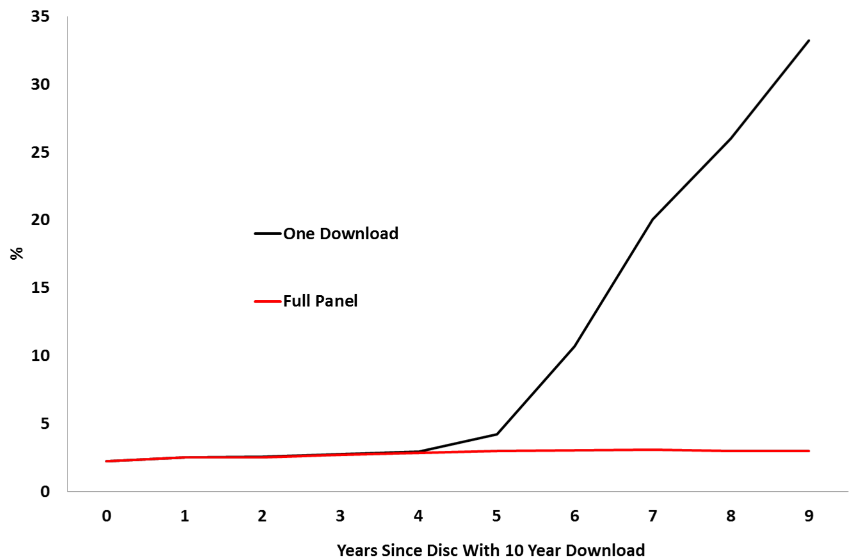
B.5 Sample Selection

Our key sample selection criteria are articulating in the main text; for completeness here we describe the conditions under which companies and observations can enter our sample.

- We restrict our sample to only include limited liability, for profit companies to which the Companies Act applies. Specifically, we include "Private Limited", "Public AIM", "Public Quoted", "Public Not Quoted". This information is contained in the "Legal Form" field in the FAME database.

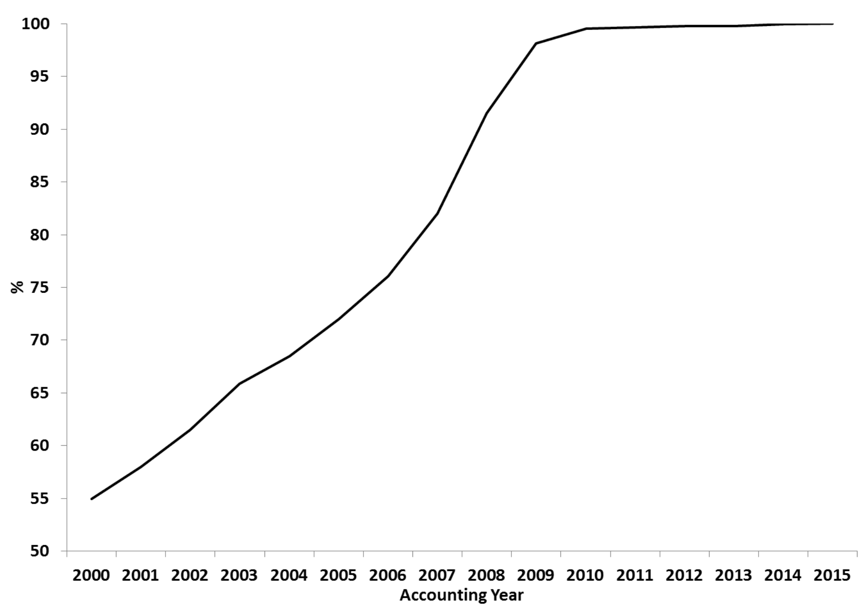
- We exclude firms in certain industries based on the "primary UK SIC code" field in the FAME database which is available for the 2003 UK Standard Industrial Classification (SIC) codes for all the discs used in our sample. We exclude from the sample firms operating in utilities (2003-SIC: 4011-4100), construction (2003-SIC: 4511-4550), finance and insurance (2003-SIC: 6511-6720), real estate (2003-SIC: 7011-7032), public administration (2003-SIC: 7511-7530), and mining (2003-SIC: 1010-1450).

Figure 4: Proportion of Observations with Total Assets Missing



Notes: the figure displays the proportion of total assets missing among companies with a non-missing statement date. *One download* refers to the 10 lagged accounts downloaded for the companies present in the August 2015 disc. *Full panel* refers to the final panel produced from the 21 discs from 2005 to 2015, as described above, covering the same period.

Figure 5: Fraction of Companies Present in August 2015 Disc



Notes: the figure displays the proportion of companies in each statement year, as derived from the full panel of 21 discs, that are present in the August 2015 disc.

- We exclude companies that have a parent or are part of a group. Our criteria for doing so is whether the company reports an ultimate owning company on FAME. Those that do not report an ultimate owner company or whose ultimate owning company name is the same as the company name remain in the sample. Crucially, the ownership information in FAME is only accurate as of the vintage of the database. There is no historical information within FAME about whether or not a company had an ultimate owner. The use of historical vintages of the database allows us to circumvent this issue. As with director information, we always take data on ownership from the earliest disc available after a company has filed its annual accounts. We decide whether to include a company or not at date

- As our empirical analysis relies upon a mix of flows, stocks and changes in stocks we exclude observations where the accounting period is irregular, e.g. if the company filed two sets of accounts within a year. Specifically, we use the BvD field "number of months since last accounts" and drop observations where this is greater than 13 or less than 11. In other words, the firm's account window must be between 11 and 13 months to enter our sample. We do not focus strictly on firms who have a 12 month accounting period as it is fairly common for firms to be recorded as filing at the end of a month in one financial-year and then recorded as filing on the first day of the following month the next financial-year. Observations where there is no information on the filing date are excluded.

- We exclude companies where no information on the company's location is recorded. That is to say the "primary trading address", "R/O address", and the first "trading address" fields are all missing.

C Company Director Characteristics

C.1 Construction of the Company Director Panel

C.1.1 Director Information: Cleaning Within Discs

To form the panel of director characteristics, variables with information on directors are first extracted from each of the 21 discs used. These variables include personal characteristics such as the full name and title of the director, their date of birth, their address (including full postcode), their nationality, and their gender. Information is also collected on all companies the director is associated with on each date, including the company name and its registered number, the role they hold with the company, and the appointment and resignation dates of all roles the director holds at the company (including some roles they held in the past). There can be multiple company observations for the same individual at a given point in time, reflecting their roles at multiple different companies.

At this stage cleaning is performed on observations and variables:

- Whilst, under the Companies Act, every company must have a director who is a person, they may have additional directors who are themselves companies. For instance, an accountancy firm may sit on the board of directors. We wish to exclude these companies from our analysis of the residential collateral channel. In the earlier discs there is no variable that flags whether a company is a director or an individual. Instead, we identify director-companies as those whose surname is non-blank but who do not record a date of birth and do not have an initial, with neither of these fields recorded for this group. As a further measure, we flag director-companies as those "surname" includes one of over 35 common expressions for companies such as "Limited", "LTD", "Accountants", "Secretaries" and "Corporation". In the latter years of the data there is a variable which explicitly flags whether a director is an individual or a company. Testing against this variable we find that our method for identifying whether a company director is an individual or a company is accurate in over 99.99% of cases. Given this accuracy, for consistency over time, we use the method for flagging director-companies based on missing date of birth and initial throughout the data set.

- All but the first three discs used (the two in 2005 and the first in 2006) have a variable indicating whether an individual is male or female. For the first three discs, this information is imputed, first using information contained in the director title (e.g. Mr or Mrs). Some titles are gender-neutral, such as Dr. For these individuals, the gender is assigned based on the 1000 most popular male and female baby names from the 1970s (to match common ages of the directors by the time of the discs).

- The information on director nationality is condensed into an indicator of whether the director is from the U.K. or not. This includes corrections for a number of different potential spellings that occur, including "UK", "United Kingdom", as well as the countries that make up the UK.

C.1.2 Director Information: Forming the Director Identification Key

Following the cleaning performed on each disc, the director information for each of the 21 discs is combined together. Key to the director panel is being able to identify the same individual, both through time, and across different companies at a given point in time. An identification key is formed for individuals based upon their initial, surname, and date of birth.

The first step in the creation of the director key is to clean director surnames. In the vast majority of cases, directors surnames are correctly recorded, however, a small number of cases are treated to ensure they are recorded in a consistent manner over time:

- Initials: some individuals list their initial as part of their surname, e.g. "J. Smith". Such initials are removed to ensure we can consistently identify the same individual across time and companies if they only occasionally include their initial in their surname.

- Prefixes: some individuals list their title as part of their surname. Common titles such as Dr, Professor, Mr, Mrs, Ms, Sir, and The Right Honorable (title for Member of Parliament in the U.K.) are removed from the start of surnames. Again, this ensures consistent matching is the title is not always listed as part of the surname.

- Lords and Ladies: the general form of these include the surname of the individual and the area of their title as in "Lord Smith of Moorgate". In such cases, "Smith" is recovered as the surname of the individual. Remaining Lords and Ladies who present their title without an area, as in "Lord Smith", have the title removed, leaving the Surname as "Smith". This cleaning allows consistent matching for the individual given the variety of ways in which their surname can be written. It also allows for the consistent identification over time of an individual who was awarded their title during our period of observation.

- Suffixes: common suffixes such as Jr., Snr., 2nd/3rd (in the variety of ways this can be written) are removed. Whilst individuals in the same family may share a common component to their name, such as "Smith Sr." and "Smith Jr.", they can be separately identified without their suffix based on their date of birth.

- Qualifications: some individuals list their qualifications (in abbreviated form) after their surname, such as "Smith M.B.A.". Common qualifications such as m.b.a., p.h.d., and l.l.m are removed.

- Symbols: common symbols are removed from surnames for consistency. This includes hyphens as in "Smith-Jones", and apostrophes as in "O'Smith". This results in no loss of information and guards against typos that can occur, with e.g. "=" or "_" mistakenly entered instead of a hyphen, and "!" or "@" mistakenly entered instead of an apostrophe.

Following the cleaning of director surnames, the following steps are taken to generate an identification key for individuals:

- It is assumed that an initial, surname, and date of birth (including year) are sufficient to uniquely identify an individual across companies and over time. Date of birth is present in 92% of cases, allowing this form of identification key to be computed for the vast majority of individuals.
- In some of the remaining cases, the director date of birth can be filled in based on additional observations on the individual. Whilst a name and initial are insufficient to identify an individual *across* companies, they are assumed sufficient to identify an individual *within* a company. With multiple observations on the same director in the same company over time, it is possible that the individual's date of birth is present in some discs and absent in others. In such cases, the missing date of birth is filled in, so long as the initial and last name are associated with a unique date of birth within the company over time, which holds in 98% of cases. This results in 94% of directors having date of birth non-missing.
- The date of birth is missing for the remaining group of individuals. However, if their initials and surname are associated with a unique company across all the discs, this is assumed sufficient to uniquely identify them.
- The individuals that don't fall into these groups (around 5% of the sample) cannot be uniquely identified across companies and time and are dropped.
- An identification key is formed for the remaining directors based on their initial, surname and date of birth. There are an average of 5.3 million different (human) directors per disc, and an average of 4.0 million of them hold a current directorship.

C.1.3 Director Information: Cleaning Across Discs

There can be observations on the same individual across their roles in multiple companies as well as multiple observations on them in the same company over time. These multiple observations are used to reduce missing data and improve the accuracy of the data. For gender and whether the individual is foreign, the modal value across all observations on the individual is taken, with ties resolved in favor of the dominant category in the population (male and U.K. national, respectively). This unique value is then used to fill any missing observations for the individual.

With individuals uniquely identified and their personal characteristics cleaned, the next step tidies the information on the positions held at each company. The ultimate unit of observation at each point in time is an individual's role at a given company. These roles are identified based on the Companies House number of the company, the director identification key, and their appointment and resignation dates at the company. Several cleaning steps are performed to produce these groups.

- There are a very small number of observations (0.09%) where the appointment date is later in time than the resignation date. From comparing these observations to the Companies House website, it appears that these are due to mistakes in which resignation or appointment dates are conflated from different times an individual worked at the same company. Such observations are dropped. Observations (1.51%) are also dropped for cases where the individual is appointed to the company on the same day as they resign. From comparison to Companies House, these appear to be genuine cases, and in communication with Companies House it was confirmed that this can occur, if, for example, a individual is appointed only for one day to register the company. These observations are excluded as the focus in this paper is on individuals who have a meaningful role at a company.

