Home Values and Firm Behaviour*

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Abstract

The homes of those in charge of firms are an important source of finance for ongoing businesses. We use firm level accounting data, transaction level house price data and loan level residential mortgage data from the UK to show that a £1 increase in the value of the residential real estate of a firm's directors increases the firm's investment and wage bill by £0.03 each. These effects run through smaller firms and are similar in booms and busts. In aggregate, the homes of firm directors are worth 80% of GDP. Using this, a back of the envelope calculation suggests that a 1% increase in real estate prices leads, through this channel, to up to a 0.28% rise in business investment and a 0.08% rise in total wages paid. We complement this with evidence on how a firm responds to changes in the value of its own corporate real estate; we find that, in aggregate, the residential real estate of directors is at least as important for activity. We use an estimated general equilibrium model to quantify the importance of both types of real estate for the propagation of shocks to the macroeconomy. *JEL Codes:* D22, E32, R30.

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1 Introduction

Economic mechanisms that generate a causal link between real estate prices and the macroeconomy have been a focus of attention in the recent literature. The extant literature pictures this link running through two main channels. First, households, particularly those that are financially constrained, use increases in real estate wealth to finance consumption (Mian and Sufi, 2011; Berger et al., 2017). Second, credit constrained firms use increases in the value of their commercial real estate to finance investment (Chaney et al., 2012; Liu et al., 2013).

This paper explores a mechanism at the intersection of these two channels. The residential wealth owned by households is an important source of collateral to finance the corporate sector. It is common for the owners of small and medium sized enterprises (SMEs) to pledge their homes to finance their firms. The literature has yet to disentangle and quantify the aggregate consequences of this.[1] The macroeconomic implications could be profound: the homes of the households who run firms are worth 80% of GDP and four times the value of owner occupied corporate real estate. And while this residential real estate largely supports the financing of smaller enterprises, such enterprises are responsible for a considerable share of economic activity and business cycle fluctuations.[2]

We address this issue 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.[3] 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. Our key microeconometric result is that a £1 increase in the value of the homes of a firm's directors leads the average firm in our sample to invest £0.03 more and

[1] The use of homes as collateral for entrants is explored in Hurst and Lusardi (2004); Corradin and Popov (2015); Kerr et al. (2015); Schmalz et al. (2017) among others. The evidence of a meaningful effect at the micro level is mixed and there is little evidence of material consequences for the macroeconomy. However, the link to incumbent firms at the micro level has not been studied. Adelino et al. (2015) explore this mechanism at the regional level, but do not distinguish between corporate and residential real estate.

[2] In the UK, SMEs (<250 employees) are responsible for 52% (42%) of employment (investment). SMEs accounted for 43% of the fall in employment from 2008-09, and 66% (57%) of the rise in employment (investment) from 2010-14. Sources: *ABS*, *SME Stats*, *BPE*. SMEs in the OECD account for 60% of employment and $50 - 60\%$ of value added on average (OECD, 2017).

[3] A director does not just refer to a member of the board of a large firm. Every firm, no matter how small, must have at least one director. There are 2.8 million active firm directors in the UK. 72% of directors report being shareholders of their firm.

spend an additional £0.03 on total wages. The effects of an increase in the total home equity value of a firm's directors are the same. These effects appear similar across periods of real estate price increases and decreases and are also consistent across subsamples for the pre- and post- crisis period. Intuitively, however, the very largest firms in our sample are insensitive to fluctuations in our measure of residential real estate values.

Our dataset also allows us to observe corporate real estate holdings on the firm's own balance sheet. We can then run a horse race between these two types of real estate. We find that a £1 increase in corporate real estate values leads firms to increase investment by around £0.05 and the wage bill by £0.03. The magnitude of the investment response is similar to US evidence on listed firms (Chaney et al., 2012).

We then consider aggregate consequences. At the level of an individual firm a £1 increase in corporate real estate values has a 70% larger effect on investment than residential real estate. However, as mentioned, we estimate that the total value of residential real estate held by firm directors is around four times greater than the total value of owner-occupied corporate real estate.[4] The macroeconomic consequences of a 1% change in real estate prices should therefore be at least as strong for residential real estate. A back of the envelope calculation, based on our microeconometric estimates, suggests that a 1% rise in real estate prices leads to a 0.28% rise in business investment and a 0.08% rise in total wages paid through the effects of residential real estate, and a respective 0.11% and 0.02% rise for corporate real estate.

Of course, such estimates omit general equilibrium feedback effects. To explore the macroeconomic implications of our channels we build a general equilibrium model featuring credit constrained entrepreneurs that extends Liu et al. (2013), and estimate the model with Bayesian methods using aggregate UK time series. We find that in response to a real estate price shock, the peak effect on the macroeconomy would be about 30% smaller when ignoring residential real estate as a source of funding for firms.

Our microeconometric estimates rely on two primary sources of variation. First, directors live

[4] By owner-occupier firms we refer to firms who own the real estate they occupy. Non-owner occupier firms are those that lease their property from a commercial real estate firm. As a consequence this aggregate number excludes property owned by real estate firms.

in homes of differing initial values (and loan-to-value). This implies that a given percentage change in real estate prices translates into differential changes in home values (and equity) measured in £ terms. Second, around 66% of directors live in a different region from their firm. This generates regional heterogeneity in the real estate price dynamics that an individual director faces depending on where he or she is located.

Four different sources of endogeneity may bias our estimates. First, a director's 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 observing the history of who has run the firms and where they have lived: we hold the properties and composition of directors constant by firm at the start of our sample, and rely solely on changes in regional real estate prices to compute the evolution of our measure of the value of director's residential real estate.

A second concern is that our regressions are simply detecting how local economic conditions – which are correlated with real estate prices – are affecting firms. Our regressions include region-time fixed effects that control for the average effect of the local economy on firm-level behaviour; for example, through demand. 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 tradable goods and hence are less sensitive to the local economy (Mian and Sufi, 2014) – are equally sensitive to our residential real estate measure; (ii) that the results are similar even if we focus only on directors that live in a different region (or sufficiently far) from their firm, so that their home values are unaffected by local factors; and (iii) that we obtain the same result when we construct an instrument for local house prices using the interaction of aggregate mortgage interest rates with regional supply constraints (similar to, for example, Chetty et al., 2017). A third linked concern is that firms are able to affect local real estate prices through their own activity. However, these latter two tests also reveal that this is not driving our results. As our sample is dominated by small and medium sized companies this concern is also unlikely to be 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 the homes the directors have will be absorbed by a firm fixed effect. However, director-level heterogeneity could lead to differing sensitivities to real estate price fluctuations at the firm level. For example, older directors could react differently to changes in real estate prices and own a systematically different type of housing. Alternatively, highly skilled directors may own bigger homes and may also be better placed to take advantage of opportunities offered by local economic booms. 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 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.

This relationship between the value of directors' homes and firm behaviour could be explained by a number of different mechanisms. It could reflect financial constraints. Alternatively, it could be explained by directors rebalancing their portfolios towards their firm following an increase in their real estate wealth.[5] Recent studies based on natural experiments that have been able to cleanly isolate collateral effects from wealth effects have demonstrated the importance of the former (Jensen et al., 2014; DeFusco, 2017). Furthermore, the literature assessing the strength and direction of such wealth effects is inconclusive (compare, for instance, the findings of Brunnermeier and Nagel (2008); Briggs et al. (2015) and Chetty et al. (2017)). In contrast, other authors have emphasised wealth effects as the main transmission mechanism from real estate prices to consumption (Kaplan et al., 2017). Ultimately, however, the exact mechanism is less important for our main contribution. Our goal is to show that the value of the homes of firm directors affects firm activity and to argue that this is consequential for understanding how real estate prices affect macroeconomic dynamics.

[5] Note, as pointed out in Hurst and Lusardi (2004), entrepreneurial jobs may be luxury goods and an increase in wealth may make households wish to start running a business. This motivation does not apply here: we focus on directors who are already running a firm and consider how a marginal change in the director's home value affects the firm's behaviour. Similarly, it is not the case that our directors, unlike new entrepreneurs, are starting out on a new risky venture, although we cannot rule out that some of our results run through changes in risk tolerance as housing wealth changes.

Related Literature The aggregate consequences of credit constrained households borrowing against their homes for consumption was first studied in a quantitative business cycle model by Iacoviello (2005). There is now a growing body of theoretical work in the macroeconomics literature emphasising this mechanism.[6] Empirically, Mian and Sufi (2011, 2014) document that sharp drops in house prices contributed to falls in demand in regions where households were highly levered during the Great Recession in the United States. Albanesi et al. (2016) clarify this story using individual level data and highlight that regional aggregation can obfuscate relationships at the micro-level. Hurst and Stafford (2004); Campbell and Cocco (2007); Stroebel and Vavra (2015) all provide empirical evidence that real estate prices affect local demand through the behaviour of homeowners in periods outside of crises as well; DeFusco (2017) provides a more comprehensive list of recent empirical studies in this area. Correspondingly on the firm side, Liu et al. (2013) uses a quantitative model to show that credit constrained firms who borrow against their real estate amplify the macroeconomic consequences of disturbances in the housing market. The works of Gan (2007); Chaney et al. (2012); Kleiner (2013); Cvijanovic (2014) among others provide microeconometric evidence on the various aspects of the links between real estate prices, firms' capital structure, collateral and firm activity.

We complement these literatures by showing that the value of residential real estate matters for firm behaviour and hence for the supply side of the economy. We quantify this effect at the firm level and explore the aggregate consequences in a business cycle model.

The link between house prices and start-up rates has been explored in the entrepreneurship literature. Some authors have found that rising house prices do enable previously collateral constrained, fledgling entrepreneurs to start new firms (Corradin and Popov, 2015 and Schmalz et al., 2017). Others have argued that the relationships between house prices and entry reflect other mechanisms (local demand, wealth effects) and that residential real estate is not key to unlocking entrepreneurship (Hurst and Lusardi, 2004; Kerr et al., 2015).[7] Even those that do find a link at the micro-level find that aggregate consequences are limited (for example, Schmalz et al. (2017) finds that a 19% increase in house prices raises total employment by 0.16% through new firm creation). Our analysis

[6]See for example Justiniano et al. (2015); Guerrieri and Lorenzoni (2017); Favilukis et al. (2017).

[7]Bracke et al. (2015) demonstrate theoretically in a model with mortgage debt that housing wealth could be either positively or negatively associated with entrepreneurship.

differs in that we look at how residential real estate values affect existing enterprises on an ongoing basis.[8] Moreover, we find that our mechanism is just as relevant for mature firms, and the effects are strong enough to influence macroeconomic dynamics.

Adelino et al. (2015) is an exception in that they are the first to argue that residential real estate prices have an aggregate effect through the behaviour of small firms and start-ups. Their key finding is that relative regional employment in small firms in certain industries is more sensitive to local house prices. Our analysis differs in a number of respects. Most importantly, we conduct our analysis at the firm level rather than the regional level and can identify both the value of the homes of directors and the firms own real estate holdings: this circumvents a number of identification issues.

The corporate finance literature has long recognised the importance of personal property as sources of collateral in the business loan market (Berger and Udell 1995; Avery et al. 1998; Jimenez and Saurina 2004; Berkowitz and White 2004; Brick and Palia 2007; Davydenko and Franks 2008; Ono and Uesugi 2009). However, the attention has focused on when and why such collateral is used. Our contribution is to quantify how changes in the value of residential real estate affects firm activity and consequently the aggregate economy.

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

2 Home Values and Corporate Borrowing

From the perspective of the macroeconomics literature, perhaps the most intuitive way for residential real estate to be used to fund a firm is via home equity extraction. In our case, this would mean that the firm's director remortgages their home and uses the funds to inject new equity into the business.

[8] Schmalz et al. (2017) also assess how the home values of entrepreneurs affects the subsequent performance of start-ups. But the scope of their research does not extend to mature firms and the effect of changes in home values after the firm has started.

In practice, the more common way to fund a firm through housing wealth is for the firm to take out a loan which the director guarantees by pledging personal assets, including their house. In effect, the director contracts away some right to limited liability in order to increase their firm's borrowing capacity. In the UK this is advantageous in the sense that the firm's tax shield is then transferred to the director.

These "personal" or "directors" guarantees can be secured directly on a property. However, even if a director's home does not explicitly secure a guarantee, it can still implicitly back it because if a director fails to fulfill a personal guarantee, the creditor can obtain a court order to seize the director's house (see Field-Fisher-Waterhouse (2012)). Guarantees for firm directors are also typically joint and several (see Riches and Allen (2009), page 84). Lenders can seize the assets of any and all directors in order to recoup the amount owed. This motivates our specification below where we use the value of the total real estate holdings across directors for our empirical analysis.[9]

To illustrate the prevalence of residential real estate and personal guarantees as security for corporate loans in the UK, we present evidence from two surveys. First, from the borrowers perspective, the UK Survey of SME Finance covering 2,500 enterprises with less than 250 employees, asks (in reference to firms that say they have a loan) *"What security was used to get this loan/mortgage?"*.[10] Our second source, from the lenders perspective, is the Bank of England's 2015 survey of UK SME and Mid-Corporate Lending. This survey covered outstanding loans at the 5 major UK banks to businesses borrowing at least £250 thousand, and whose annual revenue was no more than £500 million. The survey asks "*Does your bank hold any of the following as collateral*?". In both surveys the respondent can give multiple responses.

Table 1 summarises the evidence from the surveys on the prevalence of different types of security for business loans in the UK. First, note that it is very common for a loan to be secured explicitly on property; this occurs in 79% of cases in the borrowers' survey (panel A) and 73% of cases in the lenders' survey (panel B). More relevant for our purposes is that 42% of SMEs report their loans

[9]In the UK, banks face stringent legal barriers to seizing the share of a family home that is owned by a spouse who is not part of the business (see Royal Bank of Scotland plc versus Etridge (No 2), 2011). Hence, while we do sum twice over the same home for directors who are husband and wife, this is actually appropriate as twice as much of any equity is available to be pledged.

[10]We combine the 2004 and 2008 waves. Responses are weighted to match the population of UK firms by size and sector as measured by administrative data.

were either explicitly secured through residential real estate or via a personal guarantee (panel A, Column 2). For comparison, 44% of borrowers report using their firm's building as security. In the lenders survey we are unable to distinguish loans secured directly on residential property from those secured on other property (including the firm's buildings) but the survey reports that 29% of loans have a personal guarantee attached (panel B, Column 2).

The prevalence of this sort of security is decreasing in firm size.[11] Nonetheless, 25% of loans to firms with more than 250 employees still have a personal guarantee attached. An explanation for this may be the signaling value of a guarantee: personal wealth, particularly residential wealth, has more value to the borrower than the lender. Costly collateral pledging could help offset adverse selection problems (see Coco (2000) for a discussion) even if the amount of personal assets pledged is small relative to the loan size.

In the lenders survey, loans secured with a personal guarantee are not obviously smaller. The median sizes of loans with and without a guarantee are £550 thousand and £535 thousand, although the 90th percentile of loan size is £3.2 million for loans with a guarantee and £4.0 million for loans without. However, the same is not true in the borrowers survey: guaranteed loans and those secured on residential property have a median size of £80 thousand compared to £130 thousand for other loans. The borrowers' survey also contains information on the value of the security. Hence, we can compute an implicit loan-to-value (LTV) ratio:[12] loans that are uniquely secured by a guarantee or residential real estate have a median LTV of 65%. This is identical to the median LTV of other loans suggesting no meaningful difference in pledgeability.

The UK survey evidence is that residential real estate is an important source of collateral for firms, particularly SMEs. However, we use UK data due to its reporting standards for directors rather than anything specific about its corporate loan market. The use of residential assets and personal guarantees as a security for corporate loans is wide-spread across the world including in the United States. Appendix C provides cross-country evidence on the prevalence of guarantees as

[11] Note that the 12% figure for personal guarantees for firms with 0-1 employees in panel 2 is misleading. Such firms are typically sole-traders and have no limited liability or no separation of assets. Rather than use personal guarantees such enterprises use explicit security. This is apparent in the borrowers survey: no firm with 0-1 employee reports using a personal guarantee.

[12] We use the question *"What was the value of this security when the loan/mortgage was obtained?"*.

security for corporate loans.

[Table 1 here]

In light of this section, it is also useful to lay out a limitation to our analysis. Despite having access to data on individual mortgages, we do not observe guaranteed loans in our data as they often do not involve an explicit mortgage. Still, as we demonstrate below, there is an empirical relationship between the value of real estate held by a firm's directors and the firm's borrowing.

3 Data

We use accounting data on firms from England, Wales, and Scotland covering the period 2002-2014, merged with transaction-level house price data and loan-level mortgage data.

3.1 Data Sources

3.1.1 Firm Data - Bureau van Dijk

Our firm level data for the UK is sourced from a large micro dataset of firms' financial accounts, including annual balance sheet, income and cash flow statements, provided by Bureau van Dijk (BvD). This is a commercial database whose raw source are the publicly available filings of each firm at Companies House, the registrar of companies in the UK. The database contains information on approximately 4.8 million unique private and public firms, covering much of the corporate universe of the UK.[13] Our baseline sample is a fraction of the size of the full database as many firms are not required to report all the variables we use in our specification. However, our main result still holds when using a different regression design with the largest available sample.