- The director appointment date is missing for 0.16% of observations. Missing appointment date data is filled-in for cases in which the individual has at most one role recorded with the company on each disc, and so a common appointment date. Following this treatment the appointment date is only missing for 0.05% of observations. The remaining observations are dropped.

- Companies House first performed the data capture for company directors during 1991 and 1992. This data was a snapshot of the extant directors in the most recently filed company accounts, and the appointment date data for existing company directors was simply taken as the date of the most recent company accounts, many of which would be prior to 1991, given the filing lags. To ensure consistency for such cases, appointment dates prior to 1991 are all coded to the 1st of January 1991. This affects around 2% of observations.

- Resignation dates for the same role are often naturally missing for some discs, and then present in later discs, once the individual has resigned from the company. These dates are filled-in for all observations on that individual's role at a company at that point in time (to be distinguished from any subsequent role they may have if later reappointed), with this identified based on the director and company identifiers and the appointment date of the role.

This cleaning enables the formation of individual's roles at companies. In the dataset, it can occur that an individual is identified as having multiple directorships in the same company at the same time. Ultimately what is of interest for this paper is whether the individual has a role with the company at a given point in time, not whether there are multiple such directorships. Further cleaning is used to make these roles as parsimonious as possible, documenting the periods when the individual had a role at the company. Consider two roles held by a director in the same company with respective appointment and resignation dates (a_1, r_1), (a_2, r_2). Three types of categories are treated:

1. Duplicate roles: $a_1 = a_2$, $r_1 = r_2$: this is condensed to a single role from a_1 to r_1.

2. Subset roles: $a_1 \leq a_2,\ r_2 \leq r_1$: this is condensed to a single role from a_1 to r_1.

3. Overlapping roles: $a_1 \leq a_2$,$r_1 \leq r_2$: this is condensed to a single role from a_1 to r_2.

This process is run over all roles from all 21 discs and repeated several times to condense all the roles, enabling treatment of, for example, three overlapping roles which only overlap in pairs.

The final step is to expand the data set to monthly observations on all of the director roles, allowing accurate matching with company accounts data, which can be filed in any month of the year. Each role is expanded to a set of monthly observations, running from the last observation on the role to 24 months prior to the appointment date of the director in the role. With almost all company accounts filed at least every 24th months, this allows a match between the director role and the most recently filed accounts prior to their appointment. This results in a data set with around 2.9 billion monthly observations on director roles across all companies.

C.1.4 Company Information

A small number of well-reported company variables are selected for the calculation of director characteristics. These include

- *Company status*: an indicator of whether the company is live, on in some other state such as dormant, or dead.
- *Primary SIC Code*: the primary industry classification of the company, based on the 2003 UK Standard Industry Classification.
- *Total assets*: the total assets reported on the company balance sheet.
- *QuiScore*: a credit score for the company, ranging from 0 (worst) to 100 (best).
- *Incorporation date*: the date the company was incorporated and registered with Companies House.

Data on these, and other variables, are taken from each of the 21 BvD discs sampled and combined into a cleaned panel of company information, following the same company account cleaning procedure as the main company data set.

C.2 Calculation of Director Characteristics

The cleaned company information is merged onto the monthly director panel at the months of the company accounts. This results in company variables being present on the accounting dates of the companies in question. This company information is then filled out in the monthly panel for all the dates until the next accounts are due to be published (this due date is not proceeded beyond if the subsequent accounts are missing). Specifically, company variables for all dates between the accounting statement at t and the accounting statement at $t+1$ are filled out with information from the accounting statement at t.

The combined monthly panel of director information and company information is used to calculate a number of different characteristics for individuals at monthly frequency, broken into three groups.

Personal Characteristics

- *Age*: the number of days between the individual's date of birth and a given month, expressed in years.
- *Gender*: whether the individual is male or female.
- *Nationality*: whether the individual is a U.K. national or not.

Metrics Based on Current Information

- *Current number of roles*: the number of live companies the individual is currently a director of in a given month.
- *Average company credit score*: the average Qui credit score taken across all the live companies the individual is currently a director of in a given month.
- *Average company asset growth*: the average asset growth taken across all the live companies the individual is currently a director of in a given month.

Measures of Experience

A significant limitation of analysing director characteristics using BvD data at a given point in time is that prior experience the individual had can be lost. This is because previous roles individuals held are periodically removed as the BvD data set is updated over time. Using information from 21 different vintages of BvD data circumvents this issue and enables accurate calculation of a number of metrics that summarise the experience individuals have had in all their roles, including those in the past. A number of measures of experience are calculated at monthly frequency:

- *Experience of different companies*: the number of different companies the individual has been a director of. This measure doesn't double-count two separate periods in which an individual is a director at the same company.
- *Years of experience*: the amount of time the individual has been a director, calculated across all companies. For each month, this metric counts the number of different live companies the individual was a director of during that month and sums this over time, expressing the result

in years. The treatment of overlapping roles in the same company in the prior section enables an accurate calculation.

- *Average time spent at a company:* average number of years a director spent at each company, derived from the prior two series.
- *Experience of leaving companies*: the number of different companies the individual has resigned from. As with experience of different companies, resignations from the company at two different points in time are not counted twice.
- *Experience of starting companies*: the number of different companies where the individual was appointed in the same month the company was incorporated.
- *Experience of company failure*: the number of different companies the individual has worked for that have died. The death of the company is timed to the statement date of the first set of accounts where the company status is *dissolved.*
- *Diversity of experience*: the number of different two digit SIC code industries the individual has worked in.

With these director characteristics calculated, company balance sheet variables and variables specific to an individual's role at a given company are dropped and the unit of observation is compressed from an individual's role in a given company to the individual. This results in a monthly panel, with information on individuals and their characteristics through time. This final data set runs from January 1998 to August 2015, and has just over 1 billion observations.

D Matching Residential Addresses of Company Directors

D.1 Background and General Principles

D.1.1 The Structure of Addresses in the UK

While tedious, it is useful to first lay out what a UK address typically look likes to fix ideas ahead of explaining how our matching algorithm works. We do not use any street, town or regional information (beyond England and Wales versus Scotland as described below) when matching addresses, instead our highest unit of observation are postal codes, or postcodes for short. In the UK, postcodes are 5 to 7 characters separated by a space (for example, "EC2M 1BB"). The final three characters always have the same structure: a number followed by two letters and denote the immediate local area of the property. The first set of characters, between two and four, will always start with one or two letters and will then be followed by either a single digit number, a two digit number or, as in the example, a number followed by letter. This first set of characters denote different UK localities so that, for instance, addresses in the same town will have postcodes starting with the same three characters. These patterns make postcodes distinctive and easy to map into the regions we use for our empirical analysis. Furthermore, as far as we are aware this pattern is unique to the UK and therefore allows us to identify postcodes that are from addresses outside the UK. Crucially, there are close to 1.75 million post codes in the UK serving just under 30 million unique addresses, meaning that the average number of properties per postcode is about 17, although the total number of addresses per post code can vary between 1 and 100.[35] Once we know a director's postcode, we have essentially narrowed down where he or she lives to a small number of properties. In all the databases we use the postcode is a separate field.

For around 80% of addresses in the UK the property can be uniquely identified using its postcode and the house number (i.e. the number of the property on the street). Specifically, for 10,339,712 of the 12,448,142 unique addresses in the England and Wales Land Registry the property can be uniquely identified in this way. For the Scottish Land Registry the equivalent figure is 702 thousands out of 976 thousands.[36] This means that given an unstructured text string for the address, simply isolating the first number and postcode would be sufficient for the purposes of matching in around 80% of cases. (Although this would be a biased set of addresses as it ignores properties that are named or those that are parts of larger buildings such as flats or apartments).

Around 10% or so of addresses in the UK are uniquely identified by a property name (i.e. a string like "the East Farm" or "Green Manor" etc.) and the postcode. Some addresses have both a house name and a house number in which case the name is redundant for matching purposes. For example, if a property is called The Manor, 72 High Street; there should never be another be another property

[35] Postcodes that identify a single address tend to be for commercial properties that receive a lot of post and are less relevant in the residential sphere.

[36] Note, the Scottish figures are calculated after we have removed transactions with missing information.

at 72, High Street. The name is decorative.

Beyond this set, the structure of the address can get a bit more complicated for four main reasons:

1. When the property number is a range (e.g. 1-2).
2. When the property is part of a bigger building e.g. Flat 1, 6 the Avenue.
3. The address has been entered with a typo.
4. The address is non-residential or has a unusual structure.

As described below, our matching algorithm can work to deal with 1 and 2 above. And while it is possible to adjust for some typos (for example, the incorrect entry of the number 1 with a capital I), it is not possible to write an algorithm that corrects for every possible error. Furthermore, sometimes it is simply not possible to process the address in a coherent way, this is particularly true of non-residential addresses which we are not interested in.

D.1.2 Data Sources

We have three databases containing address information: (i) the director address information from BVD. (ii) The England & Wales Land Registry covering residential property transactions in England & Wales since 1995. (iii) The Scottish Land Registry covering property transactions in Scotland (both commercial and residential) since 2003. All three record address information in different ways, only the BVD database is a raw string, so one needs to clean the data first in order to put it in a comparable form.

Note that the Product Sales Database that we use to obtain information on residential mortgage transactions contains only postcodes; we use additional date of birth data to form a match instead.

D.1.3 Our Approach to Matching

Given the fact that UK addresses are often have a well defined structure and that the way that address information is recorded across our three data sources is different, we decided to use a precise matching approach as opposed to using fuzzy matching. Our general approach to matching is to generate 5 common variables: (i) *Postcode* – this is listed as a separate string in all database; (ii) *house_num* – this is a street number – e.g. 1a; (iii) *flat_num* – this is the number of the flat, e.g. flat 15 (iv) *house_name* – this is the name of the building (e.g. the West Building) (v) *flat_name* – this is a potential name for the flat (e.g. garden flat). *Flat_name* is the least populated and will be the hardest to match on since it seems like addresses typically have a flat number assigned as well which may not have been listed. Below, we describe some of the rules we use to isolate these 5 individual address elements. It is worthwhile emphasising that sometimes the address information is ambiguous and judgment needs to be used. The way we set up the algorithm means that false positives are unlikely (we have not encountered one in our manual testing). Even so, if a false match were to occur, this would have to be within a postcode meaning that the property values are likely to be similar among addresses (although the transaction dates will of course be incorrect).

The matching algorithm puts together 5 different potential matching strings (String construction using Stata syntax):

1. *matcher1*=*postcode*+("_")+*house_num*+("_")+*flat_num*+("_1") if *house_num* is not missing.

2. *matcher2*=*postcode*+("_")+*house_num*+("_")+*flat_name*+("_1") if *house_num* is not missing.

3. *matcher3*=*postcode*+("_")+*house_name*+("_")+*flat_num*+("_1") if *house_name* is not missing.

4. *matcher4*=*postcode*+("_")+*house_name*+("_")+*flat_name*+("_1") if *house_name* is not missing.

5. *matcher5*=*postcode*+("_")+*house_name*+("_")+*house_num*+("_1") if *house_num* is not missing.

We build each of these 5 matchers in each database, we then merge the databases based on each matcher to identify potential shared address information between the land registries and BVD. If more than one matcher works, we have the following priority ordering: $1 \succ 2 \succ 3 \succ 4 \succ 5$.

Some remarks are necessary regarding these matching strings. First, with this structure it is impossible to match based on flat information alone. Second, we also take the step of dropping situations where a particular matcher does not uniquely identify a property within a database; for instance *matcher4* will be unable to uniquely identify numbered flats in a single building. Third, *matcher5* may seem redundant but is designed to address situations where the algorithm incorrectly assigns a flat name to a *house_name*; as it is only relevant in the case of an error we treat it as the match with the lowest priority (see above). Fourth, *matcher1* and *matcher2* will give identical matches if no flat information is available.

D.2 Details of Address Fields in our three Data Sources

Here we describe how address information is stored in our three databases. In all three databases we clean the address strings in a similar manner, e.g. by removing double spaces, certain punctuation, using a single case, consistent treatment of numbers etc. Furthermore, in our treatment of the individual address fields there are multiple specific cases that we have dealt with in our code. Some of the more common problems are discussed in the following section; however, we do not wish to go into all these often quite tedious details here nor is it practical to do so, instead our cleaning code is available upon request.

Table 17: Extract of Address Information from the England and Wales Land Registry

Land Registry Address Fields			Matching Algorithm Fields			
postcode	*paon*	*saon*	*house_num*	*house_name*	*flat_num*	*flat_name*
PO345DX	EAST GREEN			eastgreen		
SA181UN	38		38			
KT199UG	162		162			
ME142HH	24A		24a			
PO211DQ	44	FLAT 1	44		1	
PO211SU	10 - 12		10-12			
SW147LY	23		23			
SW66RE	28		28			
W129EA	6A		6a			
W1G9XF	15	FLAT 1	15		1	
BN29AB	EBENEZER APARTMENTS, 24	FLAT 27	24	ebenezerapartments	27	

Note: The table shows a random extract of 9 unique addresses from the England and Wales Land Registry. The 10th address is selected to show a more complex example. The left half of the table is how the data appears in the raw data. The right half of the table shows how these fields are translated into the field for our matching algorithm.

D.2.1 The England and Wales Land Registry

This database is the best structured of the three under consideration. Ignoring fields at the street level or above, address information is saved as the postcode and two string fields called the "Primary Addressable Object Name" (*paon*) and "Secondary Addressable Object Name" (*saon*). The secondary address characteristics typically contains information on the sub building, i.e. flat name or number. The *paon* typically contains information on the main building, so house number, house name or the name of the apartment block. Table 17 contains a short extract from the relevant fields from the Land Registry. The data set is also clean: the *postcode* field is 99.9% populated and, when reported, always corresponds to the UK conventions described above. The *paon* variable has only 4,250 missing values out of 21.3 million transactions. Very occasionally (467 cases) *saon* is listed but *paon* is not, in which case we replace the missing *paon* with *saon*. The *saon* variable is less well reported but this reflects the structure of addresses in the UK as described above. Table 18, shows a breakdown of how the addresses fields are recorded for all the unique addresses in the Land Registry (i.e. after we have collapsed addresses that transacted more than once into a single observation; we group by *postcode, paon* and *saon* to do this).

Our general approach to identifying the matching variables is the following. First consider numbers. For the overwhelming majority of observations, the address information will contain only up to two sets of numbers (we define a range like 1-2 as a single set of numbers). If only one number is available then we assign it to *house_num*. if there is a number in both *saon* and a number in *paon*, then we will assign the *saon* number to the *flat_num* and the number in paon to the *house_num* (e.g *saon* = "4", *paon* = "1-2" would imply *flat_num* = "4", *house_num* = "1-2"). If there are two

Table 18: Breakdown of Address Information in the England and Wales Land Registry

	Number of Unique Addresses	Share of Unique Addresses (%)
Raw Data		
Report *paon*	12,444,713	99.97
- only report *paon*	11,090,100	89.09
- *paon* is a number*	10,717,301	86.10
- *paon* is a string**	1,369,667	11.00
Report *saon*	1,354,613	10.90
- *saon* contains the word "flat"	870,965	7.00
- *saon* contains the word "apartment"	115,826	0.93
Cleaned Data		
Report *house_num*	11,077,155	88.99
- only report *house_num*	10,339,712	83.06
Report *house_name*	1,731,071	13.91
- only report *house_name*	687,957	5.53
Report *flat_num/flat_name*	933,168	7.50
Total	12,448,142	100.00

Notes: Breakdown of unique addresses appearing in the England and Wales Land Registry. A unique addresses is one where there is a unique combination of *soan, paon* and *postcode.* Excludes addresses in the Land Registry where the *postcode* is missing. The sample of addresses is drawn from transactions in England Wales covering **paon* is a number includes cases such as *paon=15C or paon=1-2.* ** all cases where *paon* contains no numeric character (note that *paon* can contain both numbers and letters: e.g. *paon*="9, Manor House"). Our England and Wales Land Registry data covers transactions over the period Jan 2005 - April 2016.

Table 19: Extract of Address Information from the Registers of Scotland

Registers of Scotland Address Fields				Matching Algorithm Fields			
postcode	*propertynumber*	*buildingname*	*subbuilding*	*house_num*	*house_name*	*flat_num*	*flat_name*
AB245PD	34		FLAT F	34		f	flatf
AB253DB	20			20			
AB210LY	6			6			
AB116UQ		51C		51c			
AB116JB	162						
AB116JR		32A		32a			
AB219UT	19			19			
AB423DW		2 WESTERTON		2	westerton		
AB2 3UE	27	FLAT E		27		e	flate
ABN54503		MILLDALE 68-72	FLAT 4	68-72	milldale	4	

Note: The table shows a random extract of 9 unique addresses from the Registers of Scotland database. The 10th address is selected to show a more complex example. The left half of the table is how the data appears in the raw data. The right half of the table shows how these fields are translated into the field for our matching algorithm.

numbers in either *paon* or *saon* then we assign the first to *flat_num* and the second to *house_num*. An exception to this rule would be if we can identify clearly which number corresponds to a flat number (e.g. *paon* = "1, flat 3"), then the algorithm reassigns the ordering appropriately.

Turning to the name variables. The general principle is similar, *flat_name* will be a string in *saon, house_name* a string in *paon.* We take the obvious step of removing any identified numbers from these strings and any sub strings that also align with the street. One source of ambiguity is whether, when *paon* is just a number, the string in *saon* is the *house_name* or the *flat_name.* We then use some simple keyword tests to assign the string to the appropriate field.

As the registry is a database of transactions and we wish to identify all the transactions at a particular address, we convert the registry to a wide format using the three raw address fields to isolate unique addresses before matching.

D.2.2 The Registers of Scotland

The Registers of Scotland database has a similar structure to its English equivalent; the four relevant address fields are *subbuilding, buildingname, propertynumber* and *postcode.* Between them *buildingname* and *propertynumber* are supposed to contain similar information as *paon* above except that *propertynumber* is a numeric field (all other fields are strings). If the property is identified by a number then *propertynumber* is populated; properties that have property numbers that contain a string (e.g. 11a) or a range (1-2) are listed in *buildingname.* Similarly *subbuilding* contains is similar information to *saon* above. Table 19 contains an extract from the database.

The data in the Registers of Scotland database is less clean than the England and Wales Land

Table 20: Breakdown of Address Information in the Registers of Scotland Database

	Number of Unique Addresses	Share of Unique Addresses (%)
Cleaned Data		
Report *house_num*	774,004	92.42
- only report *house_num*	690,708	82.47
Report *house_name*	87,875	10.39
- only report *house_name*	55,048	6.57
Report *flat_num/flat_name*	69,142	8.26
Total	837,491	100.00

Notes: A unique addresses is one where there is a unique combination of *house_num, house_name, flat_name, flat_num* and *postcode.* Addresses that emerge from transactions where any of the postcode, date, price, or all of *buildingname, propertynumber* and *subbuilding,* are excluded. Our Registers of Scotland data covers transactions over the period April 2003 - September 2014.

Registry. Many more observations are have key fields missing (e.g. the postcode is missing for 197,871), and there is less consistency in the way information is recorded across the different fields between observations (compare for instance the first and second to last observation in table 19). If it is the case that observed transaction has insufficient information to building a match (which is the case when either *postcode* is missing or all three of the other variables are missing) then we drop the observation. We also exclude transactions where the price paid or the date of the transaction is missing. This leaves us with 1,376,888 usable transactions.

Despite these issues there is sufficiently data quality to determine our four matching fields for 837,401 unique addresses. Our approach to numbering is to use *propertynumber* in the first instance to identify *house_num.* In the case where *propertynumber* is missing (e.g. the fourth row in table 19), we would then isolate the number from *buildingname* (51c). If *buildingname* and *propertynumber* report conflicting numbers we assume that the former is the *flat_num.* If *propertynumber* is missing, we would prioritise numbers in *buildingname* over *subbuilding* for *house_num* with a number in latter being used for the *flat_num.* An exception of this latter rule is if *buildingname* is clearly marked as refering to a flat (e.g. *buildingname=*"FLAT 2"*, subbuilding=56* would mean that we assign *flat_num=2* and *house_num=56).*

For the *name* fields, we prioritise strings in *buildingname* for *house_name* and strings in *subbuilding* for *flat_num.* We also attempt to extract *flat_name* from the strings using keyword searches in case the string contains multiple elements of an address.

The inconsistency in the way the same information can be recorded across fields in the Registers of Scotland database means that it is possible that the same address is entered in two different ways in the raw data. To address this, we first cleaned the address information for each transaction and then determined unique addresses using our cleaned data fields. Table 2 presents the breakdown of the address information for the cleaned data.

As with the England and Wales registry we convert the Scottish registry into a wide format. However, for the reasons discussed in the previous paragraph, we group transactions by the cleaned address fields rather than the raw data.

D.2.3 Director Addresses in Bureau van Dijk

In BVD there are two fields that contain director address information: *directoraddress* and *directorpostcode*.[37] The latter is equivalent to the postcode in the other two databases. There is small a data quality issue regarding postcodes: in about 0.3% of cases directors sometimes give the shortened 3 digit version (corresponding to the region where the address is located) rather than the full postcode. We attempt to correct for this by exploiting our panel structure by looking at multiple address listings by the same director (where the property number matches) to try to complete the postcode.

The field *directoraddress* is the full address of the director written as string with each line of the address separated by a comma. For reference, to use a publicly available address rather than that of an individual, the Bank of England's address would be written as: "Bank of England, Threadneedle Street, London, EC2R 8AH, United Kingdom". We split the full addresses into its individual parts dividing the string about the commas. We focus only on the first two lines of the address as new fields (in the example, we would have two fields "Bank of England" and "Threadneedle Street"). For numbers, we assume that if only a single exists in the two fields then it corresponds to the *house_num* (including a range like 1-2). If two numbers are present we assume the first is the *flat_num,* unless the string is of the form where the flat number is obvious such as "1 potter street flat 3". *Flat_name* are isolated using key word searches. Having isolated these three terms, any residual string left in the first line of the address is classified as the *house_num.* If there is nothing left in the first line of the address we use the residual string from the second line. With *house_num* we also use a combination of regular expressions and keyword searches to remove road and town names from the string as well as any sub-strings containing the postcode.

D.3 The Matching Variables

In this section we briefly describe some of details of our matching variables, some more specific details on how we isolate them and some of the simple formatting requirements that we follow to build the series:

- *house_num:* this is the number of the property. It will be typically be just a number extracted from the address information. Strings such as "10a" or "2b" are also accepted. As are ranges such as "1-2a".

- *flat_num:* this the number attached to a flat. The formatting requirements are as with *house_num* except flats can also have a letter attached to them; e.g. "FLAT A" would have

[37] In some vintages of BVD these fields are entitled *directorfulladdress* and *directorfullpostcode*.

. Flat numbers are isolated using regular expression searches; for example, find "FLAT XXX" where XXX is the *flat_num*. Our algorithm also searches for other key words; for example, "APARTMENT XXX" or "SUITE XXX". For reference, looking at addresses listed in the England and Wales land registry, 850,000 unique addresses describe themselves as a flats and about 100,000 list themselves as an apartment. Other subbuilding names such as suite, unit, room etc. number a few thousand.

- *flat_name:* this should be the name of a flat such as "ground floor flat" or "penthouse apartment". We use keyword searches in the BVD database to isolate the *flat_name*. In the two land registries we rely on strings saved in the different address fields as described above.

- *house_name:* this is essentially a residual string after we extract information to fill the other fields and is designed to capture the name of the property. However, we further clean the string as described in the final bullet.

- Dealing with ranges: It is not uncommon for UK addresses to be attached to a range of numbers rather than a single number. This can happen if a single building is large and crosses several plots. This can be written in a variety of ways, for example: "1-2" could be written as 1 and 2, 1 to 2, 1/2 etc. Using regular expression searches we always convert ranges into the 1-2 format and remove any spaces between characters.