Firm Directors BvD also provide information on firm directors. These are the individuals legally responsible for running the firm and who have a duty to promote its success. All registered firms, no matter how small, must have at least one director.[14] Under UK law, all directors must provide

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

[14] Firms can themselves be directors, but every firm must have at least one director who is a natural person.

Companies House with information including their full name, full date of birth (*including year of birth*), nationality, and their appointment and resignation dates as a director at the firm. Directors are also required to report their residential address. We use a director's first initial, surname and full date of birth to identify directors across firms and different vintages of the BvD data.

In the database, 72% of directors report being shareholders in their firm at some point.[15] However, this variable is not universally reported and a missing value is not equivalent to a negative response. So the share of directors who are shareholders is unclear. For small firms (like those in our sample), the directors will also typically be shareholders of the firm so there is reason to believe the share is higher (director guarantee and personal guarantee are used synonymously for this reason). Our main empirical results are unaffected when we condition on the share of directors who are known to be shareholders.

Use of Historical Vintages BvD is a live database. This leads to several limitations. First, the firm ownership structure (e.g. whether the firm is part of a group) is only accurate at the time of access and not for historical observations. Second, firm that die appear to exit the database after five years.[16] Third, the historical information based on past filed accounts has significantly more missing data than the most recent filings. Fourth, and most importantly, BvD holds live information on who the firm's directors are and where they currently live, but the database does not have *historical* information on these variables.

To circumvent these issues, we use archived vintages of the database, sampled approximately every six months, 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 status of directors at the time the accounts were filed. As discussed in great detail Kalemli-Ozcan et al. (2015) and implemented in Gopinath et al. (forthcoming), 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. Furthermore, for our purposes, the use of historical vintages of BvD data is what makes our

[15] Across firm-director-year observations the number is 65% as some directors only report being shareholders in certain years.

[16] For example, only 60% of companies that filed accounts in 2002 are still present in the 2015 BvD vintage (see Online Appendix A).

empirical strategy possible by providing historical information on who firm directors were and where they lived at the time the firm accounts were filed. In Online Appendix A, we discuss our procedure in great detail and the corresponding advantages it brings in terms of data coverage.

3.1.2 Real Estate Price Data - Land Registries

Our primary source of house price data is the Land Registry's Price Paid dataset, which covers the universe of residential property transactions in England and Wales since 1995 (approximately 20 million). The analogous dataset on property transactions for Scotland is provided by the Registers of Scotland. These datasets have two main uses. First, they are used by the Registries to construct monthly repeat sales real estate price indices for 204 British regions (respectively, 172 regions in England and Wales and for 32 in Scotland). Second, we match the transaction level information in the datasets to the addresses of directors in BvD in order to value directors' homes at the point of purchase/sale. The England and Wales Land Registry also contains information on whether the property was purchased with a mortgage. This is used, along with the mortgage information discussed next, to calculate the equity a director holds in their house.

3.1.3 Mortgage Data - Product Sales Database

Administrative data on UK residential mortgages are taken from the Product Sales Database (PSD) provided by the UK Financial Conduct Authority.[17] We use data on the flow of mortgages, which contains information on the terms of virtually all regulated residential mortgages since 2005 at origination.[18] Crucially, the mortgage dataset includes the full postcode of the property the mortgage is secured against and the date of birth of the borrower. As these variables are also present for firm directors, we can match directors to their mortgages. As there is an average of 17 properties per postcode in the UK, the combination of full postcode and date of birth will identify unique individuals with a low probability of a mismatch. Coupled with the data on the value of directors' homes,

[17] 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.

[18] 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.

we use the mortgage information to calculate the value of the equity in the house.

3.2 Measuring Real Estate Holdings

For the purposes of our empirical analysis, an immediate concern regarding identification is that the choice of real estate holdings both by directors and firms will be endogenous to the economic environment and firm performance. For example, the firm could invest in real estate in anticipation of future growth or the director could buy a bigger home when the firm is doing well. To solve this potential endogeneity issue, we follow the corporate finance literature and rely on fluctuations in the price of real estate rather than the quantity of real estate owned – the intensive margin of collateral in the terminology of Benmelech and Bergman (2009). Specifically, we fix the composition of real estate holdings (the buildings the firm has and the home where the director lives) at the start of the sample in 2002 and then use the local real estate price index to value real estate holdings throughout the rest of the sample.

The identification of our channels of interest then relies on ensuring that: (i) there are not omitted factors that govern the sensitivity of a firm to real estate prices that are correlated with our measure of initial real estate holdings; and (ii) the firm itself is unable to influence real estate prices. We discuss these issues in Section 4.2.

Corporate Real Estate To measure corporate real estate, we use the balance sheet item "Land and Buildings" from BvD. Specifically, the variable $Corporate\, RE_{i,t}$, for firm i at time $t \geq 2002$ in region j is given by:[19]

$$Corporate\, RE_{i,t} = L^{B}_{i,2002} L^{P}_{j,t}, \tag{3.1}$$

where $L^{B}_{i,2002}$ is the book value of "Land and Buildings" in 2002 and $L^{P}_{j,t}$ is the local real estate price index in region j at time t (with the normalisation $L^{P}_{j,2002} = 1$).[20] A firm's region is defined as the

[19]Note that while our firm level data is annual, firms' accounts refer to different dates in the year based on the timing of their fiscal year end. Our real estate price data is monthly and when we use price indices to construct our variables we use the index observed in the month the accounts were filed.

[20]Our results are robust to different ways of calculating corporate real estate 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

one where its "R/O [Registered Office] Address" is located. BvD lists all addresses where a firm has operations ("Trading Addresses"). In Appendix A.1 we show that our results are robust to separating out firms with all addresses located in a single region.

Directors' Residential Real Estate We explain our methodology to value directors' homes in greater detail in Online Appendix C, which includes diagnostics of the matching algorithm and details of all the assumptions made when computing this variable.[21] However, director real estate holdings is the key variable in our analysis and we highlight the key steps in its construction here.

The addresses of firm directors 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 use an algorithm that searches the unstructured address strings for regular expressions 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.

We match the cleaned director's address to the Land Registry and find the date and price of every transaction at that property since 1995. The director's purchase (sale) price of the property is the first transaction before (after) the director first (last) lists the address in the BvD database.[22] For properties where there is no transaction in the Land Registry, we use the valuation of the property at the time of the earliest observed remortgage, if applicable. We then estimate the value of the property at dates away from the relevant transaction/remortgage using the local house price index.

Our measure of total directors' residential real estate for firm i at time t is then given by

$$Residential\ RE_{i,t} = \frac{N_i}{(\tilde{N}_i)} \sum_{d=1}^{\tilde{N}_i} L^d_{i,2002} L^P_{h_d,t}, \tag{3.2}$$

where $L^d_{i,2002}$ is the estimated home value of director d working at firm i in 2002, and $L^P_{h_d,t}$ is the

Buildings" in (3.1) with the 2002 market value, calculated through a Last In, First Out (LIFO) recursive method (Hayashi and Inoue, 1991). See Appendix A.1 for details.

[21] In Online Appendix C, we also discuss changes in legal requirements for directors to report their address. From October 2009, directors had the option to ask Companies House not to make their address publicly available. This has no impact on our analysis as we can still see where the director lived in 2002 since the law was not imposed retrospectively and we have historical data prior to 2009. Regardless, we show that stopping our sample in 2008 does not affect our results.

[22] When the purchase price is observed, we rely solely on it as it is independent of behaviour and information revealed in future. However, if no purchase transaction is recorded (because the property was bought before 1995), then we use the sale price.

regional house price index of the region h_d where the director lives in 2002.[23]

We are often unable to value the homes of all directors. This will occur if we fail to either match the property to the transactions level database or if we do not observe a remortgage.[24] In total, we are able to match and value 58% of director addresses (see Online Appendix C for details); this number rises to 65% for directors at our baseline sample of firms. In Equation 3.2, the term N_i is then the total number of directors at firm i and $\tilde{N}_i$ is the number of matched directors. Essentially, we first calculate the average of $L^d_{i,2002}L^P_{h_d,t}$ across matched directors then multiply that figure by the total number of directors. This means that we can include firms where not every director is matched in our sample and abstract from differences in the match rate between firms.

For firms within the same region, there is a single source of variation to identify the effects of changes in corporate real estate values: the differences in the initial value of real estate owned by the firm $L^B_{i,2002}$. In contrast, $Residential\, RE_{i,t}$ varies across firms because the initial value of director homes ($L^d_{i,2002}$) differs but also because directors can live in different regions from their firm, and so $L^P_{h_d,t} \neq L^P_{j,t}$. Furthermore, the number of directors (N_i) can also vary across firms. In Appendix B we explore the relative importance of these different sources of variation in $Residential\, RE_{i,t}$ and find that variation in $L^d_{i,2002}$ drives most of our results.

Directors' Residential Equity A concern with using our residential real estate measure is that directors may have levered their homes to a different extent and therefore may have different levels of housing wealth, holding the home value constant. To correct for this, we use our mortgage data to estimate the value of director home equity. This comes at the cost of observations (we must see a director sign a new mortgage) and raises measurement issues as the first mortgage contract is observed at different (potentially endogenous) dates for each director. However, we use this series as an additional robustness check replacing our baseline $Residential\, RE_{i,t}$ measure. We discuss the details of this estimation in Online Appendix D. Here, we provide only a brief summary of our

[23]The same director may hold multiple properties at the same time. If two or more properties are recorded in BvD (e.g. if the director lists a different address at two different firms where the director holds an appointment), then we value both properties separately and compute the total.

[24]Manual checks on our matching algorithm revealed that in 86% of cases a failure to match a director's address to the transactions database was due to the address not having a recorded transaction in the Land Registry since 1995. The remaining 14% were due to a combination of errors in how the address was recorded (typos etc.) or the director recording a non-residential address.

method.

We make use of the terms of the mortgage from the PSD dataset.[25] We use the details of the first observable mortgage contract for each director and calculate the evolution of the principle through time assuming no further remortgages. This assumption is to avoid potential endogeneity issues that may arise from subsequent mortgage decisions of firm directors being correlated with their firm's performance. By relying, effectively, on variation in the intensive margin of equity values, this approach is analogous to the estimation of our corporate and residential real estate measures. The variable $Residential\,Equity_{i,t}$ estimates the total value of this measure across all firm directors, based on the average equity for each matched director and the total number of directors.

3.3 Additional Calculations

Directors' Home Ownership Throughout our analysis we maintain the assumption that a director owns their home. This is an approximation, but there are three pieces of evidence to suggest that the vast majority of directors are homeowners. First, the 2011 UK census shows that 88% of individuals with occupation "managers, directors, and senior officials", and located in the same age group as the median director in our sample, own the home they live in. Second, in the Registers of Scotland dataset, the names of buyers are recorded. We cross-checked the surnames of all directors matched to a Scottish transaction with the surname of the home buyer, making no correction for typos, and found they matched in 83% of cases. The equivalent data is not available directly in the England and Wales Land Registry dataset. However, as a third piece of evidence, we randomly sampled 100 matched directors living in England and Wales and manually inspected the address' title deed (which includes the names of owners).[26] We found that 90 of the 100 directors owned the home they lived in, and a further two appeared to be owned by family members of the director.

Geographical Distance Between Directors' and Firms' Real Estate We measure the distance between the firm's location and each matched director's address by using the UK grid reference

[25] Where the director's property is not matched to the PSD, but is matched to the Land Registry, and the latter indicates the property was bought without a mortgage, the director's home equity is simply calculated as the home value (i.e. 100% equity).

[26] Individual title deeds for any address are available for purchase from the Land Registry for a cost of £3.

(measured to the nearest metre) for each location's full postcode. We then convert the grid reference into a global latitude and longitude pair. From there it is straightforward to calculate the relevant ellipsoidal distance as the crow flies. At the firm level we calculate the average distance for all of the firm's directors.

3.4 Sample Selection and Summary Statistics

Our sample focuses on private limited and public quoted firms and follows the literature in excluding firms that operate in certain industries.[27] 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 firm is correctly accounted for. In our regression analysis, we drop observations which are missing data on our measures of firm activity (investment, wages and employment), financing variables (issued equity, directors loans and short and long term debt), the control variables, and our measures of residential and corporate real estate holdings (as defined above). This leaves us with, in our baseline sample, 32,244 firm year observations covering 6,431 unique firms. The exact sample size for each specification is reported in the regression tables.

All accounting variables that enter our regressions, including real estate holdings, are scaled using the previous accounting year's "Turnover" as the scaling variable.[28] To prevent outliers distorting the results, all ratios are winsorized at the median plus minus five times the interquartile range.[29]

[27]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).

[28]Alternatively, we could have followed Chaney et al. (2012) in using property plant and equipment as the scaling variable. However, unlike their dataset, ours is not limited to listed and relatively large firms, but includes a large number of small firms 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 firms with small holdings of fixed assets. One variable with different weighting is "Number of Employees". As "Number of 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.

[29]This follows Chaney et al. (2012). Our results are robust to winsorizing these variables at the 5/95% level. An exception is the changes in firm liabilities and employment, where the interquartile range is near to or equal to zero. For these variables we use a 2/98% winsorisation.

Table 2 presents summary statistics on variables of interest for our sample of firms. The median values of "Turnover", "Total Assets" and "Number of Employees" in the whole sample are about £12.0 million, £8 million and 107, respectively. The equivalent mean values are greater indicating a left skew in the distribution typical of firm level data. By UK categorisations, our median firm is a medium sized enterprise (50 - 249 employees). Small firms (less than 50 employees) form roughly the lower quartile of our sample while large firms (at least 250 employees) form the upper quartile.

The median firm has four directors and between them they own homes worth about £2.1 million. In contrast the median firm's own real estate holdings are only £1.1 million. This suggests that residential real estate outweighs corporate real estate as a possible source of financing for the firms in our sample. As demonstrated in Figure 1, the relative importance of the two types of real estate depends on the size of the firm. For relatively small firms, residential real estate is large compared to the size of the balance sheet; this is in contrast to corporate real estate. This pattern reverses for larger firms. The explanation is that the home values of a firm's directors do not scale proportionately with the firm's size, whereas the value of the firm's own real estate tends to be a relatively stable share of assets (excepting the very smallest firms). The crossing point for the relative importance of the two types of real estate is at a firm size of 250 employees, which is exactly the UK threshold for a SME.

[Figure 1 here]

[Table 2 here]

[Table 3 here]

Table 3 presents summary statistics on the directors of the firms in our sample. The median director in our sample is 52 years old, has spent 18 cumulative years working as a director and has held positions across 3 different industries. This serves to highlight that our directors are experienced and reemphasises again that our results are not driven by new firms run by first time entrepreneurs. This is in contrast to the literature on real estate values and start ups that focuses on the switch to entrepreneurship.

The median director also owns a house worth £600 thousand, which is considerably more than the average UK house price over our sample period of £160 thousand (from the UK House Price Index by the Land Registry). Note also that two thirds of directors live in a different region from their firm and the median director lives 11 miles away from their firm. The latter is in line with the 10 miles that the average UK worker has to travel to work (from the 2011 UK census). However, there is a tail of over a quarter of directors who live more than 30 miles away from their firm. We use these individuals to identify a group of firms where the directors' home values will not be affected by real estate prices in the vicinity of the firm.

4 Empirical Strategy

4.1 Regression Specification

Our baseline regression estimates the impact of residential real estate values on firm investment. For firm i, operating in region j, in industry l, at date t, we estimate the following model:

$$Investment_{i,t} = \alpha_i + \delta_{j,t} + \mu_{l,t} + \eta \times Residential\,RE_{i,t} + \beta \times Corporate\,RE_{i,t} + \gamma \times controls_{i,t} + \varepsilon_{i,t}. \quad (4.1)$$

We define firm investment, $Investment_{i,t}$, as the change in "Fixed Assets" less "Depreciation". The two real estate measures are (i) $Residential\,RE_{i,t}$ – the total value of residential real estate held by firm i's directors, as defined in Equation 3.2 and (ii) $Corporate\,RE_{i,t}$ – the value of commercial real estate owned directly by firm i, as defined in Equation 3.1. The terms α_i, $\delta_{j,t}$ and $\mu_{l,t}$ capture firm fixed effects, region-time fixed effects and industry-time fixed effects respectively. The standard errors in (4.1) are clustered at the level of the firm's region.

As is standard in firm level investment regressions (see, for example, Hubbard (1998)), $controls_{i,t}$ includes measures of cash flow. We include two specific variables in this context: (i) from the income statement: $Profit_{i,t}$ ("Operating Profit") as a proxy for cash generated and (ii) from the balance sheet: $Cash_{i,t}$ ("Bank Deposits" less "Bank Overdrafts") to measure liquid assets on hand. Both regressors enter the regression lagged by one period. A proxy for Tobin's Q, such as the firm book-to-market ratio, is also typically included as a control variable; however, as our dataset includes mainly private firms, this is not observable. Instead, similar to Catherine et al. (2017), we include 2-digit industry-time fixed effects, $\mu_{l,t}$, to capture changes in investment opportunities for industries.

As mentioned, all these variables, including our estimates of real estimate holdings, enter our regressions as ratios to the lag of firm "Turnover". This implies the estimates of η and β have a £ per £ interpretation. However, $Residential\ RE_{i,t}$ does not scale naturally with firm size. To prevent any spurious correlation arising from this, we include $1/Turnover_{i,t-1}$ as an additional control.