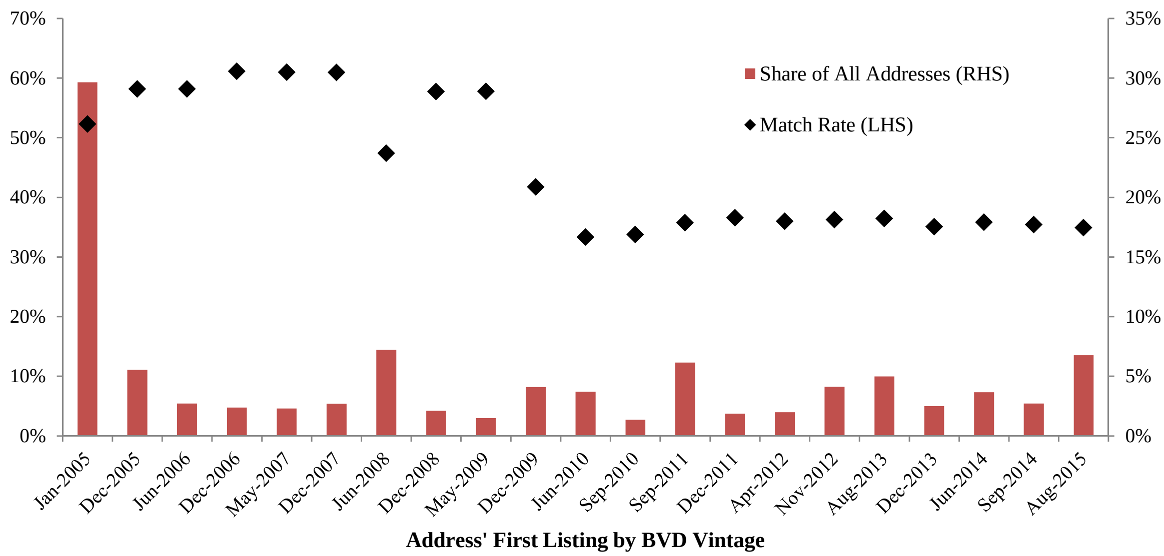
- Dealing with the string variables (*house_name/flat_name*): All characters enter our algorithm in lower case and we remove spaces. Numbers identified through *house_num* and *flat_num* will be purged from our string variables, as will any sub-strings that correspond to the postcode, street/thoroughfare or town (as listed in the land registries). For the BVD addresses we use regular expressions to remove street names.

D.4 Performance of the Algorithm

Of all the unique director addresses located in England, Wales and Scotland listed in Bureau van Dijk, 47% can be matched to at least one transaction in either land registry. The figure for addresses located in England and Wales is 48%, the figure for addresses in Scotland is 35%. The lower match rate in Scotland has two explanations. First, the Registers of Scotland database only contains transactions starting in April 2003. This increases the share of Scottish properties where no transaction has been recorded compared to England and Wales where there is an additional eight years of transaction information. Second, the increased incidence of missing data in the Registers of Scotland data compared to its English equivalent means that the record of transactions we have for the post 2003 period is less complete. Note also that only 5.8% of directors' addresses are located in Scotland.

Figure 6 presents the match rate across for addresses based upon the vintage of the BVD database when the address is first listed as well as the share of addresses the enter the database at each

Figure 6: Match Rate across BVD vintages



Notes: This chart shows the match rate between director addresses in the BVD and the land registry (black diamonds, left hand axis). Specifically, the match rate is calculated as the number of addresses in BVD for which a corresponding transaction can be found in *either* registry divided by the number of properties that have a postcode in England, Wales or Scotland. We present these rates by the the vintage of the BVD database where the address first appears. The bars, right hand axis, represent the share of addresses that first appear in each BVD vintage.

vintage. Two main points stand out. First, there is a break in the match rate that happens around the December 2009 vintage. Prior to that vintage the match rate is a little under 60%, after that vintage the match rate falls to a little 40%. This is due to a change in the law regarding the disclosure of addresses which we discuss in more detail below. Second, two thirds of the addresses in question entered the BVD database after our first vintage in 2005 and the average rate of entry is somewhat stable at roughly 2700 new addresses per day (calculated as total new addresses divided by days between disks). However, there is an unexplained spike in entry in June 2008 where the rate increases to approximately 4500 new addresses per day with a lull in the period before and after.

Also note that we have presented our match rates in terms of unique addresses, rather than weighting by address incidence. This means that we are potentially putting too much weight on addresses where the director has a short tenure and therefore is of less relevance empirically. However, if we sample addresses according to their incidence in the database (i.e. addresses that appear in more director-firm-years get more weight) we also get a match rate of 47%.

D.4.1 Manual Tests on the Matching Algorithm

As we only succeed in match roughly half of directors' addresses, it is informative to ask what the cause is when our methodology fails to match an addresses. To explore this, we randomly selected

100 unmatched unique addresses from the September 2010[38] Bureau Van Dijk vintage and manually assessed the reason for the failed match. Of the 100 unmatched addresses, 8 failed matches were due to differences in the way the addresses were recorded in BVD compared to the Land Registries, for example due to typos. Six addresses were not matched due to obviously being a business address (as opposed to residential addresses). Recall that the England and Wales Land Registry does not include commercial property.[39] The remaining unmatched addresses were addresses that did not appear commercial by inspection (although it is not possible to say with certainty that they are residential) but did still not appear in either Land Registry. There are two potential explanations for this: either the property has not transacted since 1995 (2003 in the case of Scotland) or the only transactions that took place at the address were those omitted from the Land Registry. In terms of the latter, one relevant omitted set of transactions are the purchase of houses using a Buy-to-Let mortgage. One may be concerned that these are directors that live in rental properties. However, for reasons we describe in the main text this is unlikely. Another culprit is likely business addresses that cannot obviously be classified as commercial by inspecting their names. We discuss the law regarding directors using a commercial address below. It does seem, however, that many of the unmatched addresses are those where the owner has not sold their property since 1995 (2003 in the case of Scotland).

D.4.2 Changes to the Law Regarding the Listing of Director's Usual Residential Addresses

Under Sections 288 and 289 of the Companies Act 1985, the usual residential address of company directors had to be entered on the public registrar of companies held at Companies House. This address would be published in the their firm's accounts and this forms the source of our data on addresses.

From April 2nd 2002,[40] directors had the option to waive this requirement if the director was successful in obtaining a confidentiality order, having demonstrated to the Secretary of State that placing their residential address on the public record would place them or someone living with them at risk of violence or intimidation, for example from political groups. In this case the director could remove their residential address from public record and replace it with a service address at which they could be reached, for example their company address, with the residential address held securely and only accessible by Competent Authorities. The bar for obtaining such an order is high. We discussed this issue with Company's house and they estimated that less than 1% of directors are beneficiaries of a confidentiality order at any given time.

[38] For complete clarity: we used a snapshot of all addresses available at that vintage not those addresses that were first listed in September 2010 vintage.

[39] The Registers of Scotland dataset does include a properties that are purchased by corporations but these are flagged and we exclude them from our analysis.

[40] The insertion of sections 723B to E into the Companies Act 1985 became effective on this date.

A further change in UK law on the 1st October 2009[41] means that all directors now have the option of having a service address displayed publicly rather than their usual residential address. Companies are still required to maintain a registrar of usual residential addresses alongside service addresses, with the former only available to Specified Public Authorities when the director has chosen to keep their residential address private.

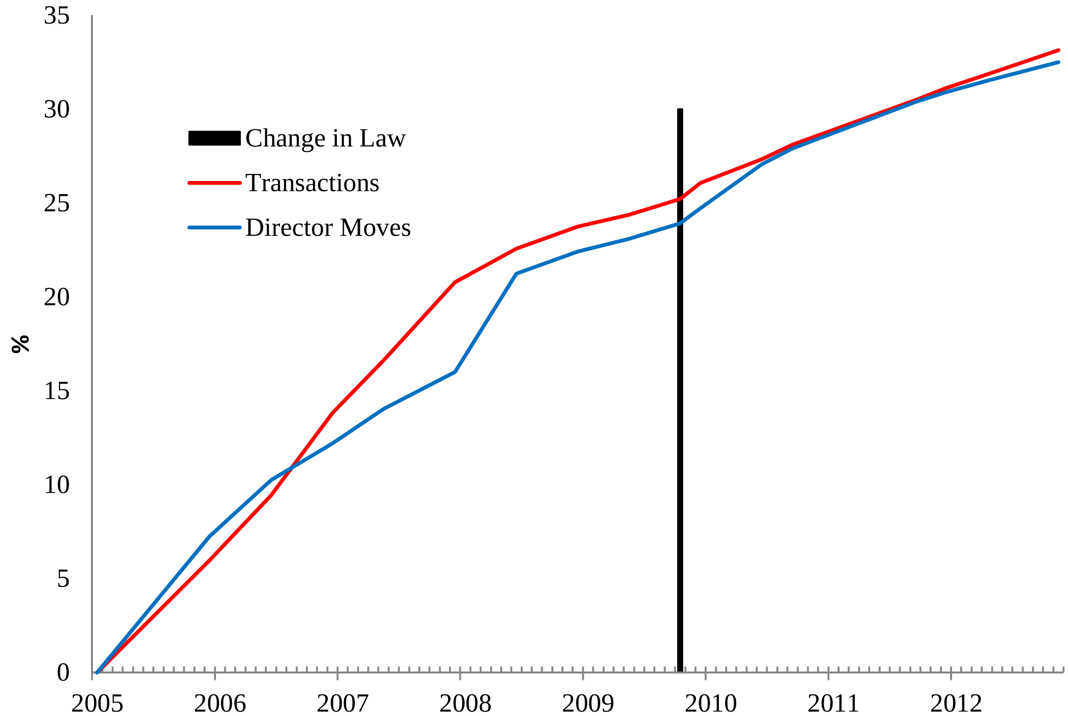
Thus, whilst prior to October 2009 the address publicly listed at companies house would be their usual residential address for over 99% of directors, after this date the rate would be lower. This is the source of the decline in the match rate seen in figure 6 after the May 2009 vintage of BVD: directors started listing service addresses rather than residential addresses. Directors must be readily contactable at the service address they provide, and so, if their residential address is not listed publicly, the address provided is most likely their office address. As the Land Registry dataset only contains information on the transactions of residential properties, it will not be possible to match such commercial addresses.

When the new law came into force in 2009, existing directors had the option to replace their publicly held residential address with a service address through filling in form CH01. However, they may have had little incentive to do so as the law was not applied retrospectively: all residential addresses held on public record at Companies House prior to 1st October 2009 continue to be held there after this date. Thus, there would not be a material increase in privacy for directors through replacing their residential address with a service address unless they moved house. In the data there is no spike in new addresses entering the database in 2009/2010: around 1.3 million new addresses entered the database in 2008 compared to 800,000 in 2009 (for the three year period 2006-2008 2.8 million new addresses where registered compared to 2.7 million three years 2009-2011). Figure 7 compares the proportion of directors present throughout our sample who had changed their listed address since January 2005 with the proportion of properties in the Land Registry that had a transaction since this date.[42] Again, there is little evidence of a spike in the proportion of directors changing their address following the change in law, and further, over the range of our sample, directors change their address at a rate closely comparable with the property transaction rate. This suggests that existing directors who did not move are not taking advantage of the change in law to remove their residential address from the public record.

[41] Specifically the implementation of Sections 162-167 (register of directors) of the 2006 Companies Act.

[42] Specifically, our set of baseline properties from the Land Registry Price Paid dataset are those that had a transaction between 1995 (when the series begins) and 2005.

Figure 7: Directors Change of Address and all Transactions



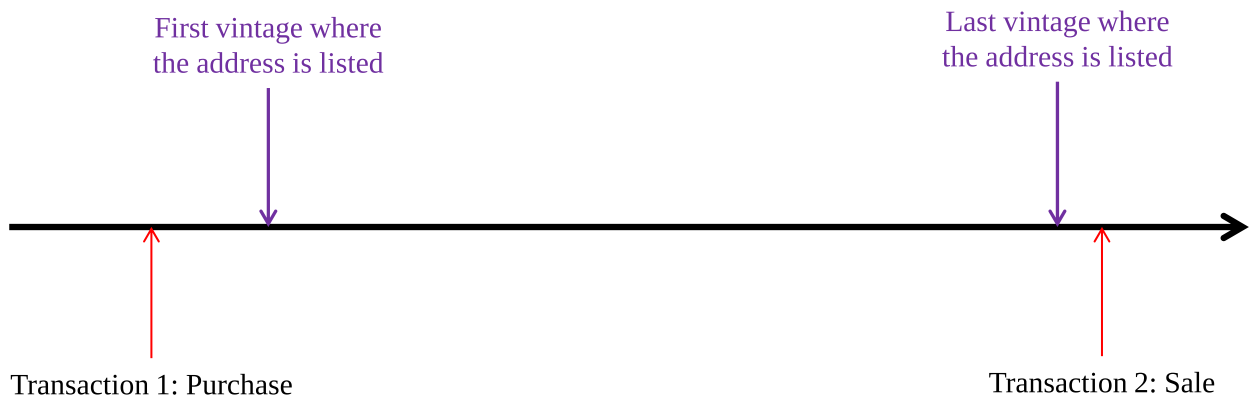
Notes: The *director moves* series comes from BVD and presents the proportion of directors present throughout 2005-2012 who had changed their listed address since January 2005. The *transactions* series comes from the Land Registry Price Paid dataset, and presents the proportion of properties that transacted between 1995 and 2005 that have transacted again by each date. The black vertical highlights the change in law on the disclosure of director residential addresses on 1st October 2009.

It is also worth noting that, for our purposes, directors switching their residential address to a service address (without moving) is less of a concern as we use all the vintages of the data to find director addresses and then use transactions level information to determine when a director moved. Specifically, imagine a director who first listed a residential address in 2007 and switched to a service address in 2009 but sold the home in 2013; our transactions based methodology would mean we would continue to record the director as owning the 2007 address until 2013.

However, our approach is not able to deal very well with directors who either move address after October 2009 or those who are first appointed after that date (26% of directors in our sample). Furthermore, while there would be little gain in privacy for existing directors who do not move house from removing their residential address from the public record, there would be for those who would potentially be entering a new residential address into the record. Hence, there are good reasons to think we are not able to measure well the residential property wealth of certain types of directors.

To addresses this, we consider the robustness of our baseline regression results to this change in law. First, we run our baseline regression up to **October 2009**, at which point the addresses provided by directors would be their residential address, save for the less than 1% of company directors with a confidentiality order. Second, to make use of information after October 2009, we limit our sample to individuals who were company directors prior to October 2009, and for dates after this, we update the value of their holdings of residential property based on changes in the value of this house. If directors move to houses of comparable value in areas with similar movements in real estate prices, this will provide a reasonable proxy to the true value of their real estate over time.

Figure 8: Time line for dating director property transactions: simple case



E Using Transactions to Value a Director's Home Addresses

E.1 Determining which Transactions Correspond to the Directors

For an address that has been matched to either land registry, we know all the transactions that happen at a particular property since the registry started. The next step is then determine what transactions correspond to the director buying and/or selling their property (recall that throughout this paper we maintain that the director is the owner of the property). Figure 1 presents a diagrammatic representation of the time line we envisage for determining the relevant transactions for a director's property. In the time line, two lines on the upper half of the time line show the dates of the first and last vintage of the BVD database where the director lists that particular address as their property.

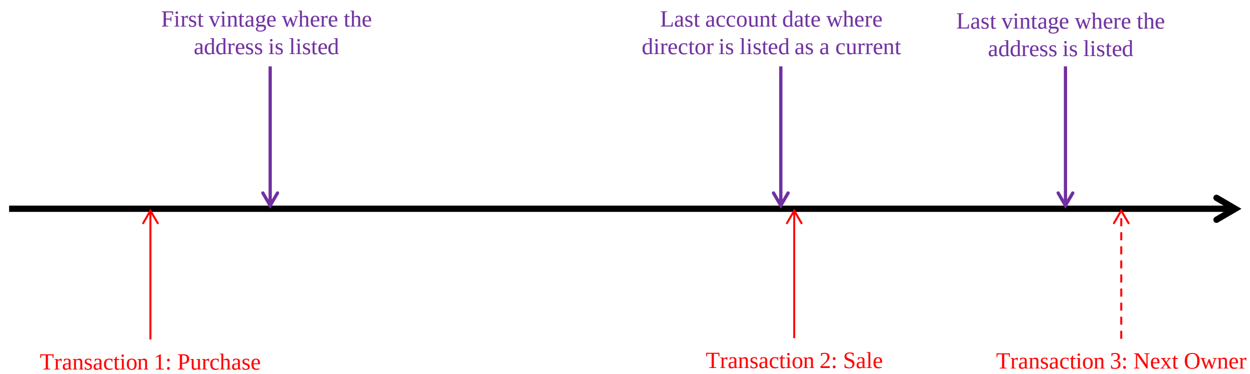
The lower half of the diagram, shows two transactions: Transaction 1 is the first transaction immediately prior to the address first being listed in BVD and will capture the director buying the property. Transaction 2 is the first transaction immediately after the last vintage of BVD where the director registered as living at the the address and will represent the director selling the property.

There may be a "Transaction 0" in the registry, which corresponds to the person who the director bought the property from buying it the first instance. There may also be a "Transaction 3", where the next owner after director sells the property on. And other transactions beyond that further down the chain.

In our data, 80.3% of director addresses conform to this time line: where there is no transaction between the first and last vintage where the address is listed in BVD. Note that Transaction 1 may not exist in the land registry if the director bought the property sufficiently far in the past (5.8% of addresses) and Transaction 2 may not exist if the director has not yet sold property (62.9% of addresses). By elimination, for 11.6% of addresses no transaction occurs between the first and last vintage and both Transaction 1 and 2 exist.

The other 19.7% of cases where there is an intermediate transaction can largely be explained by lags in reporting. BVD retains directors in the database after they have resigned (as described in

Figure 9: Time line for dating director property transactions: simple case



Appendix **C**, whether the director is currently at the company or has resigned is a field within our data) but firms have no obligation to keep the address information up to date for directors who are no longer present which means that the last vintage of BVD where the directors address is listed is not an accurate depiction of when the director left the property.

Figure 2, provides a second time line detailing how this issue can emerge and how we address it. Now rather than using the last vintage of BVD where the director registers that address we use the date of the last set of company accounts where the director both registers as living at the address and that the director says they have a current role.[43] This accounts for an additional 11.6% of addresses. As a final step, we also extend the window to include transactions to occur a year prior to the final account date where the director has a current role to allow for lags in the director in reporting a new address (2.9% of addresses).

This leaves 5.0% of addresses with transaction information that is inconsistent with BVD. We wipe transaction information on these addresses and treat the observations as missing. However, it is worth noting that for 2.2% out of those 5% of addresses (or just under half the addresses we wipe) there is no vintage of BVD where a director lists those addresses at firm where the director's role is current, i.e. the addresses predate the dataset. So it is no surprise the transaction information does not align.

[43] If the account date is missing we use the date of the last vintage of BVD where the director is listed as current instead.

F Computing Housing Equity from Contract-level Mortgage Data

F.1 Matching Company Directors with Mortgage Contracts

The purpose of this Section is to describe how we gather information on the dynamics of home equity and mortgage principal of each one of the company directors in our firm-level dataset. The key step is to merge our firm-level dataset through unique *postcode – date-of-birth* pairs of identifiers with a contract level database, known as the Product Sales Database (PSD), covering the universe of regulated mortgages in the UK. While we cannot observe the name of the mortgagor in PSD, we can see the date of birth of the mortgagor as well as the 6-digit postcode of the property on which the mortgage was taken out. A 6-digit postcode in the UK has, on average, 17 properties attached it. Therefore, these two bits of information (postcode and date of birth) make it very likely that we can uniquely match a company director from BVD with the mortgage contract he/she signed with a regulated mortgage provider. We then look at the details of each mortgage contract and, from it, we compute the dynamics of principal and home equity of each company director who has ever had a mortgage in our sample. To so, we construct a panel dataset at monthly frequency covering the period 1998m1-2015m12, with each unit corresponding to an individual mortgage contract. An additional purpose for using the PSD is to find the property values associated with company directors that we could not match in the Land Registry.

F.1.1 Describing the PSD

Since April 2005, UK providers of regulated mortgage products have reported transaction level data to the Financial Conduct Authority (FCA) and the Bank of England. The Product Sales Database (PSD) contains information both on the characteristics of mortgage contracts at origination (flow database) and on ongoing characteristics of mortgages such as the outstanding balance (stock database) as of 2015. Both the flow and stock databases cover more than 10,000,000 mortgage contracts. Note that there is a substantial lack of overlap in coverage between these two datasets because (i) mortgages originally taken out before 2005 may not be in the flow database whereas they may appear in the stock database if the borrower has not yet repaid the mortgage, or (ii) mortgages taken out after 2005 but repaid by 2015 may appear in the flow database but not in the stock database.

The flow database contains information on the loan size, date of origination, the valuation of the property, the type (fixed of variable rate) and terms of the mortgage, the initial interest rate, the number of years over which the interest rate is fixed in case of a fixed-rate mortgage, the type of borrower (remortgagor with or without equity extraction, mover or first-time buyer) of all regulated mortgages at origination since 2005. The stock database contains updated information on a number of these variables as of 2015. More importantly, the stock database reports the outstanding balance which provides us with a key input into the calculation of the dynamics of principal from the date of origination till 2015.

Characteristics of Directors vs Non-directors Tables 21–24 provide descriptive statistics that summarise some of the key characteristics of directors and non-directors based on information in the PSD. Overall, a number of findings emerge. Directors tend to live in more expensive houses, have higher income and lower LTV ratios compared to non-directors. The numbers suggest that an average company director in the UK has much more housing wealth than an average non-director.

Table 21: House Values: Directors vs Non-Directors

Date	Directors				Non-Directors			
	Median	10th	90th	N	Median	10th	90th	N
2005	232500	120000	525000	286388	150000	80000	289950	1294038
2006	245000	125000	570000	379669	160000	87500	300000	1705204
2007	250000	132500	608000	293787	170000	95000	330000	1396603
2008	270000	135900	650000	150362	175000	97500	350000	762487
2009	260000	132000	650000	97953	169950	91500	349950	595267
2010	275000	135000	675000	86285	178500	93500	380000	567338
2011	272500	135000	675000	76330	176000	92000	382500	551910
2012	275000	135000	685000	65332	178500	92500	389000	553103
2013	280000	137188	700000	62160	183000	95000	405000	619689
2014	301050	145000	750000	53383	194000	100000	440000	696520
2015	330000	150000	900000	28303	210000	105000	485000	683647
2016	350563	150000	1000000	21276	220000	105000	510000	702703

Notes: House valuations are done by the given mortgage provider at origination. The table is based on all available first mortgages taken out by directors and non-directors over the period 2005m4-2016m12. The table therefore does include information on a possible remortgage of a loan that had been taken out by a mortgagor since 2005m4. Equally, the table does not include information on mortgages taken out by a mortgagor before 2005m4.

Table 22: Income: Directors vs Non-Directors

Date	Directors				Non-Directors			
	Median	10th	90th	N	Median	10th	90th	N
2005	53000	26130	125200	283406	34638	18025	68541	1270104
2006	55285	27492	132520	376743	36000	19077	72000	1679259
2007	58000	28604	140000	289326	38000	20000	76500	1367026
2008	59000	28589	142853	146613	39000	20300	80000	740349
2009	57000	27366	137340	95176	38450	20000	81000	576367
2010	57000	27000	136000	84161	39266	20000	85389	551489
2011	56000	26200	135496	73873	39570	20096	86084	535331
2012	57000	26200	135356	62331	40157	20250	87625	534458
2013	58500	27937	135920	59826	41601	21168	90900	603793
2014	61524	29251	142326	51049	44000	22490	95097	678701
2015	64947	29994	162000	25969	46600	24000	101647	666649
2016	62888	29000	168497	18607	47085	24045	102488	683602

Notes: Income is the reported value at mortgage origination. The table is based on all available first mortgages taken out over the period 2005m4-2016m12. The table therefore does include information on a possible remortgage of a loan that had been taken out by a mortgagor since 2005m4. Equally, the table does not include information on mortgages taken out by a mortgagor before 2005m4.

Table 23: Loan-to-Value Ratio: Directors vs Non-Directors

Date	Directors				Non-Directors			
	Median	10th	90th	N	Median	10th	90th	N
2005	67	29	90	286387	68	29	94	1294028
2006	69	29	90	379665	70	28	94	1705188
2007	70	28	91	293783	71	27	95	1396585
2008	63	24	90	150360	67	25	91	762483
2009	60	22	85	97942	68	25	86	595217
2010	64	22	85	86278	69	25	87	567303
2011	64	22	85	76329	70	25	88	551896
2012	65	22	85	65330	73	27	90	553096
2013	66	23	88	62160	75	29	90	619686
2014	66	22	90	53382	75	31	90	696519
2015	52	16	85	28302	75	30	90	683630
2016	44	13	79	21271	75	30	90	702682

Notes: LTV is computed as the ratio of the house value (evaluated by the mortgage provider at origination) and the initial loan amount. The table is based on all available first mortgages taken out over the period 2005m4-2016m12.The table therefore does include information on a possible remortgage of a loan that had been taken out by a mortgagor since 2005m4. Equally, the table does not include information on mortgages taken out by a mortgagor before 2005m4.