4.2 Identification

At this stage it is informative to consider issues that may affect the identification of η and how these have been addressed by our regression design. Consider the terms in Equation 3.2. The initial value of directors' homes, $L^d_{i,2002}$, may well be correlated with omitted factors that govern the firm's behaviour, but this is a time invariant term that is absorbed by the fixed effect α_i. The same applies to the number of directors and matched directors, respectively N_i and $\tilde{N}_i$; further, we show in Online Appendix C that there is little systematic difference between matched and unmatched directors. It may be that $L^P_{h_d,t}$ is correlated with the firm's real estate price index ($L^P_{j,t}$). In turn $L^P_{j,t}$ could affect the firm's investment opportunities; for example, because an increase in local real estate prices fuels local consumption (Mian and Sufi, 2011). Region-time fixed effects, $\delta_{j,t}$, will partially address this. However, we also add as an additional control, $L^P_{j,t}$, the price index in the *month* that the firm files its account to control for any effects of real estate prices due to differences in a firm's fiscal year end.

This combination of fixed effects and controls is sufficient to account for the average effect of real estate prices and of any time invariant director characteristics on firm behaviour. However, 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 ($L^d_{i,2002}$). 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. To address this, in our baseline specification, we augment our control set with other observed characteristics of the firm's directors interacted with $L^P_{j,t}$. Specifically, for each firm we compute in 2002 the following: (i) the average age of directors; (ii) the share of directors who are male; (iii) the share of directors who have a non-UK nationality; (iv) the average number of firms each director works for and (v) has ever worked for; (vi) the average number of industries each director has worked in; (vii) the average length of experience (defined as time since first appointment) that each director has (across all the firms the director has worked for); (viii) the average number of firms the directors have resigned from; (ix) the average number of firms that each director has been a part of at birth and (x) the average number of firms each director has worked for that have died. Additional detail on the calculation of these variables is presented in Online Appendix B. For each of these 10 variables, we then place each firm into one of 5 quintiles based on where they sit in the 2002 distribution and include the interaction of the quintile dummies with $L^P_{j,t}$ in $controls_{i,t}$.

As an additional robustness check, separate from our baseline, we exploit the fact that some directors hold directorships at more than one firm at a time. For this subset of directors we are able to calculate an additional proxy for their skill: the average growth rate in "Total Assets" in *other* firms that they are a director of. This is a more limited sample, and the critical source of variation is then different, but overlapping, combinations of directors across firms. However, the variable is advantageous in that it is based on realised information of firm performance rather than just director characteristics.[30] We place firms into one of 5 quintiles based on where they sit in the annual distribution of this average asset growth variable and include the interaction of these quintile dummies with $L^P_{j,t}$ as additional controls.

An analogous problem exists regarding corporate real estate: $L^B_{i,2002}$ is correlated with firm level characteristics like size and age that may alter how a firm responds to shifts in real estate prices. We address this in a similar fashion. Following Chaney et al. (2012), we include in $controls_{i,t}$ dummy variables for which quintile of the 2002 size (measured by "Total Assets"), age and return on assets (measured by "Operating Profits" over "Total Assets") distributions the firm sits in, interacted with

[30]Specifically, let $\mathcal{F}_d$ be the set of all firms where individual d holds directorships. Further, for firm i, let $\hat{N}_i \geq 0$ be the total number of directors at firm i who also hold directorships in *other* firms. Finally, let $TotalAssets_{f,t}$ be the level of "Total Assets" at firm f at time t. Our skill proxy for firm i is then given by $\frac{1}{\hat{N}_i}\sum_{d=1}^{\hat{N}_i}\frac{1}{\left|\mathcal{F}_{d\setminus\{i\}}\right|}\sum_{f\in\mathcal{F}_d\setminus\{i\}}\left(\frac{\Delta TotalAssets_{f,t}}{TotalAssets_{f,t-1}}\right)$. In words, we take the average asset growth at each director's other companies and then average this at the firm level. In our sample two thirds of firms have at least one director who has a directorship in another company elsewhere in the UK (not necessarily in our regression sample).

$L^P_{j,t}$.

Our findings could still be confounded if our real estate measures are correlated with other omitted factors that govern the sensitivity of the firm to local economic conditions or if the behaviour of an individual firm is enough to influence those conditions. To address this, we alter our baseline regression along three dimensions.

First, we recompute our residential real estate measure using information only from directors who live in different regions from the firm (we treat directors living in the same region as unmatched). This means that the local real estate prices are not used in the construction of the variable. Our regions can still be confined in relatively small geographical areas (there are 33 regions in London for instance). Hence, as an additional check, we also consider how the distance between the directors' homes and the firm's location affects our results.

Second, we consider if there is a differential response for firms who operate in the manufacturing sector, where output is tradable and local demand effects should be irrelevant (Mian and Sufi, 2014).

Third, we construct an instrument for regional real estate prices by using the strategy adopted by Mian and Sufi (2011), Chaney et al. (2012) and Chetty et al. (2017) among others. Specifically, we instrument for local real estate prices by interacting local geographical constraints on housing supply with aggregate shifts in the interest rate on 2-year 75%-LTV mortgages.[31] When mortgage rates fall, the demand for real estate rises. The intuition behind our instrument is: if local housing supply is very inelastic, then increased demand will translate mostly into higher prices rather than more housing. 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.[32] We thus estimate, for region k, at date t, the following first-stage regression to predict house prices:

$$L^P_{k,t} = b_{0k} + b_{1t} + b_2 \times constraints_k \times r_t + u_{kt}, \tag{4.2}$$

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

[32] The data covers England (excluding the local authorities in Scotland and Wales), so we only include 150 local authorities in our regressions using the instrumented series.

where $constraints_k$ measures constraints on land supply at the regional level while r_t is the nation-wide mortgage rate at monthly frequency. The terms b_{0k} and b_{1t} are region and time fixed effects respectively. Region specific shocks to real estate prices, some of which are potentially due to the behaviour of the firm, are contained in u_{kt}. Since u_{kt} contains the terms we wish to abstract from, we can generate an instrumented house price index using the fitted values from Equation 4.2, $\hat{L}^P_{k,t}$. We then replace $\hat{L}^P_{k,t} = L^P_{h,t}$ for $k = h$ in Equation 3.2 and replace $\hat{L}^P_{k,t} = L^P_{j,t}$ for $k = j$ in Equation 3.1 as well as in all the variables in $controls_{i,t}$ containing $L^P_{j,t}$. The results from this regression are available in Appendix A.3: the estimate on b_2 is highly significant and has the intuitive negative sign.[33]

5 Main Results

5.1 Main Results

Table 4 reports our estimates for alternative specifications of Equation 4.1. The fourth column in the table presents our baseline specification. The coefficient on residential real estate suggests that a £1 rise in the total value of the residential real estate holdings of a firm's directors causes the firm's investment to increase by around £0.03. Equivalently, the coefficient on corporate real estate suggests that every £1 increase in the value of the firm's own real estate holdings causes a £0.05 increase in investment (for comparison, Chaney et al. (2012) report a figure of \$0.06 associated with a \$1 increase in the value of corporate real estate). At the firm level, this implies that corporate real estate has a 70% stronger impact on investment than residential real estate. However, as discussed in the Introduction, the total value of director real estate for the economy as a whole is 4 times larger than the real estate held by owner-occupying firms, suggesting the aggregate effect on investment through residential real estate is potentially larger. The estimates are robust to perturbations in the specification. Columns (2) and (3) in Table 4 show that the £0.03 coefficient on residential real estate is, for the most part, unaffected by altering the control set or the degree of fixed effect saturation.

[33] As discussed in Adelino et al. (2015), this style of instrument may be weak when house prices fall. A drop in demand does not lead to a destruction of the existing housing stock. However, note that, in contrast to the US, the UK did not experience a major nationwide fall in house prices in the crisis period. As a result, in our sample, house prices are rising in 75% of our firm-year observations.

[Table 4 here]

Comparing Columns (4), (5) and (6) in Table 4, one can see that the estimated coefficients on residential real estate and corporate real estate are a little diminished when the other type of real estate is controlled for. However, the relevant Coefficients in columns (5) and (6) are still within a standard error of the baseline estimate. This implies that existing estimates in the literature on the impact of corporate real estate are unlikely to be suffering from bias due to the omission of residential real estate from their specifications.

5.2 Measurement and Identification

Table 5 presents robustness tests that relate to the measurement of our variables of interest and our sample selection.

Firms may revalue their property when prices increase, generating an automatic correlation between our measure of investment and real estate prices that we do not wish to capture. Alternatively, some firms may invest in property for speculative purposes when prices rise. This may explain the sensitivity between investment and both real estate measures. To address this, we rerun our baseline specification using investment excluding the change in the book value of "Land and Buildings" as the dependent variable. Column (2) of Table 5 presents the results. As can be seen, corporate and residential real estate still both influence investment in other forms of fixed assets. Furthermore, as we discuss in Section 5.4, firms also hire more workers in response to an increase in the value of both types of real estate.

As described in Section 3.1.1 we are unable to say definitively that a director is not also a shareholder. However, in Columns (3,4) of Table 6, we re-estimate our baseline specification, interacting our residential real estate measure with a dummy variable indicating whether or not at least 50% of directors *report* being shareholders. There is a very similar coefficient on residential real estate for both types of firms, but the point estimates are slightly greater when a greater fraction of directors report being shareholders.

[Table 5 here]

As discussed in Section 3.2, defining our residential real estate measure using home values ignores the fact that directors have differing amounts of equity contained within their home. In Column (5), we substitute $Residential\,RE_{i,t}$ with $Residential\,Equity_{i,t}$. This leaves us with fewer observations; however, the coefficient estimates are again comparable.

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 voluntarily 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 in the dataset. To address this, in Column (6) of Table 5 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 then the change in "Total Assets" (as opposed to the change in "Fixed Assets" less "Depreciation"), and we scale all variables by lagged "Total Assets" rather than "Turnover". We also drop all other controls except our measure of residential real estate, which is also well reported as all firms must declare who its directors are and provide an address. This leaves us with a sample of 2.5 million firm-year observations on 260 thousand unique firms and a point estimate of £0.009 on residential real estate. 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 ability, desire or need to grow (see Pugsley and Hurst (2011)). This may explain the smaller coefficient.[34] This can be seen if we compare some summary statistics between the two samples. The median firm in our baseline sample has £8 million in assets and median asset growth is around 3% per year. In contrast, in the expanded sample the median firm has £110 thousand of assets and median asset growth is zero.

Table 6 presents additional specifications to address concerns regarding the identification of the coefficient on residential real estate as discussed in Section 4.2.

Column (2) presents results when we use our instrumented house price series. Columns (3) and (4) show what happens when we split firms into those operating in the tradable and non-tradable

[34] The change in coefficient is not explained by the change in scaling variable: the estimated coefficient in the baseline regression for the impact of Residential Real Estate on investment is insensitive to the choice of lagged "Total Assets" or "Turnover" as the scaling variable.

sectors. Column (5) shows results when we only consider directors who live in a different region from their firm. Columns (6) and (7) show results when we split firms by the average distance the director lives from the firm (greater or less than 30 miles). Last, Column (8) presents results when we use a smaller sample of multi-firm directors and proxy director skill using the performance of their other firms. In every case the coefficients are similar to the baseline.

There are additional measurement challenges that arise regarding the impact of corporate real estate. We discuss the specifics of how we address these and the related results in detail in Appendix A. For the sake of brevity, in the main text we only reassure the reader that our estimates are robust to these issues.

[Table 6 here]

5.3 Firm Financing

We now turn to how firms finance the increase in investment documented above. Recall that residential real estate can affect the available funding for the firm either through granting a claim on the director's house when guaranteeing a loan to the firm, or via the director extracting equity from their house to inject funds directly into the firm. The latter can be 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 residential and corporate real estate on changes in specific parts of the liability side of the firm's balance sheets. Specifically, we rerun our specification with four liability measures as left hand side variables: (i) the change in "Issued Capital"; (ii) the sum of the change in "Long Term Director Loans" and "Short Term Director Loans" liabilities; (iii) the change in short term external debt liabilities;[35] and (iv) the change in long term external debt financing.[36]

The results are presented in Table 7. As for the effects of corporate real estate, the impact of an increase in the value of the firm's buildings only has a significant positive effect on measures of

[35]This is defined as the sum of the change in "Short Term Loans and Overdrafts" and "Trade Credit" less the change in "Short Term Director Loans". Short term loans are supposed to refer to maturities less than a year but there may be some discrepancies across firms.

[36]This is defined as the change in "Long Term Debt" less the change in "Long Term Director Loans".

external debt financing: a £1 increase in corporate real estate increases long-term debt by about £0.037. Short-term external debt increases by an additional £0.032 and the sum is of the same magnitude as the £0.05 increase in investment. As would be expected, the change in the value of the firm's real estate does not lead to a change in issued equity. However, there is a negative coefficient on director loans. This is only significant at the 10% level but the interpretation would be that part of the external financing obtained from an increase in the value of a firm's real estate is used to repay loans from insiders.

[Table 7 here]

Residential real estate 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 value of directors' homes increases net equity and short-term external debt by about £0.002 and £0.021, respectively. The point estimate on long-term external borrowing suggests a £0.002 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 real estate, 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 overdraft facilities in the UK (see Riches and Allen (2009), page 80), which may explain why it is primarily short term financing that responds. Summing across these four estimates, the firm increases its liabilities by an additional £0.025 for every £1 increase in the value of residential real estate, which is similar to the investment response (there is a small discrepancy but this is not statistically significant from zero).

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 real estate.[37] The mechanism at work is, for the most part, not one where directors remortgage their property to extract funds which they then inject into their firms. Instead, the estimate related to increased short-term debt is consistent with residential real estate operating through increasingly valuable personal guarantees from firm directors that expand the corporate borrowing capacity of the firm.

[37] Our estimates are for existing firms. The sensitivity of the initial liability structure of new start-ups to the house value of their directors may be quite different (see Robb and Robinson (2014); Schmalz et al. (2017)).

5.4 Labour Market Implications

The increases in the value of real estate can also have implications for a firm's use of labour inputs as well as physical capital. Since an increase in residential real estate values primarily unlocks short-term funding it may provide the working capital for the firm to hire new workers. To test this we alter our left hand side variable and consider two separate labour inputs: (i) the change in the "Remuneration" paid to employees; and (ii) the change in 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 8 here]

Table 8 reports the estimates for the effect of real estate on labour market outcomes. A £1 rise in our residential real estate measure increases the firm's total wage bill by around £0.033. The equivalent figure for corporate real estate is £0.033. The employment estimate (0.0009) can be interpreted as an increase of £1.1 million (in 2005 prices) in residential real estate values resulting in the hiring of approximately one additional worker. The equivalent figure is one worker for every £650 thousand increase in corporate real estate values.

Additional identification tests for the labour market regressions are provided in Tables 12 and 13 in Appendix A, with little impact on the results.

5.5 The Role of Heterogeneity

Having estimated the average effect of residential real estate on firm activity, we now turn to how the channels vary through time and by firm characteristics. To explore whether the effects may be asymmetric, we include in the baseline regression the interaction of both types of real estate with a dummy variable indicating whether house price growth in the firm's region is positive or negative.[38]

[Table 9 here]

Columns (1)-(2) in Table 9 show that the impact of residential real estate on investment is similar when house prices are rising and falling. We also consider how our results vary if we allow differing

[38] Just over 25% of our firm-year observations occur when the regional house price is falling.

effects in the pre- (2002-2006) and post-crisis (2007-2014) period. Inspecting Columns (3)-(4) one sees that the effect of residential real estate is almost identical across the two subsamples. In contrast, the effect of corporate real estate has weakened in the post crisis period and seems weaker in periods characterised by falling house prices.

We now consider how the strength of both channels varies by various firm characteristics such as age, a proxy for credit constraints, and size. Columns (1)-(2) of Table 10 show that the effect of residential real estate is at least as important for older firms as for younger firms. This highlights the contrast between our study and the entrepreneurship literature that has focused on the role of housing wealth in financing start-ups (Corradin and Popov, 2015; Schmalz et al., 2017). We show that our mechanism is just as relevant for mature firms.

Columns (3)-(4) consider how the financing position of firms shapes our baseline results. As argued by Kaplan and Zingales (1997) and emphasised by Chaney et al. (2012), it is unclear a priori whether the sensitivity of investment to real estate values should increase with the extent of financing constraints, so this remains ultimately an empirical question.[39] Similarly to Chaney et al. (2012) we use dividend payouts as a proxy for ex-ante financial constraints.[40] The point estimates in Columns (3)-(4) of Table 10 suggest that the effect of residential real estate on investment is larger for firms that are "constrained" (those with low dividend payout ratios), though we cannot reject statistically that the point estimates are the same.

[Table 10 here]

Finally, Columns (5)-(6) show how the sensitivity of investment to real estate values changes across firm size. Our classification considers two groups: small and medium-sized firms (less than 250 employees using the UK classification), and large firms (greater than or equal to 250 employees). These correspond to the firms in the lower three quartiles and upper quartile of our sample respectively. As one would expect, residential real estate has a statistically significant effect among small and medium-sized firms. The coefficient is not statistically different from zero for large firms.

[39] See Hubbard (1998) for a survey of the literature on whether (Fazzari et al., 1988) or not (Kaplan and Zingales, 1997) estimated investment-cash flow sensitivities can be used as a proxy for financing constraints.

[40] We construct a payout ratio, defined as the ratio of "Dividends" to "Total Assets", setting the ratio to 0 when no dividends are reported. Firms with 'high' dividend payout ratios are those with a payout ratio above the 75th percentile in a given year.

However, the point estimates do suggest that large firms (£0.066) respond more than small firms (£0.025). This counter intuitive finding is partly due to our regression design: the value of directors' real estate does not scale with the size of the firm. The residential real estate variable enters the regression scaled by the lag of "Turnover", which means its value is mechanically falling with size. This leads to two issues.

First, the amount of variation in the regressor then also falls with firm size. Specifically, the standard deviation of $Residential\,RE_{i,t}$ is 0.58 for small versus 0.22 for large firms. This diminishing variation increases the coefficient estimate. If we, instead, re-express the coefficients in terms of standard deviation moves, then a one standard deviation increase in residential real estate leads to a 0.16 standard deviation increase in investment for small firms and a 0.14 increase for large firms.

Second, and related, the average ratio of investment to real estate values for small firms is higher compared to large 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=ηR, where I is the £ value of investment and R is the £ value of residential real estate. The point estimate of η is about 2.7 times larger for large firms than for small and medium-sized firms (0.066/0.025). We can convert our estimate into an elasticity by using the expression $\frac{\Delta I}{I}=\eta\frac{R}{I}\frac{\Delta R}{R}$. The median residential real estate to investment ratio (R/I) is about 9 times larger for SMEs than for the large firms. Thus, the estimated elasticity is about three and a half times larger for small firms than for large firms: a 1% increase in the value of directors' homes leads to a 0.16% increase in investment by small firms and a 0.05% increase in investment for large firms.

As a final sense check of our results, we examine whether residential real estate affects the behaviour of the very largest of firms in our sample, where the value directors' homes should be small compared to the size of the balance sheet. Specifically, in Column (7) of Table 9, we limit our regression sample to the 90 firms in our baseline sample who employ more than 10,000 people on average.[41] As one would expect, for such firms, residential real estate does not have a statistically significant impact on firm behaviour, furthermore the sign is counter intuitive.

[41] As a more direct test we have also looked at restricted sample of firms for whom the total value of directors' homes is less than 1% of "Total Assets". This coefficient on *Residential RE* in this sample is also negative and not statistically significant.

6 Macroeconomic Consequences

In this section we illustrate the macroeconomic implications of our firm level estimates on the impact of directors' residential real estate values, and how they compare to the effects of corporate real estate values.

6.1 Back of The Envelope Calculation

Our first pass is to perform a simple back of the envelope calculation combining our firm level estimates with aggregate numbers for total firm investment and wages, and director and corporate real estate holdings. We estimate that in 2014, at the end of our sample period, the total value of residential property held by all current firm directors in the UK, including those at firms outside our baseline sample, is £1.5 trillion,[42] with the total value of commercial property held by all owner-occupying firms around 4 times smaller at £350 billion (IPF (2016)). For comparison, 2014 GDP was £1.8 trillion, so in aggregate the real estate owned by firm directors is around 80% of GDP, with the aggregate commercial property held by owner-occupying firms around 20% of GDP.

Our baseline regression estimates are that a £1 increase in the value of directors' residential real estate increases a firm's investment by £0.030 and total wage bill by £0.033. Similarly, a £1 increase in the value of corporate real estate increases a firm's investment by £0.051 and total wage bill by £0.033. Aggregate UK investment by private non-financial corporations in 2014 was £157 billion with another £567 billion spent on remunerating employees. Combining these numbers implies that a 1% increase in real estate prices increases investment by 0.28% and total wages paid by 0.08% through the effects of residential real estate, and 0.11% and 0.02% respectively through the effects of corporate collateral real estate.

As we confirmed in Section 5.5, residential real estate only has a statistically significant impact on the investment of SMEs (firms with less than 250 employees). In the UK, only 42% of investment

[42]To compute this in each year t we calculated $V_t = n_{D,t} \times p_{H,t} \times o_t$, where V_t is the total value of residential property held by firm directors in year t, $n_{D,t}$ is the number of distinct individuals with at least one current directorship at a live firm in year t, $p_{H,t}$ is average house price of these directors in year t, and o_t is the proportion of directors that own the property they live at. For 2014 there are 2.8 million directors and the average value of their properties is £570 thousand. Furthermore, from Section 3, the home ownership rate for directors is estimated at 90% which we plug in for o_t. The estimate of V_t ranges from around £1 Trillion in 2005 to £1.5 Trillion in 2014.

is conducted by SMEs.[43] One might be concerned, therefore, that the simple calculations above represent a stark overestimate of the aggregate effects. This is not the case. To see this, first note that 99% of the residential real estate by value held by firm directors is held by directors of SMEs. Only 0.4% of firms in the UK are large firms with at least 250 employees.[44] While large firms have on average two more directors and their directors have homes worth more than twice as much, the weight of numbers means almost all the residential real estate owned by directors is owned by the directors of SMEs.[45] Specifically, we estimate that directors of large firms have real estate worth £18 billion compared to the £1.5 trillion total. Now consider the estimates above for aggregate investment using our estimates based on size. A 1% increase in real estate prices increases the value of the real estate of directors of SMEs by £14.5 billion and, in Table 10, we estimate for every £1 increase their firms invest £0.025. This will increase investment by £360 million or about 0.23% of aggregate investment. In contrast, the same increase in prices raises the value of the homes of directors of large firms by £180 million. The point estimate in Table 10 is not significantly different from zero, however, taking it at face value the estimate of £0.066 implies an increase in investment of £12 million (or less than 0.01% of investment).

In contrast, the effects of an increase in real estate prices running through corporate real estate holdings is mainly through large firms. To estimate this, we use the fact that the mean ratio of corporate real estate holdings to "Turnover" is almost identical for SMEs and large firms in our sample. In aggregate, turnover is split 46% to SMEs and 54% to large firms,[46] suggesting that corporate real estate holdings are split 54-46 between large firms and SMEs. Plugging in the necessary figures based on our size regression, we obtain an estimate that a 1% increase in real estate prices raises investment by 0.07% via the behaviour of large firms and 0.04% via the behaviour of SMEs.

We may still be overestimating the aggregate effects of residential real estate if our sample is not representative of the behaviour of SMEs in general. If we instead assume that a £1 increase in residential real estate values leads an SME to invest £0.009 more - consistent with our large

[43]From the UK Annual Business Survey, for 2014.

[44]From the UK Annual Business Survey, for 2014.

[45]We use our data to obtain the average house value for all (matched) directors, £570 thousand. For the directors of firms with at least 250 employees the average house value is £1.3 million. The average large firm has 5.8 directors versus 4.1 directors for the SMEs in our sample.

[46]From the UK Annual Business Survey, for 2014.

sample regression in Column (6) in Table 5 - then a 1% increase in real estate prices would increase investment by 0.08%. Even then, the effect of an increase in real estate prices on investment running though residential real estate would be of similar magnitude to that running through corporate real estate.

Of course, all of our calculations so far are based on static, microeconometric estimates. Such calculations omit general equilibrium feedback effects and thus may underestimate the implications for economic aggregates. To address this we now turn to an estimated DSGE model.

6.2 Results From A General Equilibrium Model

To explore potential feedback effects in the macroeconomy, this section extends the general equilibrium model of Liu et al. (2013) and Liu et al. (2016) by incorporating both forms of real estate as sources of finance in a model with financially constrained firms.

The model features two types of agents in the spirit of Kiyotaki and Moore (1997): 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 a labour input supplied by the household. An additional key feature of our model is the introduction of an additional asset to the entrepreneurial sector: residential land. The entrepreneur derives utility flow from holding residential land which can also be used as collateral to fund firm borrowing. Note that here we explicitly assume that the source of our regression results is financial constraints.

The full description of the model and details about the estimation and calibration are presented in Online Appendix E. The model is log-linearised and estimated using Bayesian methods to fit six UK time series over 1975Q3-2015Q1: 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.

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

$$B_t \leq \theta_t \mathbb{E}_t \left[q_{l,t+1} \left(\omega_1 L_{c,t} + \omega_2 L_{r,t} \right) + \omega_3 q_{k,t+1} K_t \right], \tag{6.1}$$

where B_t is the real value of debt issued by the entrepreneur, θ_t is a shock to the collateral constraint, $q_{l,t}$ is the market price of land, $L_{c,t}$ is commercial land, $L_{r,t}$ is residential land owned by the entrepreneur, $q_{k,t}$ is the relative price of investment in consumption units and K_t is physical capital. The parameters ω_1, ω_2 and ω_3 measure the pledgeability of commercial land, residential land and physical capital. Following Liu et al. (2016), we normalise $\omega_1 = 1$, and estimate ω_3 as part of the Bayesian estimation. To calibrate the value of ω_2, we use our microeconomic estimates of the relative sensitivity of debt to commercial and residential real estate values (Table 7). This yields the value $\omega_2 = 0.33$.[47]

The Impact of Housing Demand Shocks Households in the model are also owners of land and they derive utility from their land holdings. The utility flow is subject to stochastic disturbances referred to as housing demand shocks. This shock features prominently in Liu et al. (2013) and Liu et al. (2016), and can explain a large fraction 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 allowing the entrepreneur to own residential land and pledge it to finance the firm (this is our main departure from Liu et al. (2013)). To quantify the relative importance of this, we solve and simulate the model under different values of ω_2 in the credit constraint. Our main goal is to see how changing the value of ω_2 (and thereby changing the pledgeability of residential real estate owned by the entrepreneur) changes the dynamic propagation of housing shocks

[47] Calculated as $\frac{0.0210+0.0023}{0.0318+0.0373}$.

to the macroeconomy. This exercise can be interpreted as a way of assessing the macroeconomic importance of our channel.[48]

For this exercise, we use a combination of calibrated and estimated parameters to fit the model to UK data. As described above, we use our micro estimates to calibrate the relative pledgeability of corporate and residential real estate. A second important aspect of our calibration, which is also informed by our micro-data, is the assumption that 25% of total residential land is owned by the entrepreneur in steady state.[49] This introduces a non-trivial source of residential collateral for the production sector.

[Figure 2 here]

To explore how important borrowing against residential real estate is for macroeconomic fluctuations, we first analyse the effects of the housing demand shock *with* and *without* our mechanism of interest. To perform this exercise, Figure 2 shows the impulse response functions for the baseline ($\omega_2 = 0.33$) and for the model when residential real estate is not pledgeable ($\omega_2 = 0$). In the baseline, depicted by the black circled lines, a shock which increases house prices by 1% on impact has a 0.2-0.3% peak effect on output and employment, and it has a 1.2% peak impact on investment. 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 *30%* smaller effect on all macroeconomic variables relative to the baseline.

Interpreting the UK Business Cycle

[Figure 3 here]

To shed light on the historical importance of our mechanism over the past four decades of UK business cycles, we use the estimated model to compute the counterfactual path of investment that

[48]Note that while changing ω_2, we keep the steady-state level of corporate debt fixed. This means that when we set $\omega_2 = 0$, then the credit constraint 6.1 becomes $B_t \leq \theta_t \mathbb{E}_t \left[q_{l,t+1} \left(\omega_1 L_{c,t} + \Phi\right) + \omega_3 q_{k,t+1} K_t\right]$, where the level of Φ is set to equal the steady-state of $\omega_2 \bar{L}_r$ 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.

[49]This is the ratio of our estimate of the total value of residential real estate held by firm directors to the total housing stock in the UK.

would have been realised if the residential real estate had not been pledgeable. 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_2 from the baseline value of 0.33 to 0, thereby shutting down the channel, and then 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 variable 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 real estate 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 borrowing against residential real estate played a major role in the fall of investment in the early 1990s as well as during the Great Recession. Conversely, it had a sizeable positive contribution to the economic expansion during the housing boom of the late 1980s and early 2000s.

7 Conclusion

The global housing boom of the 2000's 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 quantifying mechanisms operating through household balance sheets and consumer demand as well as on mechanisms operating through corporate balance sheets and firm activity. Our paper attempts to quantify an additional channel which links household balance sheets with firm activity via the residential real estate of firm directors. We have shown that a £1 increase in the total value of directors' residential real estate leads the directors' firm to increase investment and wages by around £0.03. We have also corroborated previous studies and found that a £1 increase in the value of a firm's corporate real estate leads the firm to increase investment by around £0.05 and to spend £0.03 more on wages. We showed that a simple general equilibrium model with credit constraints can embed both forms of real estate, and we argued that residential real estate can play an important role in propagating house price shocks to the wider economy through its direct impact on corporate behaviour.

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 mechanisms linking real estate prices and the economy must be determined to evaluate the effectiveness of such policies. This paper highlights one such channel, quantifying the causal impact of a change in real estate prices on firm activity, acting through the residential real estate of firm directors. This is important as it implies that residential real estate has implications for aggregate supply as well as aggregate demand. This alters the trade-offs associated with using macroprudential tools to target the housing market and complicates the interaction with monetary policy.

Appendix

A Additional Regressions

A.1 Measurement of Corporate Real Estate

Table 11 presents additional results to address concerns regarding the measurement of corporate real estate holdings.

[Table 11 here]

A potential criticism of our estimated results for the corporate real estate measure is the use of residential house prices to proxy changes in the market value of commercial real estate. We therefore re-estimate the baseline regression using commercial real estate prices to compute our measure. 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 coefficient estimates for both corporate and residential real estate, 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 firm's real estate is the index for the region where its registered office (using the BvD field "R/O Full Postcode") is located. This may be problematic if the firm has buildings in multiple different regions. We do, however, see in our dataset the addresses of all locations where the firm has operations (BvD field "Trading Addresses"). Columns (3) and (4) in Table 11 present results which interact our real estate measures with a dummy indicating if firms operate in one unique region or have operations outside the region of their registered office, with similar results for both groups.

The book value of "Land and Buildings" in 2002 may be a poor proxy for their 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 treats the valuation of land in a "last in, first out" (LIFO) fashion. The recursion can be written as follows:

$$L^Y_{i,t} = \begin{cases} L^Y_{i,t-1}\frac{L^P_{j,t}}{L^P_{j,t-1}} + dB_{i,t} & if\ dL^B_{i,t} \geq 0 \\ L^Y_{i,t-1}\frac{L^P_{j,t}}{L^P_{j,t-1}} + dB_{i,t}\frac{L^P_{j,t}}{L^A_{i,t-1}} & if\ dL^B_{i,t} < 0 \end{cases}$$

$$L^A_{i,t} = \begin{cases} L^P_{j,t} & if\ dL^B_{i,t} \geq 0 \\ L^A_{i,t-1} & if\ dL^B_{i,t} < 0, \end{cases} \tag{A.1}$$

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

To implement this method one needs to make an assumption regarding the market value of land in the base year, $L^Y_{i,0}$. 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 $L^Y_{i,t}$, we then recompute our corporate real estate measure by fixing land holdings at the market value in 2002, $L^Y_{i,2002}$, and iterating forward using the regional price index. Column (5) of Table 11 shows a larger point estimate for corporate real estate when doing this, with a very similar estimate for residential real estate.

We also test the extent to which our choice to fix the initial stock of "Land and Buildings" in 2002, as opposed to letting it vary after this date, may influence our results. To do this we redefine our measure as:

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

where $L^B_{i,t-1}$ 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 real estate 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 real estate values are redefined in this fashion. The coefficient on corporate real estate is now negative and remains highly significant. An explanation for this result is that investment in "Land and Buildings" may have a negative serial correlation: if a firm bought a building in the previous period it is unlikely to invest in a new building in the current period, which would bias down the coefficient estimate. Indeed, as shown in Column (7), if one looks at investment excluding "Land and Buildings" the coefficient on corporate real estate is positive once more and has a similar value to the baseline regression in Column (1). This finding illustrates our reasoning behind the use of our baseline corporate real estate measure. Importantly for the robustness of our main result; the coefficient on residential real estate remains highly significant and of similar magnitude when using this alternative definition of corporate real estate.

A.2 Identification for Labour Market Variables

Tables 12 and 13 repeat the identification regressions of Table 6 with the dependent variable replaced by the change in remuneration and change in employment respectively.

[Table 12 here]

[Table 13 here]

A.3 First Stage Regression for Real Estate Price Instrument

Recall that we generate an instrumental series for real estate prices in 150 regions in England using the specification in Equation 4.2. We estimate this equation over the period January 1995 until January 2016. Table 14 presents the results of the regression.

[Table 14 here]

To give context to the coefficient estimate, note that the mean share of $constraints_k$ is 37%, which implies for the average region a 1 percentage point increase in mortgage rates translates into an additional 3.5% fall in house prices compared to a region where no land was developed in 1990. Alternatively, a one standard deviation tightening in our measure of supply constraints (27% shift in the developed land share) causes an additional 2.5% fall in house price for every 1 percentage point increase in the interest rate. This effect is highly significant and the marginal F-stat for $constraints_k \times r_t$ is 36.

B Sources of Variation

Recall that our measure of residential real estate as defined in Equation 3.2 had three different sources of variation: (i) the initial value of director homes differs ($L^d_{i,2002}$); (ii) directors can live in different regions from their firm (and so $L^P_{h_d,t} \neq L^P_{j,t}$); and (iii) firms may have different numbers of directors (N_i). To assess the importance of these three sources of variation we define three alternative series with each source of variation turned off one by one:

1. Directors all live in the same valued house. We modify Equation 3.2, to

$$Residential\ RE\ samehouse_{i,t} = \frac{N_i}{(\tilde{N}_i)} \sum_{d=1}^{\tilde{N}_i} \bar{L}_{2002} L^P_{h_d,t},$$

   where $\bar{L}_{2002}$ is the mean value of a directors house in 2002.