Table 24: Describing the PSD Database: Fixed vs Variable Rate

Mortgage Type	Directors		Non-Directors	
	Number of Mortgages	Fraction (%)	Number of Mortgages	Fraction (%)
Standard Variable Rate	95,601	6.0	368,949	3.6
Tracker	375,254	23.4	1,566,361	15.5
Fixed for 1 year	21,667	1.4	127,253	1.3
Fixed for 2 years	901,994	56.3	6,286,789	62.1
Fixed for 3 years	83,810	5.2	594,563	5.9
Fixed for 4 years	7,311	0.5	70,182	0.7
Fixed for 5 years	79,949	5.0	872,285	8.6
Fixed for > 5 years	35,974	2.2	243,160	2.4
Total	1,601,560	100	10,129,542	100

Notes: The fixed rates denote the interest rate that applies during the introductory period of the mortgage.The table is based on all available first mortgages taken out over the period 2005m4-2016m12. The table therefore does include information on a possible remortgage of a loan that had been taken out by a mortgagor since 2005m4. Equally, the table does not include information on mortgages taken out by a mortgagor before 2005m4.

Missing Interest Rate Values One data constraint one has to overcome is related to about 32% of mortgage contracts not reporting interest rates in the PSD flow database. Given that we have virtually full coverage on other contract characteristics, we estimate an interest rate model in the spirit of Best, Cloyne, Ilzetzki, and Kleven (2015) and use the estimated parameter for out-of-sample prediction to fill in the missing interest rate values. The interest rate is modelled as follows:

$$\begin{aligned} r_i = \beta_1 LTV_i + \beta_2 lender_i + \beta_3 type_i \otimes month_i + \beta_4 repayment_i \\ \beta_5 term_i + s_1\left(age_i\right) + s_2\left(income_i\right) + \nu_i, \end{aligned} \tag{F.1}$$

where r_i is the mortgage rate for individual i. LTV_i is a vector of dummies, each corresponding to a 0.25%-points bin of the LTV, starting at the bin 54% and ending with the bin 99%. $lender_i$ is a vector of mortgage provider dummies. $type_i$ is a vector mortgage type dummies. We use 12 different types: standard variable rate (SVR) mortgage, tracker mortgage, or fixed rate mortgage with an introductory period of 1 year, 2 years,..., 10 years. $month_i$ is vector of month-year dummies associated with the date at which the mortgage was taken out. $repayment_i$ is a dummy controlling for whether the mortgage is capital-and-interest or interest-only. $term_i$ is a vector of dummies capturing the mortgage term. s_1 and s_2 are cubic splines with knots at the quintiles of the distribution of age and income and $\otimes$ denotes the outer product. Given the reasonably good fit (adjusted $R^2 = 0.81$, $N \approx 9.8\ million$) of the estimated interest rate model F.1, we use the estimates to fill in the missing interest rate values via out-of-sample forecasting. We winsorise the fitted values at 0% and 15%. For the remaining missing interest rate values (because of missing values for some of the RHS variables in F.1) we use the 2-year 75% LTV mortgage rate at the time of origination.[44]

[44] This affects only less than 1% of the sample.

F.1.2 Mortgage Principal Calculation

To compute the monthly payment on a fixed rate mortgage, notice that the amount owed on a loan at the end of each period equals the amount owed at the end of the previous period plus this period's interest, net of the fixed amount repaid during the current period. Thus, the schedule of a mortgage loan (i.e. the dynamics of the principal over the life of the mortgage) with initial loan amount L, monthly interest rate i and monthly repayment M can be written as:

$$\begin{aligned} P_{1-month} &= (1+i)\,L - M \\ P_{2-month} &= (1+i)^2\,L - [1 + (1+i)]\,M \\ P_{3-month} &= (1+i)^3\,L - \left[1 + (1+i) + (1+i)^2\right] M \\ &\vdots \\ P_{k-month} &= (1+i)^k\,L - \left[1 + (1+i) + (1+i)^2 + \cdots + (1+i)^{k-1}\right] M, \end{aligned} \tag{F.2}$$

where the polynomial can be simplified as $1 + (1+i) + (1+i)^2 + \cdots + (1+i)^{k-1} = \frac{(1+i)^k - 1}{i}$. By convention, mortgage providers in the UK calculate the monthly repayment M by setting the principal in the final (N) period to zero:

$$M = \frac{i}{(1+i)^N - 1} L\,(1+i)^N\,. \tag{F.3}$$

Substituting F.3 into F.2 yields an expression of the principal at any point of time, which is a (non-linear) function of the monthly interest rate on the mortgage, the mortgage term and the initial loan amount. After rearranging, the period-k principal can be written as:

$$P_{k-month} = \left[\frac{(1+i)^N - (1+i)^k}{(1+i)^N - 1}\right] L. \tag{F.4}$$

It is important to note that formula F.4 together with the interest rate i are applied to computing monthly payments for mortgages whose terms are typically much longer than the initial period to which the fixed interest rate applies. The initial period usually lasts for two years after which the mortgage provider sets a floating interest rate that is typically much higher than the fixed interest rate used in the introductory period. This can be avoided by the borrower remortgaging at the end of the initial period. Mortgagors have a strong incentive to do that so that they avoid paying the higher floating rate. In addition, they can also potentially get a better deal and lock in a more favorable fixed rate if the property has increased in value during the initial period and, as a result, the borrower falls in a lower LTV bucket at the time of remortgaging. Given the prevalence of remortgaging in the UK (Cloyne, Huber, Ilzetzki, and Kleven, 2017), it is important to take it into account when estimating the dynamics of principal of each company director in our sample. The next example provides an illustration of the benefits of remortgaging.

Two Approaches to Calculating Principal As mentioned in Subsection 2.4 in the main text, we use two methods to compute mortgage principal and home equity. The first method ("Passive") uses only initial information in the flow data. The second method ("Active") uses the initial information as well as all subsequent information, both from future remortgaging and the value in the stock. The passive method simply computes the principal based on the above formula F.4, which ignores any subsequent housing choices directors may make (which could possibly correlate with their firm's performance).

The active method accounts for UK borrowers' potential remortgaging decisions that could make use of the falling mortgage rate environment since the 1990s. The PSD flow database provides us information on mortgages at origination and on remortgages that included equity extractions or moving to another bank. The PSD stock database provides us information on all outstanding mortgages in 2015. These bits of information allow us to estimate the amortisation curve associated with each mortgage contract. Specifically, for each mortgagor, we compute a counterfactual monthly payment amount $M^\star$ that would have delivered a principal dynamics since the mortgage origination consistent with the next observable loan amount, B, as reported at the next remortgaging date in the PSD flow database. If we can not find any more remortgaging dates associated with the given contract in the PSD flow database, then B refers to the 2015 outstanding balance as reported in the PSD stock database. For each mortgagor j, we compute $M_j^\star$ as:

$$M_j^\star = \frac{i_j^\star}{\left(1+i_j^\star\right)^{k_j} - 1}\left(L_j\left(1+i_j^\star\right)^{k_j} - B_j\right). \tag{F.5}$$

Note that all variables in F.5 are specific to the given borrower j. The term k_j denotes the number of months elapsed since the origination date, $t_j^\star$, till the next observed loan amount, and $i^\star$ is the effective interest rate applied to the mortgage. Given F.5, the principal of mortgagor j at each period t (k_j months after the origination date $t_j^\star$) can be computed as:

$$P_{j,t} = \left(1+i_j^\star\right)^{k_j} L_j - \frac{\left(1+i_j^\star\right)^{k_j} - 1}{i_j^\star} M_j^\star. \tag{F.6}$$

While the calculation F.5–F.6 can be applied to the majority of mortgages in our sample, there are a number of cases where remortgaging coincides with equity releases which introduces jumps in the estimated principal dynamics. Our baseline approach (F.5–F.6) is designed to splice smooth curves using observed principal values at dates of mortgaging, remortgaging and from the 2015 PSD stock database. Hence, our baseline approach does not take into account jumps caused by equity releases. We address this issue explicitly further below.

We use our method to construct a panel dataset at monthly frequency covering the period 1995m1-

2015m12, where each unit corresponds to a mortgage contract. As a first step, we keep observations from the PSD flow dataset (1,572,390) and stock dataset (1,241,750) that correspond to a unique *postcode – date-of-birth* pairs of identifier from BVD. We then merge these two datasets with the results summarised in Table 25.

Table 25: Mortgage of Company Directors: Merging the PSD Stock and Flow Databases

	Observations
Only in PSD Flow	563,840
Only in PSD Stock	233,200
In Flow and in Stock	1,008,550

Notes: The table summarises the number of mortgage contracts of company directors that are contained only in the PSD flow database, or only in the PSD stock database, or appear in both databases.

Equity Extraction Equity extraction can generate jumps in the estimated principal dynamics which needs to be addressed. We aim to address this issue in two ways. First, we use information on borrower type from the PSD flow at remortgaging dates which states explicitly whether the remortgaging decision coincided with release of housing equity. Second, we broaden this definition by also including all remortgages where the observed loan amount was at least £5000 larger than the loan amount at the previous observed remortgaging date. This more than doubles the number of observed equity releases. In both cases, we proceed by computing the dynamics of principal between the previous remortgaging date and the current remortgaging date (when equity release occurs) which typically yields a gradually declining principal profile (unless the mortgage was an interest-only mortgage). Computationally, this is done by using the standard formula F.3 instead of the splicing method F.5.

Pre-2005 Values Given that the PSD Flow starts in 2005 and our firm-level data starts in 2000, we need further computations to align our panel of director mortgage principal with the panel of firm balance sheets. To impute principal observations for this period, we adjust our splicing formula F.5 as follows. We compute a counterfactual monthly payment amount $M^\star$ that would have delivered a principal dynamics since 1998m1 with the next observable loan amount, B_j, as reported at the first available remortgaging date in the PSD flow database. Given that we do not know the loan amount in 1998m1, we use the average interest rate between 1998m1 and the first remortgaging date, $i_j^\star$, and the imputed mortgage term N_j.[45] To compute $M^\star$ is then given by:

$$M_j^\star = B_j \left(\frac{i_j^\star \left(1 + i_j^\star\right)^{N_j}}{\left(1 + i_j^\star\right)^{N_j} - \left(1 + i_j^\star\right)^{k_j}} \right), \tag{F.7}$$

[45] For example, if a mortgage in 2007 has an outstanding term of 18 years, we assume that that the mortgage term in 2000 was 25 years.

where k_j is the number of months elapsed between 1998m1 and the first time the given mortgage with loan value B_j appears in the PSD flow database.

Using Transaction Price Data from the Land Registry A natural criticism of imputing principal dynamics prior to first observing the given mortgage in the PSD flow database (F.7) is the lack of information on when a mortgage on the given property was actually first taken out by the given director. To address this issue, we merge in property transaction information from the Land Registry database as described by Appendix D, and match the transaction data with the mortgage data via *postcode – date-of-birth* pairs of identifiers. Around 73% of directors' mortgage contracts from the PSD flow database can be matched with property transaction data from the Land Registry. Given the successful matches, we use the property purchase data from the Land Registry as the starting date for the mortgage in cases where the mortgage origination date precedes the date that is registered in the PSD flow database.

G Residential Collateral and Corporate Borrowing: Additional Results

G.1 Cross-country Comparison

As mentioned in the main text, a recent Bank of England survey of major lenders shows that about 29% of lending to SMEs and mid-size corporations was secured with a personal guarantee (PG henceforth). Table 26 summarises previous research confirming that similar numbers were obtained for Ireland and Finland, whereas the prevalence of PGs seems higher in Australia, US and Japan. Here, we provide a brief summary of the results.

Carroll, McCann, and O'Toole (2015) uses data from the Irish Department of Finance SME Credit Demand Survey and finds that the probability of PG usage is decreasing in number of employees, turnover, age and profitability. They also provide strong evidence on the complementarity between PGs and real estate collateral: "For loans without any specific collateral item attached, personal guarantee usage is 29% whereas for firms that post a specific security such as land, property, machinery or other assets, personal guarantee usage is 59%" (pp. 2). Ono and Uesugi (2009) employs data from the Survey of the Financial Environment conducted by the Small and Medium Enterprise Agency of Japan in October 2002. The document that the use ratios of collateral and PGs are 71.7% and 66.7%, respectively. However, these numbers may likely be biased upwards, as firms in their sample have multiple loan contracts with a main bank. Calcagnini, Farabullini, and Giombini (2014) uses information on loans from a large sample of Italian non-financial firms and document that about 40% the total number of loans were secured on a PG. Peltoniemi and Vieru (2013) uses a Finnish confidential contract-level corporate loan database to document that personal guarantee is used in about 30% of the loans. Davydenko and Franks (2008) studies incidents of corporate bankruptcies, and find that French banks are very likely to activate the entrepreneur's PG with about 35% of total collateral comprising of PGs at default.