2. Directors all live in the same region as their firm. We modify Equation 3.2, to

$$Residential\ RE\ sameregion_{i,t} = \frac{N_i}{(\tilde{N}_i)} \sum_{d=1}^{\tilde{N}_i} L^d_{i,2002} L^P_{j,t},$$

   where $L^P_{j,t}$ is the firm's regional house price index.

3. Firms have the same number of directors. We modify Equation 3.2, to

$$Residential\ RE\ samedirectors_{i,t} = \frac{\bar{N}}{(\tilde{N}_i)} \sum_{d=1}^{\tilde{N}_i} L^d_{i,2002} L^P_{h_d,t},$$

   where $\bar{N}$ is the mean number of directors per firm in 2002.

Columns (2)-(4) in Table 15 present results when we replace $Residential\ RE_{i,t}$ in Equation 4.1 with each of these three measures in turn. As can be seen, the coefficient on our residential real estate measure goes to zero when all directors are assumed to live in a house of the same value, whereas assuming all directors live in the same region as their firm has almost no impact on the coefficient. Assuming all firms have the same number of directors lowers the coefficient a little but we cannot reject that the coefficient is the same as the baseline.

It is true then, that variation in $L^d_{i,2002}$ is key to our results. However, it is not sufficient alone to generate our results. To see this, we define a new measure

$$Residential\ RE\ sameregion\&directors_{i,t} = \frac{\bar{N}}{(\tilde{N}_i)} \sum_{d=1}^{\tilde{N}_i} L^d_{i,2002} L^P_{j,t},$$

so that for firms within the same region the only source of variation in Residential Real Estate is the average initial house price of their directors. In Column (5) in Table 15 we see that the coefficient estimate on this variable is around half of the baseline results, with this estimate only marginally significant at the 10% level. Hence, to obtain our estimates we need variation in $L^d_{i,2002}$ plus one of the other two sources of variation.

[Table 15 here]

C Home Values and Corporate Borrowing: 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 16 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 et al. (2015) uses data from the Irish Department of Finance SME Credit Demand Survey and finds that the probability of PG usage is decreasing in a firm's 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. They 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.

[Table 16 here]

Calcagnini et al. (2014) uses information on loans from a large sample of Italian non-financial firms and document that about 40% of the total number of loans were secured with a PG. Peltoniemi and Vieru (2013) uses a confidential contract-level corporate loan database for Finland to document that PGs are used in about 30% of loans. Davydenko and Franks (2008) studies incidents of corporate bankruptcies, and finds 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.

In the US, Bathala et al. (2006) conducted a survey among 201 privately-owned SMEs 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 the larger National Survey for Small Business Finances (conducted by the Federal Reserve Board), Meisenzahl (2014) reports that in the 1998 and 2003 waves, about 54% of firms receiving bank credit gave PGs.

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Tables

Table 1: Survey Evidence On The Type Of Security Used When Obtaining A Business Loan In The UK

	Secured on Any Property	Secured By Guarantee or Res. Property
	(1)	(2)
0-1 Employees	80%	46%
2-49 Employees	81%	40%
50-249 Employees	67%	27%
250+ Employees	–	–
All Firms	79%	42%

(a) Results from Surveys of Borrowers

	Secured on Any Property	Secured By 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). Only firms that have a commercial loan outstanding (46%) answer this question. In the survey there 13 responses for the types of security: (a) the firm's stock or trade debtors; (b) equipment or vehicles; (c) business owned securities; (d) business property; (e) personal property (e.g. house); (f) mixed property (e.g. flat above shop); (g) other personal assets; (h) floating charge; (i) directors or personal guarantee; (j) other reserves; (k) life insurance policy; (l) other; (m) do not know. Column (1) shows the share of firms that answer (d)-(f) and hence secure their loan against property of any type. Column (2) shows the share of firms that report using non-business property (e)-(f) or a personal guarantee (i) to secure a loan. Both columns report the share of firms that respond they did use the particular form of security when borrowing, broken down by firm size. Responses are weighted using the sampling weights provided by the surveys. We exclude firms that operate in the real estate and construction sector (note that no firms operating in the financial or mining sectors are included in the survey).

Notes for Panel B: The panel presents the results of the Bank of England's 2015 survey of UK SME and Mid-Corporate Lending. This survey covered loans from the five major UK banks to businesses borrowing at least £250k, and whose annual revenue was no more than £500million. Our values are calculated from responses to the question: *'Does your bank hold any of the following as collateral?'*. The bank can give 5 potential answers: (a) property; (b) debenture including charges over plant, equipment and vehicles; (c) cash or cash equivalent; (d) other tangible collateral/security; (e) personal guarantee. Column (1) shows the fraction of business loans (weighted by number) where the response was (a), 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, response (e), also broken down by the size of business being lent to. We exclude lending to firms in mining and quarrying, construction, financial and insurance activities, and commercial real estate sectors. We reweight the sample to correct for some oversampling of certain loan types by the Bank of England that was done for regulatory purposes.

Table 2: Firm Summary Statistics

Variable	Mean	Median	25%tile	75%tile	sd	N
Levels						
Turnover (£ 000s)	142,318	11,922	5,534	31,379	1.255e+06	32,244
Total Assets (£ 000s)	150,419	8,040	3,711	21,144	1.377e+06	32,244
No. Employees	1,182	107	50	258	11,343	32,244
Residential Real Estate (£ 000s)	3,535	2,143	1,228	3,934	4,830	32,244
Corporate Real Estate (£ 000s)	29,221	1,118	73.09	4,201	351,374	32,244
No. Directors (2002)	4.196	4	3	5	1.890	32,244
Ratios (to Lagged Turnover)						
Investment	0.0403	0.0169	0.00263	0.0573	0.0922	32,244
Residential Real Estate	0.389	0.166	0.0637	0.427	0.535	32,244
Residential Equity	0.162	0.0701	0.0257	0.183	0.224	14,909
Corporate Real Estate	0.215	0.0754	0.00613	0.225	0.335	32,244
Cash	0.0102	0.00126	-0.0449	0.0534	0.134	32,244
Profit	0.0306	0.0286	0.00519	0.0664	0.0912	32,244
Change in Remuneration	0.0132	0.00754	-0.00690	0.0298	0.0566	32,244
Change in Employment	0.000251	4.51e-05	-0.000441	0.000740	0.00235	32,244
Change in Issued Equity	0.000985	0	0	0	0.00576	32,244
Change in Director Loans	-1.24e-05	0	0	0	0.0100	32,244
Change in ST Debt	0.0121	0.00549	-0.0215	0.0385	0.0857	32,244
Change in LT Debt	0.00667	-0.00278	-0.0168	0.00757	0.0921	32,244

Notes: The statistics are calculated using the sample of observations for the baseline regression, covering the period 2002-2014. 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 3.1.1. Residential Real Estate is defined by Equation 3.2, and Corporate Real Estate is defined by Equation 3.1. Investment is defined as the change in "Fixed Assets" less "Depreciation". Cash is defined as "Bank Deposits" less "Bank Overdrafts". Profit is defined as "Operating Profit". Change in Remuneration is defined as the change in "Remuneration". Change in Employment is defined as the change in "Number of Employees". Change in Issued Equity is defined as the change in "Issued Capital". Change in Director Loans is defined as the sum of the change in "Long Term Director Loans" and "Short Term Director Loans" liabilities. Change in Short Term Debt is defined as the sum of the change in "Short Term Loans and Overdrafts" and "Trade Credit" less the change in "Short Term Director Loans". Change in Long Term Debt is defined as the change in "Long Term Debt" less the change in "Long Term Director Loans". All ratios are winsorized. The changes in firm liabilities and employment are winsorized at the 2/98% level. All other ratios are winsorized at the median plus minus five times the interquartile range.

Table 3: Director Summary Statistics

Variable	Mean	Median	25%tile	75%tile	sd	N
Director House Value (£000s)	1,043	615.9	347.8	1,150	1,660	95,523
Director Outside Firm Region	0.657	1	0	1	0.475	78,029
Director Distance From Firm (Miles)	32.95	11.01	4.366	31.11	56.97	77,714
Director Age (Years)	52.79	52.29	44.79	60.10	11.03	145,885
Male Directors	0.847	1	1	1	0.360	144,341
Non-UK Directors	0.0556	0	0	0	0.229	145,532
Experience (Years)	35.39	18.25	8.750	39.58	59.16	145,911
No. Industries Worked In	3.644	3	1	5	3.167	145,911
Firms With At Birth	2.006	1	0	2	7.925	145,911
Firms That Have Failed	3.231	1	0	3	10.32	145,911

Notes: The statistics are calculated for all the directors in the sample of observations used for the baseline regressions (2002-2014). 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 3.1.1. Director House Value is the value of individual director houses as described in Online Appendix C. Director Outside Firm Region is a dummy variable that takes the value 1 when a director's matched address is in a different region to their firm's location. Director Distance From Firm is the distance between a director's house and their firm's location, as defined in Section 3.3. Full definitions of remaining director variables are given in Online Appendix B.

Table 4: Firm Investment And The Real Estate Channels

	Investment					
	Residential RE Alone	Fixed Effects, No Controls	Controls, No Fixed Effects	Baseline	Just Residential RE	Just Corporate RE
	(1)	(2)	(3)	(4)	(5)	(6)
Residential RE	0.0478***	0.0300***	0.0232**	0.0298***	0.0375***	
	(0.007)	(0.008)	(0.010)	(0.011)	(0.011)	
Corporate RE		0.0494***	0.0691***	0.0511***		0.0600***
		(0.016)	(0.016)	(0.017)		(0.016)
Cash			0.0768***	0.0777***	0.0778***	0.0778***
			(0.012)	(0.012)	(0.012)	(0.012)
Profits			0.1250***	0.1092***	0.1079***	0.1069***
			(0.016)	(0.016)	(0.016)	(0.016)
Observations	32509	32244	32509	32244	32244	32244
Adjusted R^2	0.21	0.24	0.23	0.25	0.25	0.25
Add. Firm, Dir. Controls	No	No	Yes	Yes	Yes	Yes
Region-time FE	No	Yes	No	Yes	Yes	Yes
Industry-time FE	No	Yes	No	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: This Table reports the link between residential real estate, corporate real estate, and firm investment. The sample covers reporting UK firms over the period 2002-2014. The dependent variable, Investment, is defined as the change in “Fixed Assets” less “Depreciation”. Residential RE is the total value of residential property held by directors of the firm, holding the composition of directors and their properties fixed in 2002, updating the value through time with changes in their respective regional house price indices, as defined in Equation 3.2. Corporate RE is the 2002 book value of firm “Land and Buildings” iterated forward using the regional house price index, as defined in Equation 3.1. Cash and Profits enter with a lag. All of these variables are scaled by the lag of firm "Turnover". Add. Firm. Dir. Controls comprises of quintiles for firm and director characteristics in 2002 interacted with the house price index in the firm region; the firm’s regional house price index; and the inverse of lagged “Turnover” (see Section 4). All ratios are winsorized at the median ± 5 times the interquartile range. Standard errors, clustered by firm region, in parentheses. Column (1): the effect of residential real estate excluding all further controls with the exception of firm fixed effects. Column (2): both real estate channels, region-time, industry-time and firm fixed effects. Column (3) includes the firm controls and only firm fixed effects. Column (4) is the baseline regression including all controls and fixed effects. Column (5) presents the baseline regression omitting Corporate RE. Column (6) presents the baseline regression omitting Residential RE.

Table 5: Residential Real Estate: Measurement

	Investment					
		Non-Land-Building	Known Shareholder		Residential	Large
	Baseline	Investment	$\geq 50\%$	$< 50\%$	Equity	Sample
	(1)	(2)	(3)	(4)	(5)	(6)
Residential RE	0.0298***	0.0176**	0.0304***	0.0289**		0.0087***
	(0.011)	(0.008)	(0.011)	(0.011)		(0.000)
Residential Equity					0.0316*	
					(0.017)	
Corporate RE	0.0511***	0.0502***	0.0511***		0.0713**	
	(0.017)	(0.013)	(0.017)		(0.032)	
Cash	0.0777***	0.0391***	0.0777***		0.0973***	
	(0.012)	(0.008)	(0.012)		(0.018)	
Profit	0.1092***	0.0828***	0.1090***		0.0900***	
	(0.016)	(0.010)	(0.016)		(0.029)	
P-Value, Equality of Residential Coeffs.			0.7811			
Observations	32244	30692	32244		13993	2468859
Adjusted R^2	0.25	0.28	0.25		0.29	0.13
Add. Firm, Dir. Controls	Yes	Yes	Yes		Yes	No
Region-time FE	Yes	Yes	Yes		Yes	Yes
Industry-time FE	Yes	Yes	Yes		Yes	Yes
Firm FE	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: This Table reports the link between residential real estate, corporate real estate, and firm investment. The sample covers reporting UK firms over the period 2002-2014. The dependent variable, Investment, is defined as the change in “Fixed Assets” less “Depreciation”. Residential RE is the total value of residential property held by directors of the firm, holding the composition of directors and their properties fixed in 2002, updating the value through time with changes in their respective regional house price indices, as defined in Equation 3.2. Corporate RE is the 2002 book value of firm "Land and Buildings" iterated forward using the regional house price index, as defined in Equation 3.1. Cash and Profits enter with a lag. All of these variables are scaled by the lag of firm "Turnover". Add. Firm. Dir. Controls comprises of quintiles for firm and director characteristics in 2002 interacted with the house price index in the firm region; the firm’s regional house price index; and the inverse of lagged “Turnover” (see Section 4). All ratios are winsorized at the median ± 5 times the interquartile range. Standard errors, clustered by firm region, in parentheses. All regressions include firm, region-time and (2 digit) industry-time fixed effects. Column (1) presents the baseline results whilst in Column (2) the dependent variable is Investment, excluding Investment in "Land and Buildings". Columns (3)-(4) include the interaction of Residential RE with a dummy indicating whether at least 50% of the current directors have ever been known shareholders of the firm. In Column (5) Residential RE is replaced as an explanatory variable by Residential Equity. Column (6) estimates the link between Investment and Residential RE on the maximum possible sample size. Specifically, it regresses the change in “Total Assets” on Residential RE, with both variables scaled by the lag of “Total Assets” rather than firm “Turnover”.

Table 6: Residential Real Estate: Identification

	Investment							
			Firm Type		Director Different	Director-Firm Distance		Multi Firm
	Baseline	IV	Tradables	Non-Tradables	Regions	> 30 Miles	≤ 30 Miles	Directors
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Residential RE	0.0298***	0.0237**	0.0349**	0.0291**	0.0305***	0.0315**	0.0256**	0.0310**
	(0.011)	(0.011)	(0.018)	(0.011)	(0.011)	(0.015)	(0.012)	(0.013)
Corporate RE	0.0511***	0.0464***	0.0673**	0.0451**	0.0404*	0.0516***		0.0559***
	(0.017)	(0.017)	(0.029)	(0.021)	(0.021)	(0.017)		(0.018)
Cash	0.0777***	0.0801***	0.0779***		0.0678***	0.0773***		0.0804***
	(0.012)	(0.013)	(0.012)		(0.013)	(0.012)		(0.013)
Profit	0.1092***	0.1012***	0.1096***		0.1153***	0.1106***		0.1067***
	(0.016)	(0.016)	(0.016)		(0.019)	(0.016)		(0.018)
P-Value, Equality of Residential Coeffs.			0.7503			0.7302		
Observations	32244	29299	32244		23501	32035		26800
Adjusted R^2	0.25	0.25	0.25		0.25	0.25		0.25
Add. Firm, Dir. Controls	Yes	Yes	Yes		Yes	Yes		Yes
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: This Table reports the link between residential real estate, corporate real estate, and firm investment. The sample covers reporting UK firms over the period 2002-2014. The dependent variable, Investment, is defined as the change in "Fixed Assets" less "Depreciation". Residential RE is the total value of residential property held by directors of the firm, holding the composition of directors and their properties fixed in 2002, updating the value through time with changes in their respective regional house price indices, as defined in Equation 3.2. Corporate RE is the 2002 book value of firm "Land and Buildings" iterated forward using the regional house price index, as defined in Equation 3.1. Cash and Profits enter with a lag. All of these variables are scaled by the lag of firm "Turnover". Add. Firm. Dir. Controls comprises of quintiles for firm and director characteristics in 2002 interacted with the house price index in the firm region; the firm's regional house price index; and the inverse of lagged "Turnover" (see Section 4). All ratios are winsorized at the median ± 5 times the interquartile range. Standard errors, clustered by firm region, in parentheses. All regressions include firm, region-time and (2 digit) industry-time fixed effects. Column (1) presents the baseline results whilst Column (2) replaces the regional house price index in the calculation of all variables with the instrumented local house price series. Columns (3)-(4) include the interaction of both Residential and Corporate RE with a dummy indicating whether the firm is in the tradables sector, proxied by being in the manufacturing sector. Column (5) repeats the baseline estimation with the estimated value of director properties based only on directors that live in a different region from the firm. Residential RE is then estimated as this average value multiplied by the total number of directors in the firm (in all regions). Columns (6)-(7) include the interaction of Residential RE with a dummy indicating whether the directors of the firm live at least 30 miles from the firm on average. Column (8) adds a proxy for director skill for firms where at least one director has directorships at multiple companies. For such firms, it includes the interaction of the house price index with five quintiles of the average growth in "Total Assets" at the directors' *other* companies.