In Spain, CEET (2010) shows that about 80% of SMEs are required to offer some form of collateral when applying for a bank loan, and about 35% of collateral is made up of PGs. Bathala, Bowlin, and Dukes (2006) conducted a survey among 201 privately-owned SMEs in the US and found that about 53% of these firms used PGs from major stockholders, officers or directors as a form of covenant for bank loans. Using a larger survey data National Survey for Small Business Finances (conducted by the Fed Board), Meisenzahl (2014) reports that in the 1998 and 2003 waves, about 54% of firms gave PGs to receive bank credit.

G.2 Evidence from the 19-20th Century UK

It is worth noting that the use of real estate and personal guarantees as security for business lending dates back to the development of the modern UK corporate structure in the early 20th century. The

Table 26: Cross-country Comparison of Personal Guarantees

Country	Paper	Use of PGs	Notes
Australia	Connolly, Cava, and Read (2015)	>UK/US	as a % of new SME loans
Ireland	Carroll, McCann, and O'Toole (2015)	33%	as a % of new SME loans
Japan	Ono and Uesugi (2009)	67%	as a % of new SME loans
Italy	Calcagnini, Farabullini, and Giombini (2014)	40%	as % of number of new loans
Finland	Peltoniemi and Vieru (2013)	30%	as % of number of new loans
France	Davydenko and Franks (2008)	35%	value at default as % of total collateral
Spain	CEET (2010)	30-45%	as a % of new SME loans
UK	BoE	34%	as a % of new SME loans
	Franks and Sussman (2005)	50-60%	as % of loans of distressed companies
USA	Bathala, Bowlin, and Dukes (2006)	53%	as a % of new SME loans
	Meisenzahl (2014)	54%	as a % of new SME loans

Notes: The table provides a summary of the results from the recent empirical literature. The %-values typically capture the share of the number of loans at origination that are secured by a personal guarantee of a company director. The exception is Davydenko and Franks (2008) that focuses on firms with loan exposure at default.

comprehensive work of Collins and Baker (2003) gathered loan-level data to study the evolution of the relationship between commercial banks and firms over the period 1880-1914. Table 27 summarises some of their key findings relevant to our study.

Table 27: The evolution of personal guarantees in the UK

	Ratio of private firms to companies	Type of Security Taken Against Loans (as % of total loans)			
		None	Personal Guarantee	Claims to Property	Others
1880-1884	5:1	46.6	19.3	17.0	17.1
1888-1892	1.4:1	33.9	30.0	20.5	15.6
1898-1902	0.6:1	20.6	36.2	16.7	26.5
1910-1914	0.3:1	17.7	33.8	19.0	29.5

Notes: This table is based on Tables 9.3 and 9.5 of Collins and Baker (2003). Others include debentures, life policies, shares, uncalled capital and promissory notes.

At the beginning of their sample, 1880-1884, a large fraction of bank loans in their samples were unsecured. This is associated with the prevalence of sole traders and private partnerships in the UK corporate universe: these entities outnumbered limited companies by a ratio of 5:1 during this period. Since sole traders and private partnerships were personally responsible for their firms' debt, banks had little incentive to require security when granting loans. By 1910-1914, the UK corporate structure changed drastically with the ratio of private firms to companies falling to 0.3:1.[46] As a result, banks began to ask increasingly for directors' personal guarantees that became the most common security taken by commercial banks. By the First World War, 34% of total loans in their sample were secured on a personal guarantee, and this number was substantially higher amongst companies with limited

[46]This change was catalysed by the landmark case of Salomon versus Salomon (1897) whereby the House of Lords ruled against the doctrine of corporate personality (as implied by the Companies Act 1862) and effectively triggered the spreading of limited company as a dominant legal form of conducting business.

liability.[47]

G.3 Anecdotal Evidence

Practical advise to bankers:

> "There is yet another risk which you have to consider when you make advances to a limited company, which is this, – its articles of association may not give it the power to borrow from a bank: but even if they do, the exercise of the power may be hedged round with difficult forms of legal observance, of the due performance of which you can never be perfectly assured [...] Except, therefore, where the undertaking is one of acknowledged success, with ample capital and immediately available trade assets, sufficient at all times to discharge its trade liabilities, you require the personal guarantee of its Directors, when you make advances to a limited company. These gentlemen will know whether such advances are within the scope and limit of their borrowing powers, and what resources will be at hand to meet the advances when due. " (p. 31, Rae (1920))

Notable case of personal guarantee:

> "What's no less memorable, though less well known, is how [Donald] Trump pulled off that Houdini-like escape from creditors. Back in 1990, both Atlantic City and Manhattan real estate were reeling from recession, and Trump was drowning under $960 million in personally guaranteed loans. Those guarantees meant that if a loan on an asset like the Grand Hyatt defaulted and the price of the hotel was not enough to cover the loan, the banks could grab Trump's other properties–which meant the casinos. That's basically what happened when in 1990 Chemical, Bankers Trust, and other lenders one by one took liens on Trump's equity in the casinos. If Atlantic City rebounded, they, not Trump, would get the income. And if Trump failed to make interest payments they could foreclose and either sell the casinos or try to run them." (22 July, 1996, Fortune Magazine[48])

Notable case of personal guarantee:

> "It was November 2008. Three-and-a-half years earlier the bank had loaned [Donald] Trump the cash to build one of his grandest projects yet: a hotel and mega-tower in Chicago. Trump had given his personal guarantee he would repay the $640m. As per

[47] Collins and Baker (2003) provides a number of additional results. For example, they show this remarkable change in the UK corporate structure and banks' collateral policies did not coincide with changes in the stated purpose/use of loan: around 75% of loans were taken out for working capital or to address cash flow difficulties (Table 9.8). Also, the actual duration of loans was also stable throughout the sample, with 50-60% of loans being short term (<12month) and 40-50% of loans being long term (>12month).

[48] http://archive.fortune.com/magazines/fortune/fortune_archive/1996/07/22/214724/index.htm

agreement, he was now due to hand over a large chunk, $40m." (16 February, 2017, The Guardian[49])

On public perception of personal guarantees:

> "An alarming 55% of small business owners across the UK did not know what a personal guarantee was. Yet the majority of SMEs have agreed to one. More than one in five SME owners incorrectly believe that a personal guarantee requires only that the director 'personally guarantees' repayments will be made on time, to the best of their ability. 17% believed it meant that the director would guarantee sufficient funds in the business bank account to make repayments and 7% incorrectly thought that business assets would be seized if they defaulted but personal assets would remain untouched. Reality is far harsher. One leading high-street bank states within its terms and conditions that: 'any property given as security, which may include your home, may be repossessed if you do not keep up repayments on debts secured on it."' (Wirefund[50])

[49] https://www.theguardian.com/business/2017/feb/16/how-donald-trump-became-deutsche-bank-biggest-headache

[50] https://www.wirefund.com/pages/personal-guarantee

H Theoretical Appendix

H.1 The Full Model

The model builds on previous models with corporate collateral constraints as in Kiyotaki and Moore (1997), Liu, Wang, and Zha (2013) and Pinter (2015), and models with household collateral constrains as in Iacoviello (2005) and Iacoviello and Neri (2010). The model is infinite horizon and is in discrete time. The economy features two types of agents: a representative household and a representative entrepreneur. The household consumes and saves through a one-period riskless discount bond. The entrepreneur consumes, produces, hires household labour, purchases capital, residential and commercial land which it partly finances with credit, collateralised with their capital stock, residential and commercial land holdings. The model description follows closely the notation of Liu, Wang, and Zha (2013).

H.1.1 Household

The representative household maximises the utility function:

$$U = \mathbb{E}_0 \sum_{s=0}^{\infty} \beta^s \left\{ A_{t+s} \log \left(C_{h,t+s} - h_h C_{h,t+s-1} \right) + \varphi_{t+s} \log L_{h,t+s} - \psi_{t+s} N_{t+s} \right\}, \tag{H.1}$$

where $C_{h,t}$ denotes consumption and h_h is the degree of internal habit formation. The parameter β is the subjective discount factor, and the intertemporal preference shock A_t follows the stationary process:

$$A_t = A_{t-1} \left(1 + \lambda_{a,t}\right), \quad \ln \lambda_{a,t} = (1 - \rho_a) \ln \bar{\lambda}_a + \rho_a \ln \lambda_{a,t-1} + \varepsilon_{a,t}. \tag{H.2}$$

The parameter $\bar{\lambda}_a > 0$ is a constant, ρ_a is the degree of persistence. The innovation ε_a is iid with variance σ_a^2. Moreover $L_{h,t}$ is residential real estate of the household with the corresponding taste shifter φ_t. This land demand shock follows the stationary process:

$$\ln \varphi_t = (1 - \rho_\varphi) \ln \bar{\varphi} + \rho_\varphi \ln \varphi_{t-1} + \sigma_\varphi \varepsilon_{\varphi,t}, \tag{H.3}$$

where $\bar{\varphi} > 0$ is a constant, $\rho_\varphi \in (-1, 1)$ measures the persistence of the land demand shock, σ_φ is the standard deviation of the i.i.d innovation $\varepsilon_{\varphi,t}$. The labour supply shock ψ_t follows the stationary process:

$$\ln \psi_t = (1 - \rho_\psi) \ln \bar{\psi} + \rho_\psi \ln \psi_{t-1} + \sigma_\psi \varepsilon_{\psi,t}, \tag{H.4}$$

where $\bar{\psi} > 0$ is a constant, $\rho_\psi \in (-1, 1)$ measures the persistence and σ_ψ is the standard deviation of the i.i.d innovation $\varepsilon_{\psi,t}$. The flow-of-funds constraint of the representative household is:

$$C_{h,t} + q_{l,t}\left(L_{h,t} - L_{h,t-1}\right) + \frac{S_t}{R_t} = W_t N_t + S_{t-1}, \tag{H.5}$$

where R_t is the gross riskfree return, S_t is the purchase in period t of the loanable bond that pays off one unit of consumption good in all states of the world in period $t+1$, which is known in advance. In period 0, the household starts with $S_{-1} > 0$ units of the loanable bonds. The household's problem is to choose a sequence $\{C_{h,t}, S_t, L_{h,t}\}_{t=0}^{\infty}$ to maximise its utility.

H.1.2 Entrepreneur

The entrepreneur's utility function is written as:

$$U = \mathbb{E}_0 \sum_{s=0}^{\infty} \beta^s \left\{\log\left(C_{e,t+s} - h_e C_{e,t+s-1}\right) + \upsilon \log L_{r,t+s}\right\}, \tag{H.6}$$

where $C_{e,t}$ denotes the entrepreneur's consumption, h_e is the habit persistence $L_{r,t}$ is residential land and υ is a scale parameter. The entrepreneur is the producer in this economy, and the production function Y_t is a function of physical capital (K_t), entrepreneurial commercial land ($L_{c,t}$) and household labour (N_t):

$$Y_t = Z_t \left[K_{t-1}^{1-\kappa} L_{c,t-1}^{\kappa}\right]^{\alpha} N_t^{1-\alpha}, \tag{H.7}$$

where $\alpha \in (0,1)$, $\kappa \in (0,1)$ and $\phi \in (0,1)$ are the output elasticities of the production factors. The total factor productivity Z_t is composed of a permanent component Z_t^p and a transitory component ν_t such that $Z_t = Z_t^p \nu_{z,t}$, where the permanent component Z_t^p follows the stochastic process:

$$Z_t^p = Z_{t-1}^p \lambda_{z,t}, \quad \ln \lambda_{z,t} = (1-\rho_z)\ln \bar{\lambda}_z + \rho_z \ln \lambda_{z,t-1} + \varepsilon_{z,t}, \tag{H.8}$$

and the transitory component follows the stochastic process:

$$\ln \nu_{z,t} = \rho_{\nu_z} \ln \nu_{z,t-1} + \varepsilon_{\nu_z,t}. \tag{H.9}$$