Table 7: Firm Financing And Real Estate Channels

	Financing			
	Issued Equity	Director Loans	ST Debt	LT Debt
	(1)	(2)	(3)	(4)
Residential RE	0.0015**	-0.0001	0.0210**	0.0023
	(0.001)	(0.001)	(0.010)	(0.012)
Corporate RE	-0.0007	-0.0027*	0.0318*	0.0373**
	(0.001)	(0.002)	(0.016)	(0.018)
Observations	32244	32244	32244	32244
Adjusted R^2	0.29	-0.02	-0.00	0.04
Add. Firm, Dir. Controls	Yes	Yes	Yes	Yes
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

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

Notes: This Table reports the empirical link between residential real estate, corporate real estate, and firm financing. The sample covers reporting UK firms over the period 2002-2014. Issued Equity is the change in "Issued Capital" whilst Director Loans is the sum of the change in "Long Term Director Loans" and "Short Term Director Loans" liabilities. Short Term Debt is defined as the sum of the change in "Short Term Loans and Overdrafts" and "Trade Credit" less the change in "Short Term Director Loans". Long Term Debt is defined as the change in "Long Term Debt" less the change in "Long Term Director Loans". Residential RE is the total value of residential property held by directors of the firm, holding the composition of directors and their properties fixed in 2002, updating the value through time with changes in their respective regional house price indices, as defined in Equation 3.2. Corporate RE is the 2002 book value of firm "Land and Buildings" iterated forward using the regional house price index, as defined in Equation 3.1. All of these variables are scaled by the lag of firm "Turnover". Add. Firm. Dir. Controls comprises of quintiles for firm and director characteristics in 2002 interacted with the house price index in the firm region; the firm's regional house price index; and the inverse of lagged "Turnover" (see Section 4). All ratios are winsorized at the median ± 5 times the interquartile range, except for the financing variables which are winsorized at the 2/98% level. Standard errors, clustered by firm region, in parentheses. All regressions include firm, region-time and (2 digit) industry-time fixed effects.

Table 8: Firm Employment And Wages

Labour Market Variables		
	Change in Remuneration	Change in Employment
	(1)	(2)
Residential RE	0.0332***	0.0009***
	(0.006)	(0.000)
Corporate RE	0.0332***	0.0015***
	(0.010)	(0.000)
Cash	0.0043	0.0003
	(0.006)	(0.000)
Profit	0.1455***	0.0037***
	(0.012)	(0.000)
Observations	32244	32244
Adjusted R^2	0.21	0.18
Add. Firm, Dir. Controls	Yes	Yes
Region-time FE	Yes	Yes
Industry-time FE	Yes	Yes
Firm FE	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: This Table reports the link between residential real estate, corporate real estate, and two employment variables. The sample covers reporting UK firms over the period 2002-2014. Change in Remuneration is the change "Remuneration", whilst Change in Employment is the change in "Number of Employees". Residential RE is the total value of residential property held by directors of the firm, holding the composition of directors and their properties fixed in 2002, updating the value through time with changes in their respective regional house price indices, as defined in Equation 3.2. Corporate RE is the 2002 book value of firm "Land and Buildings" iterated forward using the regional house price index, as defined in Equation 3.1. Cash and Profits enter with a lag. All of these variables are scaled by the lag of firm "Turnover". Add. Firm. Dir. Controls comprises of quintiles for firm and director characteristics in 2002 interacted with the house price index in the firm region; the firm's regional house price index; and the inverse of lagged "Turnover" (see Section 4). All ratios are winsorized at the median $\pm$ 5 times the interquartile range, except for Change in Employment which is winsorized at the 2/98% level. Standard errors, clustered by firm region, in parentheses. All regressions include firm, region-time and (2 digit) industry-time fixed effects.

Table 9: Heterogeneous Responses: Asymmetries Over Time

	Investment			
	House Prices		Time Period	
	Rising	Falling	Pre-2007	Post-2007
	(1)	(2)	(3)	(4)
Residential RE	0.0291***	0.0364***	0.0321***	0.0314***
	(0.011)	(0.010)	(0.010)	(0.011)
Corporate RE	0.0547***	0.0301*	0.0650***	0.0408**
	(0.017)	(0.017)	(0.018)	(0.017)
Cash	0.0787***		0.0791***	
	(0.012)		(0.012)	
Profit	0.1090***		0.1101***	
	(0.016)		(0.016)	
P-Value, Equality of Residential Coeffs.	0.0459		0.8692	
Observations	32244		32244	
Adjusted R^2	0.25		0.25	
Add. Firm, Dir. Controls	Yes		Yes	
Region-time FE	Yes		Yes	
Industry-time FE	Yes		Yes	
Firm FE	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: This Table reports the link between residential real estate, corporate real estate, and firm investment. The sample covers reporting UK firms over the period 2002-2014. The dependent variable, Investment, is defined as the change in "Fixed Assets" less "Depreciation". Residential RE is the total value of residential property held by directors of the firm, holding the composition of directors and their properties fixed in 2002, updating the value through time with changes in their respective regional house price indices, as defined in Equation 3.2. Corporate RE is the 2002 book value of firm "Land and Buildings" iterated forward using the regional house price index, as defined in Equation 3.1. Cash and Profits enter with a lag. All of these variables are scaled by the lag of firm "Turnover". Add. Firm. Dir. Controls comprises of quintiles for firm and director characteristics in 2002 interacted with the house price index in the firm region; the firm's regional house price index; and the inverse of lagged "Turnover" (see Section 4). All ratios are winsorized at the median ± 5 times the interquartile range. Standard errors, clustered by firm region, in parentheses. All regressions include firm, region-time and (2 digit) industry-time fixed effects. Columns (1)-(2) include the interaction of both Residential and Corporate RE with a dummy variable indicating whether annual house price growth in the firm region is positive or negative. Columns (3)-(4) include the interaction of both Residential and Corporate RE with a dummy variable indicating whether the observations fall within the 2002-2006 or the 2007-2014 period.

Table 10: Heterogeneous Responses: Age, Leverage, Size

	Investment						
	Age		Pay Out Ratio		Size		
	Young	Old	Low	High	Small	Large	Largest Firms
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Residential RE	0.0295***	0.0304**	0.0307***	0.0261**	0.0249**	0.0663	-0.0451
	(0.011)	(0.013)	(0.011)	(0.011)	(0.011)	(0.045)	(0.344)
Corporate RE	0.0544***	0.0482**	0.0579***	0.0241	0.0428**	0.0620*	0.0536
	(0.017)	(0.020)	(0.017)	(0.020)	(0.019)	(0.034)	(0.052)
Cash	0.0776***		0.0788***		0.0775***		0.1380*
	(0.012)		(0.012)		(0.012)		(0.077)
Profit	0.1091***		0.1127***		0.1089***		0.6138***
	(0.016)		(0.016)		(0.016)		(0.097)
P-Value, Equality of Residential Coeffs.	0.9206		0.3522		0.3794		
Observations	32244		32244		32244		689
Adjusted R^2	0.25		0.25		0.25		0.22
Add. Firm, Dir. Controls	Yes		Yes		Yes		Yes
Region-time FE	Yes		Yes		Yes		No
Industry-time FE	Yes		Yes		Yes		No
Time FE	No		No		No		Yes
Firm FE	Yes		Yes		Yes		Yes

Firm region clustered standard errors in parentheses

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

Notes: This Table reports the link between residential real estate, corporate real estate, and firm investment. The sample covers reporting UK firms over the period 2002-2014. The dependent variable, Investment, is defined as the change in “Fixed Assets” less “Depreciation”. Residential RE is the total value of residential property held by directors of the firm, holding the composition of directors and their properties fixed in 2002, updating the value through time with changes in their respective regional house price indices, as defined in Equation 3.2. Corporate RE is the 2002 book value of firm "Land and Buildings" iterated forward using the regional house price index, as defined in Equation 3.1. Cash and Profits enter with a lag. All of these variables are scaled by the lag of firm "Turnover". Add. Firm. Dir. Controls refers to additional controls quintiles for firm and director characteristics in 2002 interacted with the house price index in the firm region, as well the firm’s regional house price index, and the inverse of lagged “Turnover” (see Section 4). All ratios are winsorized at the median ± 5 times the interquartile range. Standard errors, clustered by firm region, in parentheses. Columns (1)-(2): both Residential RE and Corporate RE are interacted with a dummy variable indicating whether the age of the given firm is below or above the median in the given year. Columns (3)-(4): both Residential and Corporate RE are interacted with a dummy variable indicating whether the dividend payout ratio (defined as the ratio of “Dividends” to “Total Assets”, with the ratio set to 0 when no dividends are reported) of the given firm is below or above the 75th percentile in the given year. Column (5-6): both Residential and Corporate RE are interacted with a dummy variable indicating whether the average number of employees of the given firm is within 0-249 (small & medium sized enterprises), or $\geq$ 250 (large). The inverse of lagged “Turnover” is also interacted with this dummy variable. Column (7): sample of firms with more than 10000 employees on average.

Table 11: Corporate Real Estate: Identification

	Investment						
					2002	Lagged Book Value	
			Firm Dispersion		Market Value		Non Land-Build.
	Baseline	CRE	Single-Region	Multi-Region	Land	Investment	Investment
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Residential RE	0.0298***	0.0229	0.0291***	0.0312***	0.0275*	0.0443***	0.0213***
	(0.011)	(0.015)	(0.011)	(0.011)	(0.016)	(0.011)	(0.008)
Corporate RE	0.0511***	0.0701**	0.0531***	0.0463**	0.1030*	-0.0728***	0.0637***
	(0.017)	(0.030)	(0.017)	(0.019)	(0.054)	(0.010)	(0.008)
Cash	0.0777***	0.0578***	0.0775***		0.0772***	0.0691***	0.0443***
	(0.012)	(0.015)	(0.012)		(0.017)	(0.012)	(0.008)
Profit	0.1092***	0.1151***	0.1092***		0.1080***	0.1108***	0.0840***
	(0.016)	(0.020)	(0.016)		(0.026)	(0.016)	(0.010)
P-Value, Equality of Residential Coeffs.			0.6684				
Observations	32244	15043	32244		12078	31238	30692
Adjusted R^2	0.25	0.26	0.25		0.24	0.25	0.29
Add. Firm, Dir. Controls	Yes	Yes	Yes		Yes	Yes	Yes
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 residential real estate, corporate real estate, and firm investment. The sample covers reporting UK firms over the period 2002-2014. The dependent variable, Investment, is defined as the change in "Fixed Assets" less "Depreciation". Residential Real Estate is the total value of residential property held by directors of the firm, holding the composition of directors and their properties fixed in 2002, updating the value through time with changes in their respective regional house price indices, as defined in Equation 3.2. Corporate RE is the 2002 book value of firm "Land and Buildings" iterated forward using the regional house price index, as defined in Equation 3.1. Cash and Profits enter with a lag. All of these variables are scaled by the lag of firm turnover. Add. Firm. Dir. Controls comprises of quintiles for firm and director characteristics in 2002 interacted with the house price index in the firm region; the firm's regional house price index; and the inverse of lagged "Turnover" (see Section 4). All ratios are winsorized at the median ± 5 times the interquartile range. Standard errors, clustered by firm region, in parentheses. All regressions include firm, region-time and (2 digit) industry-time fixed effects. Column (1) presents the baseline results. Column (2) calculates Corporate RE by iterating forward the 2002 book value of "Land and Buildings" using a commercial real estate price index instead of the house price index. Columns (3), (4) include interactions of both Residential and Corporate RE with a dummy variable taking the value one when all of a firm's trading addresses are in a single region. Column (5) calculates Corporate RE 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 Corporate RE using the one-year lagged book value of "Land and Buildings", iterated forward using the regional house price index. Column (7) uses the same definition of Corporate RE, but with investment, excluding investment in "Land and Buildings", as the dependent variable.

Table 12: Residential Real Estate And Remuneration: Identification

	Change in Remuneration							
			Firm Type		Director Different	Director-Firm Distance		Multi Firm
	Baseline	IV	Tradables	Non-Tradables	Regions	> 30 Miles	≤ 30 Miles	Directors
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Residential RE	0.0332***	0.0262***	0.0362**	0.0331***	0.0370***	0.0446***	0.0270***	0.0319***
	(0.006)	(0.006)	(0.014)	(0.007)	(0.006)	(0.009)	(0.007)	(0.007)
Corporate RE	0.0332***	0.0315***	0.0550***	0.0254**	0.0360***	0.0347***		0.0305***
	(0.010)	(0.011)	(0.021)	(0.013)	(0.011)	(0.010)		(0.010)
Cash	0.0043	0.0057	0.0046		0.0111	0.0042		0.0040
	(0.006)	(0.007)	(0.007)		(0.008)	(0.007)		(0.007)
Profit	0.1455***	0.1439***	0.1460***		0.1502***	0.1451***		0.1345***
	(0.012)	(0.013)	(0.012)		(0.011)	(0.012)		(0.012)
P-Value, Equality of Residential Coeffs.			0.8525			0.0568		
Observations	32244	29299	32244		23501	32035		26800
Adjusted R^2	0.21	0.22	0.21		0.22	0.21		0.22
Add. Firm, Dir. Controls	Yes	Yes	Yes		Yes	Yes		Yes
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 residential real estate, corporate real estate, and firm remuneration. The sample covers reporting UK firms over the period 2002-2014. The dependent variable, Change in Remuneration, is defined as the change in "Remuneration". Residential RE is the total value of residential property held by directors of the firm, holding the composition of directors and their properties fixed in 2002, updating the value through time with changes in their respective regional house price indices, as defined in Equation 3.2. Corporate RE is the 2002 book value of firm "Land and Buildings" iterated forward using the regional house price index, as defined in Equation 3.1. Cash and Profits enter with a lag. All of these variables are scaled by the lag of firm "Turnover". Add. Firm. Dir. Controls comprises of quintiles for firm and director characteristics in 2002 interacted with the house price index in the firm region; the firm's regional house price index; and the inverse of lagged "Turnover" (see Section 4). All ratios are winsorized at the median ± 5 times the interquartile range. Standard errors, clustered by firm region, in parentheses. All regressions include firm, region-time and (2 digit) industry-time fixed effects. Column (1) presents the baseline results whilst Column (2) replaces the regional house price index in the calculation of all variables with the instrumented local house price series. Columns (3)-(4) include the interaction of both Residential and Corporate RE with a dummy indicating whether the firm is in the tradables sector, proxied by being in the manufacturing sector. Column (5) repeats the baseline estimation with the estimated value of director properties based only on directors that live in a different region from the firm. Residential RE is then estimated as this average value multiplied by the total number of directors in the firm (in all regions). Columns (6)-(7) include the interaction of Residential RE with a dummy indicating whether the directors of the firm live at least 30 miles from the firm on average. Column (8) adds a proxy for director skill for firms where at least one director has directorships at multiple companies. For such firms, it includes the interaction of the house price index with five quintiles of the average growth in total assets at the directors' *other* companies.

Table 13: Residential Real Estate And Employment: Identification

	Change in Employment							
			Firm Type		Director Different	Director-Firm Distance		Multi Firm
	Baseline	IV	Tradables	Non-Tradables	Regions	> 30 Miles	≤ 30 Miles	Directors
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Residential RE	0.0009***	0.0008***	0.0002	0.0011***	0.0011***	0.0012***	0.0007**	0.0008**
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Corporate RE	0.0015***	0.0013**	0.0026***	0.0011**	0.0015***	0.0015***		0.0015***
	(0.000)	(0.001)	(0.001)	(0.000)	(0.001)	(0.000)		(0.000)
Cash	0.0003	0.0002	0.0003		0.0003	0.0003		0.0002
	(0.000)	(0.000)	(0.000)		(0.000)	(0.000)		(0.000)
Profit	0.0037***	0.0037***	0.0037***		0.0039***	0.0037***		0.0036***
	(0.000)	(0.000)	(0.000)		(0.000)	(0.000)		(0.000)
P-Value, Equality of Residential Coeffs.			0.1055			0.1614		
Observations	32244	29299	32244		23501	32035		26800
Adjusted R^2	0.18	0.19	0.18		0.19	0.18		0.19
Add. Firm, Dir. Controls	Yes	Yes	Yes		Yes	Yes		Yes
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 residential real estate, corporate real estate, and firm employment. The sample covers reporting UK firms over the period 2002-2014. The dependent variable, Change in Employment, is defined as the change in "Number of Employees". Residential RE is the total value of residential property held by directors of the firm, holding the composition of directors and their properties fixed in 2002, updating the value through time with changes in their respective regional house price indices, as defined in Equation 3.2. Corporate RE is the 2002 book value of firm "Land and Buildings" iterated forward using the regional house price index, as defined in Equation 3.1. Cash and Profits enter with a lag. All of these variables are scaled by the lag of firm "Turnover". Add. Firm. Dir. Controls comprises of quintiles for firm and director characteristics in 2002 interacted with the house price index in the firm region; the firm's regional house price index; and the inverse of lagged "Turnover" (see Section 4). All ratios are winsorized at the median ± 5 times the interquartile range, except for Change in Employment, which is winsorized at the 2/98% level. Standard errors, clustered by firm region, in parentheses. All regressions include firm, region-time and (2 digit) industry-time fixed effects. Column (1) presents the baseline results whilst Column (2) replaces the regional house price index in the calculation of all variables with the instrumented local house price series. Columns (3)-(4) include the interaction of both Residential and Corporate RE with a dummy indicating whether the firm is in the tradables sector, proxied by being in the manufacturing sector. Column (5) repeats the baseline estimation with the estimated value of director properties based only on directors that live in a different region from the firm. Residential RE is then estimated as this average value multiplied by the total number of directors in the firm (in all regions). Columns (6)-(7) include the interaction of Residential RE with a dummy indicating whether the directors of the firm live at least 30 miles from the firm on average. Column (8) adds a proxy for director skill for firms where at least one director has directorships at multiple companies. For such firms, it includes the interaction of the house price index with five quintiles of the average growth in total assets at the directors' *other* companies.