The parameter $\bar{\lambda}_z$ is the steady-state growth rate of Z_t^p, the parameters ρ_z and ρ_{ν_z} measure the degree of persistence. The innovations $\varepsilon_{z,t}$ and $\varepsilon_{\nu_z,t}$ are iid with variances σ_z^2 and $\sigma_{\nu_z}^2$. The entrepreneur is endowed with K_{-1} units of initial capital stock and $L_{-1,e}$ units of land. Capital accumulation follows the law of motion:

$$K_t = (1-\delta) K_{t-1} + \left[1 - \frac{\Omega}{2}\left(\frac{I_t}{I_{t-1}} - \bar{\lambda}_l\right)^2\right] I_t, \tag{H.10}$$

where I_t denotes investment, $\bar{\lambda}_l$ denotes the steady-state growth rate of investment, and $\Omega > 0$ is the adjustment cost parameter. The entrepreneur faces the following flow-of-funds constraint:

$$C_{e,t} + q_{l,t}\left[(L_{c,t} - L_{c,t-1}) + (L_{r,t} - L_{r,t-1})\right] + B_{t-1} = Y_t + \frac{B_t}{R_t} - \frac{I_t}{Q_t} - W_t N_t, \tag{H.11}$$

where B_{t-1} is the amount of matured entrepreneurial debt and B_t/R_t is the value of new debt. Following Greenwood, Hercowitz, and Krusell (1997), Q_t is the investment-specific technological change, defined as $Q_t = Q_t^p \nu_{q,t}$, where the permanent component Q_t^p follows the stochastic process:

$$Q_t^p = Q_{t-1}^p \lambda_{q,t}, \quad \ln \lambda_{q,t} = (1-\rho_q)\ln \bar{\lambda}_q + \rho_q \ln \lambda_{q,t-1} + \varepsilon_{q,t}, \tag{H.12}$$

and the transitory component follows the stochastic process:

$$\ln \nu_{q,t} = \rho_{\nu_q} \ln \nu_{q,t-1} + \varepsilon_{\nu_q,t}. \tag{H.13}$$

The parameter $\bar{\lambda}_q$ is the steady-state growth rate of Q_t^p, the parameters ρ_q and ρ_{ν_q} measure the degree of persistence. The innovations $\varepsilon_{q,t}$ and $\varepsilon_{\nu_q,t}$ are iid with variances σ_q^2 and $\sigma_{\nu_q}^2$. The entrepreneur's ability to obtain credit subject to the following collateral constraint:

$$B_t \leq \theta_t \mathbb{E}_t \left[q_{l,t+1}\left(L_{c,t} + \omega L_{r,t}\right) + q_{k,t+1}K_t\right], \tag{H.14}$$

where $q_{k,t+1}$ is the shadow value of capital in consumption units, also referred to as Tobin's q, and ω is the weight of residential land in the collateral value. The credit constraint H.14 limits the amount of borrowing by a fraction of the gross value of the collateralisible assets - land and capital. As in Kiyotaki and Moore (1997), the credit constraint reflects problems of limited contract enforceability. The θ_t is the entrepreneurial collateral shock which is written as:

$$\ln \theta_t = (1-\rho_\theta)\ln \theta + \rho_\theta \ln \theta_{t-1} + \sigma_\theta \varepsilon_{\theta,t} \tag{H.15}$$

where θ is the steady-state value of θ_t, and $\rho_\theta \in (0.1)$ is the persistence parameter, and $\varepsilon_{\theta,t}$ is iid with variance σ_θ^2. The entrepreneur's problem is to choose a sequence $\{C_{e,t}, B_t, N_t, K_t, I_t, L_{c,t}, L_{r,t}\}_{t=0}^{\infty}$ to maximise utility.

H.1.3 Market Clearing

In a competitive equilibrium, the markets for goods, labour, land and bonds all clear. The goods market clearing condition is:

$$C_{h,t} + C_{e,t} + \frac{I_t}{Q_t} = Y_t. \tag{H.16}$$

The land market clearing condition implies:

$$L_{h,t} + L_{r,t} + L_{c,t} = \bar{L}, \tag{H.17}$$

where $\bar{L}$ is the fixed aggregate land endowment. Finally, the bond market clearing condition implies:

$$S_t = B_t. \tag{H.18}$$

A competitive equilibrium consists of sequences of prices $\{W_t, q_{l,t}, R_t\}_{t=0}^{\infty}$ and allocation of quantities $\{C_{h,t}, C_{e,t}, I_t, N_t, L_{h,t}, L_{r,t}, L_{c,t}, S_t, B_t, K_t, Y_t\}_{t=0}^{\infty}$ such that taking prices as given, the allocations solve the optimising problems for the household and the entrepreneur, and all markets clear.

H.2 Model Estimation

H.2.1 Data

The baseline DSGE model is estimated on six UK aggregate time series: real house prices ($q_{l,t}^{data}$), the inverse of the relative price of investment (q_t^{data}), real per capita investment (I_t^{data}), real per capita consumption (C_t^{data}), lending to corporates (B_t^{data}), working hours (N_t^{data}). The sample covers the period from 1975:Q3 to 2015:Q1. The observable series are defined as follows:

$$q_{l,t}^{data} = \frac{Nationwide}{cdef}$$

$$q_t^{data} = \frac{cdef}{idef}$$

$$I_t^{data} = \frac{inv}{popindex}$$

$$C_t^{data} = \frac{(pcons - imprent - actrent)\,/cdef}{popindex}$$

$$B_t^{data} = \frac{Bcorp/cdef}{popindex}$$

$$N_t^{data} = \frac{TotalHours}{popindex}$$

Nationwide: Seasonally adjusted house price index of all houses, derived from Nationwide lending data for properties at the post survey approval stage.

cdef: Quarterly private consumption deflator, seasonally adjusted (constructed using ONS codes: (ABJQ + HAYE)/ (ABJR + HAYO)).

idef: Quarterly total gross fixed capital formation deflator, seasonally adjusted (constructed using ONS codes: (NPQS+NPJQ)/(NPQT+NPJR)). We use the 2011:Q3 vintage of this series updated to 2015 using the latest (2015:Q4) vintage. We take this step in order to omit R&D prices from the data. The ONS changed the treatment of R&D expenditure from intermediate consumption to gross fixed capital formation as part the implementation of ESA2010 in 2014. As a result, in the latest vintage of the UK national accounts, relative investment prices no longer display the downward trend prevalent in other countries. Our use of an earlier vintage is to capture shifts in the relative price of tangible capital only, which is more closely aligned with the model definition (not least because intangible capital is much harder to collateralise).

popindex: The index of the UK working age (16+) population (source: LFS and ONS; code: MGSL).

inv: Total gross fixed capital formation, seasonally adjusted, at constant prices, £m (source: ONS; code: NPQT).

pcons: Private final consumption expenditure, seasonally adjusted, at current prices, £m (source: ONS; constructed using codes: ABJQ+HAYE).

imprent: Household consumption of imputed rents, seasonally adjusted, at current prices, £m (source: ONS; code: GBFJ).

actrent: Household consumption of actual rents, seasonally adjusted, at current prices, £m (source: ONS; code: ZAVP).

Bcorp: Quarterly amounts outstanding of monetary financial institutions' (MFI) sterling net lending to private non-financial corporations, seasonally adjusted, at current prices, £m. (source: Bank of England Interactive Database, code: LPQBC57).

TotalHours: Total actual weekly hours worked, seasonally adjusted, millions (source: ONS; code: YBUS).

All national accounts data are from the 2015:Q4 vintage unless otherwise stated.

H.2.2 Steady State Calibration

To calibrate the steady state of the model we make use of five ratios observable in the data. Some of the key details in the UK national account estimates of sectoral non-financial balance sheets are only available from 1997 onwards. Hence, our approach is to compute the ratios on an annual basis and take the average over the 1997-2014 period for the purpose of calibration. Where the ratio is defined as a stock over a flow, we multiply the ratio by four to convert back to a quarterly frequency. We use data in current prices. Let variables without time subscripts denote steady state values.

Capital to output ratio $(K/Y) = 4.99$. Capital is defined as total economy fixed assets less dwellings and less buildings other than dwellings. Output is defined as total economy gross value added. This ratio is constructed using ONS codes: 4×(NG23-CGLK-CGMU)/ABML. The entrepreneur's subjective discount rate β is set to deliver this ratio.

Investment to capital ratio $(I/K) = 0.03576$**.** Capital is defined as above. Investment is defined as total economy gross fixed capital formation. This ratio is constructed using ONS codes: NPQX/(4×(NG23-CGLK-CGMU)). The depreciation rate δ is set to deliver this ratio.

Entreprenuerial land to output ratio $q_l L_c/Y = 2.80$. Corporate land is defined as the total economy dwellings plus total economy buildings other than dwellings less dwellings owned by the household sector. Output is defined as above. This ratio is constructed using ONS codes: 4×(CGLK+CGMU-CGRI)/ABML. The production scale parameter κ is set to deliver this ratio.

Residential land to output ratio $q_l(L_h + L_r)/Y = 9.28$. Residential land is defined as the total value of dwellings owned by the household sector. Output is defined as above. This ratio is constructed using ONS codes: 4×CGRI/ABML. The utility scale parameter $\bar{\varphi}$ is set to deliver this ratio.

Entrepreneurial share of residential land $L_r/(L_h+L_r) = 0.2$ which is set following the discussion in section 6. The utility scale parameter ν is set to deliver this ratio.

Loan to value ratio $\theta = B/(q_lL_c+q_l\omega L_r+q_kK) = 0.53$**.** We define the total value of corporate debt (B) as the loan and debt security liabilities of the non-financial corporate sector. The entrepreneur's residential land is 0.2 times total residential land (defined as above). Corporate land plus corporate capital ($q_lL_c + q_kK$) is defined as the fixed assets of the non-financial corporate sector. This ratio is constructed using ONS codes: (NOOG+NOPI)/(NG2D+0.2×CGRI). We set $\omega = 1$ in the baseline.

H.2.3 Estimated Model Parameters

Table 28 summarises the results from the Bayesian estimation of the model. A system of measurement equations links the observables, defined in subsection H.2.1 above, to the state variables. We use dynare 4.4.2 to perform the estimation. First we use the Kalman-filter to construct the likelihood function. After combining the likelihood with the priors we use numerical optimisers to maximise the posterior kernel. Using the modes of the maximised posterior kernel as starting points, we employ the Metropolis Hastings algorithm to simulate 200,000 random draws to approximate the shape of the posterior distributions.

Table 28: MCMC Results: Prior and Posterior Distributions of Structural Parameters

Parameter	Prior			Posterior		
	Distribution	$\underline{a}$	$\underline{b}$	Mean	Low	High
h_h	Beta(a,b)	1.00	2.00	0.0267	0.0000	0.0542
h_e	Beta(a,b)	1.00	2.00	0.6502	0.4891	0.8023
Ω	Gamma(a,b)	1.00	0.50	0.2697	0.2203	0.3156
$100\,(g_\gamma - 1)$	Gamma(a,b)	1.86	3.01	0.6758	0.4500	0.9762
$100\,(\bar{\lambda}_q - 1)$	Gamma(a,b)	1.86	3.01	0.2347	0.0748	0.3865
ρ_z	Beta(a,b)	1.00	2.00	0.4584	0.2629	0.6519
ρ_{ν_z}	Beta(a,b)	1.00	2.00	0.1792	0.0000	0.3522
ρ_q	Beta(a,b)	1.00	2.00	0.4634	0.0695	0.7562
ρ_{ν_q}	Beta(a,b)	1.00	2.00	0.0592	0.0000	0.1354
ρ_φ	Beta(a,b)	1.00	2.00	0.9998	0.9998	0.9998
ρ_a	Beta(a,b)	1.00	2.00	0.8846	0.8624	0.9072
ρ_θ	Beta(a,b)	1.00	2.00	0.9804	0.9728	0.9881
ρ_ψ	Beta(a,b)	1.00	2.00	0.9914	0.9844	0.9992
σ_z	Inv-Gam(a,b)	0.3261	1.45e-04	0.0072	0.0052	0.0091
σ_{ν_z}	Inv-Gam(a,b)	0.3261	1.45e-04	0.0060	0.0045	0.0077
σ_q	Inv-Gam(a,b)	0.3261	1.45e-04	0.0065	0.0035	0.0101
σ_{ν_q}	Inv-Gam(a,b)	0.3261	1.45e-04	0.0106	0.0089	0.0124
σ_φ	Inv-Gam(a,b)	0.3261	1.45e-04	0.0584	0.0489	0.0675
σ_a	Inv-Gam(a,b)	0.3261	1.45e-04	0.1118	0.0721	0.1494
σ_θ	Inv-Gam(a,b)	0.3261	1.45e-04	0.0182	0.0164	0.0201
σ_ψ	Inv-Gam(a,b)	0.3261	1.45e-04	0.0076	0.0069	0.0084

Note: The parameters $\underline{a}$ and $\underline{b}$ denote the shape and scale parameters of the corresponding prior distributions. The *High* and *Low* columns refer to the posterior probability intervals at the 90% level, obtained by running 200,000 MCMC chains from the posterior simulation.