Table 14: First Stage Regression For Real Estate Price Instrument

	Real Estate Prices
	Baseline
	(1)
$constraints_k \times r_t$	-9.500***
	(1.583)
Observations	37800
Adjusted R^2	0.95
Time FE	Yes
Region FE	Yes

Standard errors clustered at the region level in parentheses

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

Notes: The table reports the results for the estimation of Equation 4.2 over the sample period Jan-1995 to Mar-2016 for 150 English regions. The dependent variable, real estate prices, is defined in log levels. The explanatory variable is the regional share of developable land that was developed in 1990 ($constraints_k$) interacted with as the 2-year 75%-LTV UK mortgage rate (r_t). Region and time fixed effects both included.

Table 15: Residential Real Estate: Sources Of Variation

	Investment				
	Baseline	Same House	Same Region	Same Directors	Same Region & Directors
	(1)	(2)	(3)	(4)	(5)
Residential RE	0.0298***	-0.0001	0.0308***	0.0277***	0.0161*
	(0.011)	(0.008)	(0.012)	(0.011)	(0.010)
Corporate RE	0.0511***	0.0600***	0.0503***	0.0526***	0.0555***
	(0.017)	(0.016)	(0.017)	(0.017)	(0.016)
Cash	0.0777***	0.0778***	0.0777***	0.0776***	0.0778***
	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
Profit	0.1092***	0.1069***	0.1096***	0.1084***	0.1084***
	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)
Observations	32244	32244	32244	32244	32244
Adjusted R^2	0.25	0.25	0.25	0.25	0.25
Add. Firm, Dir. Controls	Yes	Yes	Yes	Yes	Yes
Region-time FE	Yes	Yes	Yes	Yes	Yes
Industry-time FE	Yes	Yes	Yes	Yes	Yes
Firm FE	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 real estate, corporate real estate, and firm investment. The sample covers reporting UK firms over the period 2002-2014. The dependent variable, Investment, is defined as the change in "Fixed Assets" less "Depreciation". Residential RE is the total value of residential property held by directors of the firm, holding the composition of directors and their properties fixed in 2002, updating the value through time with changes in their respective regional house price indices, as defined in Equation 3.2. Corporate RE is the 2002 book value of firm "Land and Buildings" iterated forward using the regional house price index, as defined in Equation 3.1. Cash and Profits enter with a lag. All of these variables are scaled by the lag of firm "Turnover". Add. Firm. Dir. Controls comprises of quintiles for firm and director characteristics in 2002 interacted with the house price index in the firm region; the firm's regional house price index; and the inverse of lagged "Turnover" (see Section 4). All ratios are winsorized at the median ± 5 times the interquartile range. Standard errors, clustered by firm region, in parentheses. Column (1) is the baseline regression including all controls and fixed effects. In Column (2) *Residential RE* is replaced with *Residential RE samehouse*. In Column (3) *Residential RE* is replaced with *Residential RE sameregion*. In Column (4) *Residential RE* is replaced with *Residential RE samedirector*. In Column (5) *Residential RE* is replaced with *Residential RE sameregion&director*.

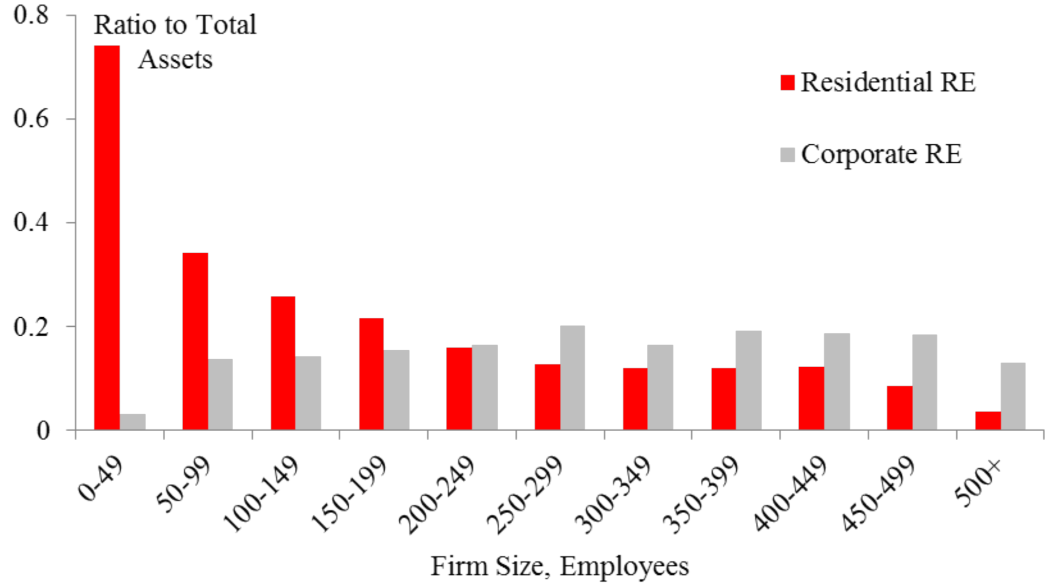
Table 16: Cross-country Comparison Of Personal Guarantees

Country	Paper	Use of PGs	Notes
Australia	Connolly et al. (2015)	>UK/US	as a % of new SME loans
Ireland	Carroll et al. (2015)	33%	as a % of new SME loans
Japan	Ono and Uesugi (2009)	67%	as a % of new SME loans
Italy	Calcagnini et al. (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	Bank of England	29%	as a % of new SME loans
UK	Franks and Sussman (2005)	50-60%	as % of loans to distressed companies
USA	Bathala et al. (2006)	53%	as a % of new SME loans
USA	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 PG of a company director. The exception is Davydenko and Franks (2008) that focuses on firms with loan exposure at default.

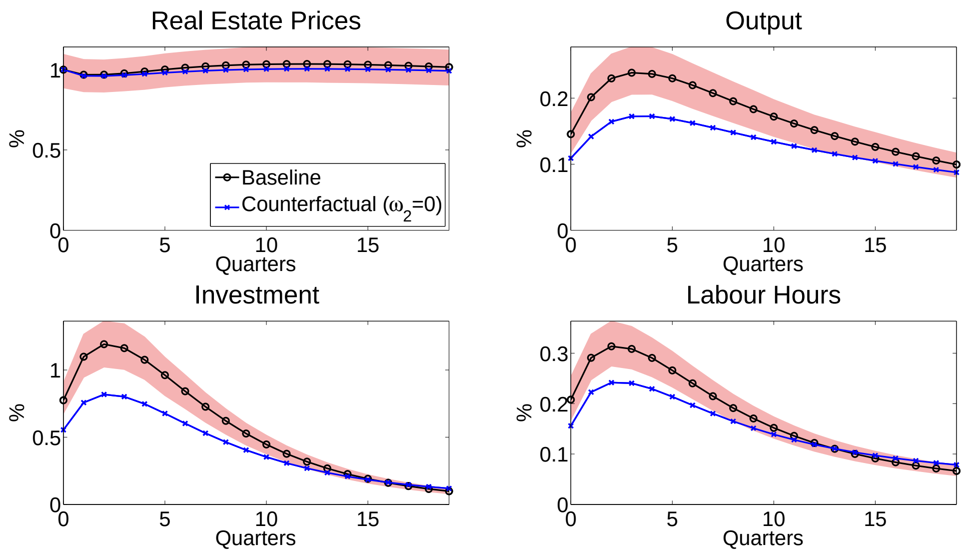
Figures

Figure 1: Median Ratio Of Residential & Corporate RE To Total Assets By Firm Size Bucket



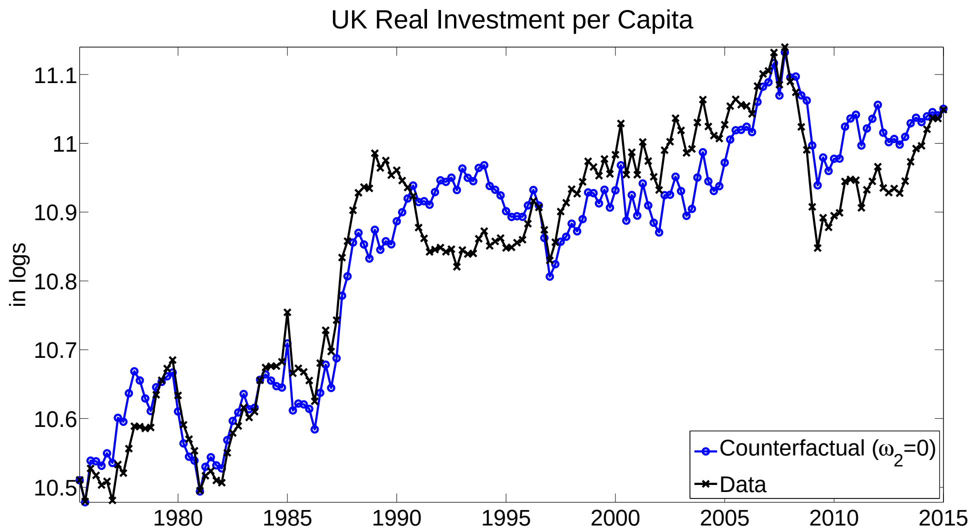
Notes: The figure shows how the ratios of residential and corporate real estate to total assets vary by firm size. The statistics are calculated using the sample of observations for the baseline regression, covering the period 2002-2014. This excludes firms who have an ownership stake greater than 50%, operate in certain industries, and report the main variables of interest for our regressions. Full details on sample selection are given in Section 3.1.1. Residential Real Estate is defined by Equation 3.2, and Corporate Real Estate is defined by Equation 3.1. Both real estate measures are scaled by "Total Assets". The figure displays the median values of these ratios for different firm size buckets. The firm size buckets are based on the mean "Number of Employees" the firm has over our sample period.

Figure 2: The Impact Of A Housing Demand Shock In The DSGE Model



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 median of the estimated parameters are used to compute the baseline impulses (black line), the shaded area is the 90% probability region. The counterfactual responses (blue lines) are calculated by setting $\omega_2 = 0$.

Figure 3: The Importance Of Residential Real Estate Over The UK Business Cycle



Note: The counterfactual path of the investment is computed in three steps. First, we estimate the model and save the time series of the structural shocks. Second, we change $\omega_2 = 0.33$ to $\omega_2 = 0$ and recompute the model's policy functions. Third, we apply the Kalman filter to the newly computed policy functions and the estimated time series of the structural shocks from the first step, which yields the counterfactual investment time series (in blue).

Appendix for Online Publication

A UK Accounting Data

A.1 Firm Reporting Rules in the United Kingdom

The statutory reporting requirements for firms 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 Companies Act 2006 came into force on 1 October 2009. This means that firms in the United Kingdom used varying reporting standards during our sample period, with the most relevant change in standards for our purposes being 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 to 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 UK. The agency has the responsibility for examining and storing all the statutory information that companies in the UK are required to supply. Companies House also has the responsibility to make the filed information public. There are, however, some exceptions to what a firm (or individuals that run or exert significant control over a firm) have to make publicly available. While Companies House filings often go hand in hand with firm tax returns (annual accounts can be filed jointly with a tax return), the information held by the Registrar is not directly used for the purposes of calculating corporation tax. Tax returns by firms are dealt with separately by Her Majesty's Revenue and Customs, the United Kingdom Tax Authority.

Reporting Requirements At the end of a firm's fiscal year the firm 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 firms are required to report in one 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).

Companies House must also be informed of the firm's name, registered office, share capital and charges against the firm's assets for the purposes of securing a loan. Firms must also maintain, interalia, a register of directors (including the director's usual residential address). If any of these details change the firm must inform Companies House via an event driven filing. Key for our purposes is the information on directors' usual residential addresses. One of the last provisions to be implemented in the Companies Act 2006, on 1 October 2009, allowed firm 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). In Online Appendix C.3.2 we show that this change in the law does not have a meaningful impact on our results.

Time Lags Firms 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 firm's fiscal year end for private firms and 6 months of the firm's year end for public companies. Firms can amend the accounts retrospectively to fix errors and present data revisions. Firms can also amend the end of their accounting year (but not retroactively), which can lead to irregular accounting windows of lengths different than a year. However, firms 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 firm's directors should be reported to Companies House within 14 days of the changes being made.

A.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 provide 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 datasets).

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 BvD database would have their latest accounts filed within the past year (9 months after the firm's financial year plus one-two months of 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 firm 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 dataset it seemed 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. We discuss this issue in more detail below.

A.3 Treatment of the BvD UK Accounting Data

A.3.1 The Sample of BvD Vintages 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 firms filed new annual accounts and as firms conducted event driven filings with Companies House (such as form CH01 which is used to notify Companies House of a change in the details of a firm'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 firm 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 firm, 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, firms can occasionally have irregular filing periods, if a firm changes its financial year end date, and files twice within a year. Second, as described above, director and other firm information can change outside of accounting periods. These are so-called event driven filings (e.g. when 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.

A.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 vintage 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 vintages in the middle of our sample. For the first vintage (January 2005) in the sample we downloaded five years of lagged data (ten years in the case of Land and Buildings data) to add additional historical coverage. For the final vintage, August 2015, we downloaded the full 10 years of data in order to evaluate the benefits of using the archived vintages versus a single snapshot of the database.

A.4 Merging the Discs into a Combined Firm Panel

Each firm in the UK is assigned a unique Companies House Registration Number (CRN) upon formation which stays with the firm 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. The benefits the merged panel structure brings over a single vintage 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 firm directors across all the discs is separately combined to form a panel of director characteristics, as discussed in Online Appendix B. The firm and director panels are then merged for the regression analysis.

A.4.1 Treatment of the First Vintage

In the first vintage (January 2005), we use the additional lagged accounting information to generate 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) to iterate backwards. For young firms, this process can generate purported accounting periods before the firm was born. To correct for this, all generated historical observations where the "Incorporation Date" is after the statement date are dropped.

As discussed above, information on firm directors can change outside of accounting periods, for example if a new director is appointed to the firm or if they move house. To determine which of the directors present at the firm in January 2005 were present in the firm at the time of the generated historical accounts, we use the *"Director Appointment Date"*. We retain directors for all generated 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 Registers of Scotland (for Scotland), as discussed in detail in Online Appendix C. 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.

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

Since we sample from BvD at a biannual frequency, the same set of firm accounts frequently appear in multiple different BvD vintages (up to a maximum of 21 observations on the same accounts). The next step in the formation of the merged panel is to bring together these multiple observations on the same set of accounts. At this point the dataset is restricted to companies that report the statement date of their accounts, allowing a given set of firm accounts to be uniquely identified using the CRN and statement date. The data is broken up into three groups that are treated differently, summarised by the following three paragraphs.

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 vintage where the accounts are filed. In particular, we omit information on directors appointed after the vintage 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 firm 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 vintage 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 17 provides a stylised example of this for variables with and without missing data. This treatment also covers lagged accounting information by vintage.

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. Firms revise their historical accounts over time and using the panel structure such revisions are captured. The general principle is to use the latest data

Table 17: Treatment of Duplicate Accounts:

Variables *Only* Revised When Missing

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

Table 18: Treatment of Duplicate Accounts:

Variables Revised *Unless* Missing

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

on the firm'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 this problem, the latest non-missing data is taken for this group of variables. Table 18 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.

A.4.3 Treatment of Downloaded Lagged Accounting Information

Following the data harmonisation in the prior step, for each firm 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 firm 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 firm 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 firm observations have no accounts missing. As with the treatment for the first vintage, observations on firm directors appointed after the "Statement Date" for the generated accounts are removed. Variables with lagged accounting data are treated for the missing accounts in the same way as for the rest of the dataset, as discussed next.

Harmonisation of Accounting Data. As accounting data can be revised, our general principle is to use the latest available non-missing data. A stylised set of accounts are presented in Table 19. 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 19. 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

Table 19: 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.

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. Further, 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.

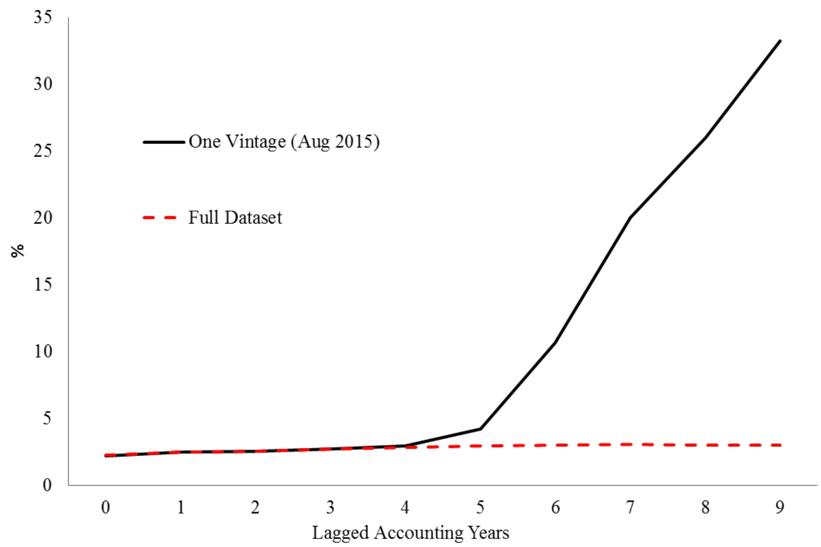
A.4.4 Enhancement of Data Coverage Through Combining Vintages

The final combined panel of firms, comprised of companies with non-missing statement dates, contains 28.9 million firm-account observations, with 4.8 million unique firms. The combination of data across several vintages has significant advantages over data extracted from a single vintage:

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

- Second, even within the time period covered by the 10 lagged accounts, our merged dataset brings significant benefits in terms of coverage of the accounting information firms report. To demonstrate this, we downloaded 10 accounts for each firm from the August 2015 vintage and compared the value of firm's "Total Assets", a particularly well-reported variable, to the same variable over the same set of 10 accounts using the data as created from the our combined dataset using all 21 vintages. The proportion of observations for which "Total assets" are

Figure 4: Proportion of Observations with Total Assets Missing

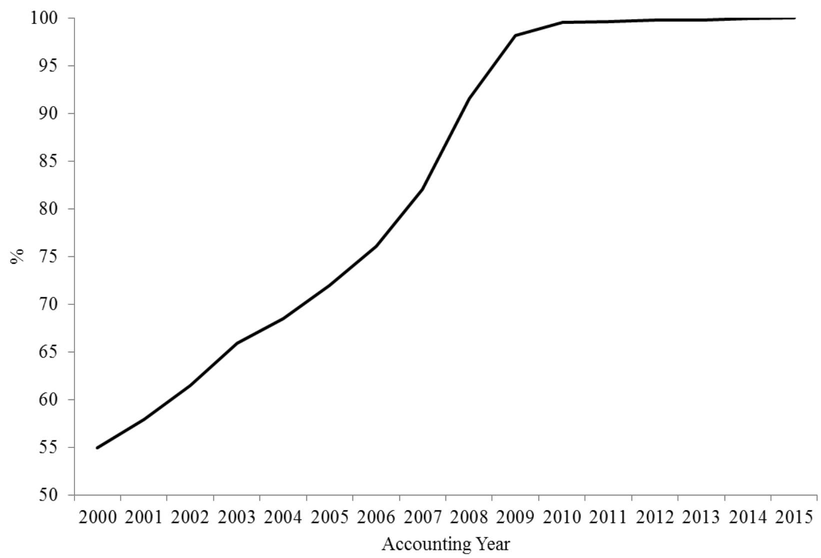


Notes: the figure displays the proportion of total assets missing among companies with a non-missing statement date. *One vintage* refers to the 10 lagged accounts downloaded for the companies present in the August 2015 vintage. *Full dataset* refers to the final panel of firms produced from the 21 vintages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

missing from each dataset is shown in Figure 4. Using the combined dataset, "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 vintage 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 combined dataset has significantly greater coverage of firms. Figure 5 displays the proportion of companies present in each accounting year in our combined dataset that are still present in the August 2015 vintage. Only 55% of the companies that filed accounts in 2000 are still present in the August 2015 vintage. Note, this is not the requirement that the firm *accounts* from 2000 are present in the 2015 vintage, only that information on the *firm* itself is still present. The difference in asset reporting in Figure 4 is driven largely by firms exiting the database before the 2015 vintage. Indeed, 94% of the firm observations where "Total Assets" is reported in the full panel but not from the 2015 vintage have had their "Company Status" become no longer *Live* at a date prior to 2015.

Figure 5: Fraction of Firms Present in August 2015 vintage



Notes: the figure displays the proportion of firms in each statement year, as derived from the full set of 21 vintages, that are present in the August 2015 vintage.

A.5 Sample Selection

Our key sample selection criteria are articulated 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.

- For a firm-year observation to be included, the firm must have had a "Company Status" of *Live* when the accounts were first filed.

- 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). Firms occasionally switch industry, we take the modal value across the firm's observations and resolve ties in favour of the highest number to assign a firm to the same industry for the complete sample.

- We exclude companies that have a parent or are part of a group. Our criteria for doing so is whether the firm 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 firm 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 firm 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 vintage available after a company has filed its annual accounts.

- 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 firm filed two sets of accounts within a year. Specifically, we use the BvD field "Number of Months Since Last Accounts" and exclude observations where this is not equal to 12 months. Observations where there is no information on the filing date are excluded.

- We exclude companies where no information on the firm's location is recorded. That is to say the "R/O Address", "Primary Trading Address", and the first "Trading Address" fields are all missing.

B Firm Director Characteristics

B.1 Construction of the Firm Director Panel

B.1.1 Treatment of Directors Within BvD Vintages

To form the panel of director characteristics, we first extract information on all directors contained in each of the 21 vintages of BvD. Key fields on the personal characteristics are the directors "Director Full Name" , "Director Surname", "Director Title", "Date of Birth", "Full Address", "Director Full Postcode", "Director Nationality", and "Director Gender".[50] We also collect information on the firms the director is associated with on each date, including its "Registered Number" (CRN, the firm identifier), and the "Director Appointment Date" and "Director Resignation Date" (if applicable) of all roles that the director held at the firm (note that directors sometimes resign and are then reappointed). There can be multiple firm observations for the same director at a given point in time, reflecting their roles at multiple different companies.

Within each vintage, we then clean the data in the following fashion:

- We exclude directors who are firms. Under the Companies Act, every firm must have at least one director who is a natural person; however, the firm may also have additional directors who are themselves firms (director-firms). For instance, an accountancy firm may sit on the board of directors. Including such entities makes no sense from the point of view of our research question. In the earlier vintages of BvD there is not a variable that flags whether a director is a firm or an individual. Instead, we identify director-firms as those whose full name/surname is recorded but the date of birth and first name/initial is missing (as neither of these fields are recorded for directors who are firms but are required for directors who are individuals). As a further measure, we flag director-firms as those whose "Director Full Name" includes one of over 35 common expressions for a firm name such as "Limited", "LTD", "Accountants", "Secretaries" and "Corporation". In the latter vintages of the database there is a variable which explicitly flags whether a director is an individual or a firm ("Director Individual or Company"). Testing against this variable we find that our method for identifying whether a director is an individual

[50] For some vintages we only observe "Director Initial"/"Director First Name" and "Director Surname".

or a firm is accurate in over 99.99% of cases. Given this accuracy, for consistency over time, we use the method for flagging director-firms based on missing date of birth and initial throughout the dataset.

- All but the first three vintages 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, we impute the director's gender using different information. We first use the "Director Title" (e.g. Mr or Mrs) to assign genders. However, 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.

B.1.2 Forming the Director Identification Key

We then combine the information from the 21 vintages of BvD together by generating a key to identify the same individual, both through vintages, and across different companies at a given point in time. Our identification key is formed for individuals based on their first initial, surname, and date of birth. We have sufficient information to compute this key in every BvD vintage we use. We then take the following steps to clean the variables that enter the key:

- The "Director Surname" string is cleaned to remove any prefixes, suffixes, initials and titles that are on occasion mistakenly included in the surname field.

- "Date of Birth" is present in 92% of cases, allowing this form of identification key to be computed for the majority of individuals. In some of the missing cases, the date of birth can be imputed based on repeat observations on an individual at the same company. Specifically, we assume that surname and initial are 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 vintages and absent in others. In such cases, the missing date of birth is imputed, so long as the initial and last name are associated with a unique date of birth within the company over time. 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 over time and are dropped.

Note that on this basis there are 9.7 million unique surname/initial/date of birth combinations. We cannot guarantee that our key identifies every director uniquely, particularly for individuals with common surnames. However, since the population of directors is smaller compared to the country as a whole, collision probabilities are sufficiently low not to introduce meaningful measurement error into our analysis.

B.1.3 Cleaning Across Discs

There can be observations on the same director across their roles in multiple firms or in multiple roles within firms. We use these multiple observations to fill in missing data and correct for inaccuracies of the data. For the director gender and whether the individual is foreign, we take the modal value across all observations on the individual, 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 is to extract information on the positions held at each firm. The unit of observation now is an individual's role at a given company. These roles are identified based on the Companies House number of the firm, the director identification key, and their appointment and resignation dates at the firm. 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, an individual is appointed only for one day to register the company. These observations are excluded as the focus of this paper is on individuals who have a meaningful role at a company.

- The director appointment date is missing for 0.16% of observations. If the individual has at most one role recorded with the firm in every vintage of BvD, we fill in missing appointment dates with data from other vintages. Following this treatment, the appointment date is only missing for 0.05% of observations. The remaining observations are dropped.

- Companies House first collected data on firm directors during 1991 and 1992. To initialise their database, Companies House took a snapshot of existing directors in the most recently filed company accounts. As historical information on appointment dates was not available, the date 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 naturally missing for vintages of BvD that predate the resignation. We correct for this using the information from subsequent vintages and build a consistent set of appointment and resignation dates for each role the director has at the company (distinguishing between roles when the director has resigned and is reappointed).

In the dataset, it sometimes turns out 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 vintages 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 dataset to a monthly panel of director roles. This allows for 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 24 months, this allows a match between the director role and the most recently filed accounts prior to their appointment.

B.1.4 Company Information

We selected a small number of well-reported company variables for the calculation of director characteristics:

- "Company Status:" an indicator of whether the firm is live, or in some other state such as dormant or dissolved.

- "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 firm balance sheet.

- "Incorporation Date:" the date the firm was incorporated and registered with Companies House.

Data on these, and other variables, are taken from each of the 21 BvD vintages sampled and combined into a cleaned panel of firm information, following the same account cleaning procedure as the main firm level dataset.

B.2 Calculation of Director Characteristics

We merge the cleaned company information onto the monthly director panel at the months of the company accounts. This firm level 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.

We use the combined monthly panel of director information and company information 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 filing date, expressed in years.
- *Male*: a dummy variable taking the value 1 when the director is male.
- *Non-UK*: a dummy variable taking the value 1 when the director is not a U.K. national.

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 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 dataset 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. We calculate a number of measures of experience at monthly frequency:

- *Number Of Roles*: the number of different companies the individual has been a director of. This measure does not double-count two separate periods in which an individual is a director at the same company.

- *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 Firm:* average number of years a director spent at each company, derived from the prior two series.

- *Experience Of Leaving Firms*: 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.

- *Firms With At Birth*: the number of different companies where the individual was appointed in the same month the company was incorporated.

- *Firms That Have Failed*: 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.*

- *Number Of Industries Worked In*: 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 dataset runs from January 1998 to August 2015, and has just over 1 billion observations.

C Matching Residential Addresses of Firm Directors

C.1 Background and General Principles

C.1.1 The Structure of Addresses in the UK

While tedious, it is useful to first lay out what a UK address typically looks 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 is 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 a 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 postcodes 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 postcode can vary between 1 and 100).[51] 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 thousand

[51] 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.

out of 976 thousand.[52] 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 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 for non-residential addresses which we are not interested in.

C.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 and (iii) the Registers of Scotland covering property transactions in Scotland (both commercial and residential) since 2003. All three record address information in different ways,

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

with only the BvD database recording it as a raw string, so one needs to clean the data first in order to put it in a comparable form.

C.1.3 Our Approach to Matching

Given the fact that UK addresses 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 databases; (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, 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 preference 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.

C.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.

C.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

Table 20: 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	

Notes: 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.

Addressable Object Name" (*paon*) and "Secondary Addressable Object Name" (*saon*). The secondary address characteristics typically contain 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 20 contains a short extract from the relevant fields from the Land Registry. The dataset 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 21 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*,

Table 21: 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. Our England and Wales Land Registry data covers transactions over the period Jan 1995 - April 2016.
* *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").

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 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.

C.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 22 contains an extract from the database.

The data in the Registers of Scotland database is less clean than the England and Wales Land Registry. Many more observations are missing (e.g. the postcode is missing for 197,871 observations), 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 22). If the observed transaction has insufficient information to form 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

Table 22: 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	

Notes: 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 shows 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.

Table 23: 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 missing, are excluded. Our Registers of Scotland data covers transactions over the period April 2003 - September 2014.

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 sufficient 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 22), 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 referring 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 23 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.

C.2.3 Director Addresses in BvD

In BvD there are two fields that contain director address information: *directoraddress* and *directorpostcode.*[53] The latter is equivalent to the postcode in the other two databases. There is a small data quality issue regarding postcodes: in about 0.3% of cases directors give the shortened 3 digit

[53] In some vintages of BvD these fields are titled *directorfulladdress* and *directorfullpostcode.*

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 one 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* is 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.

C.3 Performance of the Algorithm

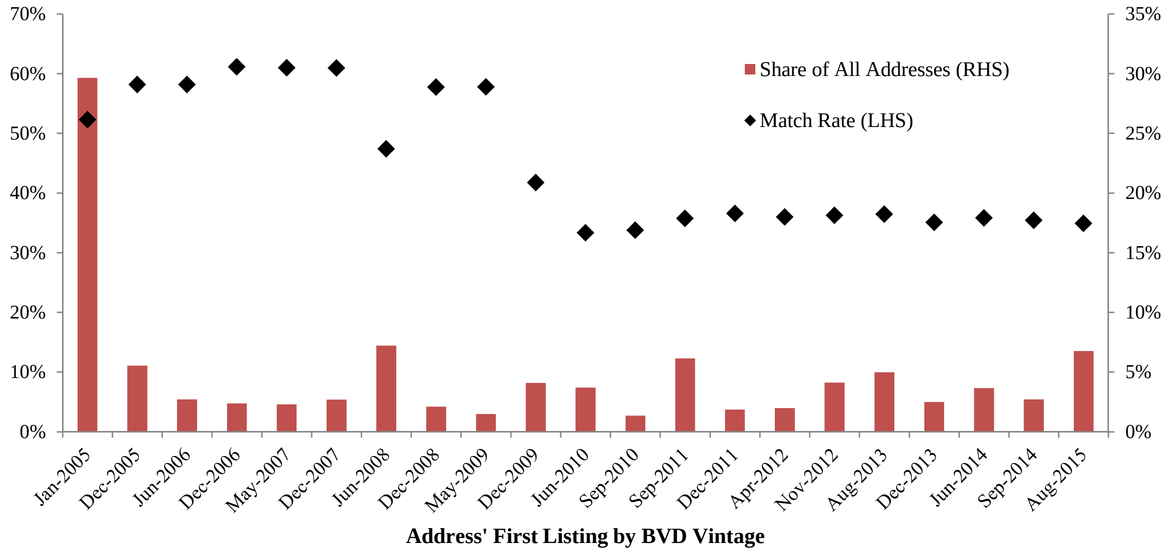
Of all the unique director addresses located in England, Wales, and Scotland listed in Bureau van Dijk, 47% can be matched to at least one transaction in either Land Registry. The figure for addresses located in England and Wales is 48%, the figure for addresses in Scotland is 35%. The lower match rate 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 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 for addresses based upon the vintage of the BvD database when the address is first listed as well as the share of addresses that enter the database at each 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 below 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%.

As discussed below, we can also obtain an estimate of the value of a director's house through matching director-address pairs to mortgage data. This allows us to match the house value of directors whose properties have not transacted since the start of our Land Registries, but have taken out a new mortgage, for example, a remortgage. Including this additional source of information increases the match rate. The match rate is also higher when we focus on directors who have a current job at a live company, which ensures that address information is kept up to date. Using the Land Registries and mortgage dataset, and focusing on directors with current jobs at live companies, the match rate rises to 58% during the period of our regression sample from 2002-2014. When we further restrict ourselves to the directors of the companies that appear in our regression sample, this match rate rises to 65%.

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.

C.3.1 Manual Tests on the Matching Algorithm

As we only succeed in matching roughly half of directors' addresses to the Land Registries, it is informative to ask what the cause is when our methodology fails to match an address. To explore this, we randomly selected 100 unmatched unique addresses from the September 2010[54] BvD vintage and manually assessed the reason for the failed matches. 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.[55] 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

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

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

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).

C.3.2 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 firm directors had to be entered on the public registrar of companies held at Companies House. This address would be published in their firm's accounts and this forms the source of our data on addresses.

From April 2nd 2002,[56] 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 firm 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 Companies House and they estimated that less than 1% of directors are beneficiaries of a confidentiality order at any given date.

A more material change in UK law on the 1st October 2009[57] meant that all directors had the option of having a service address displayed publicly rather than their usual residential address after this date. Usual residential addresses are still required alongside service addresses but the former are kept confidential at the director's request. This is the source of the decline in the match rate seen in Figure 6 after the May 2009 vintage of BvD: directors started reporting service addresses, which are

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

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

commercial and not in the Land Registry, rather than their residential addresses. However, 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 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 the director 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).

For the purpose of our analysis, this legal change has little impact since we fix both the composition of directors and their houses in 2002. Only directors who move or are appointed (for the first time) after 2009 are affected by this change in the law but this variation is not included in our analysis. However, to be completely sure this is not distorting our results, in Table 24 we rerun our baseline specification excluding observations after 2008. The coefficient on residential real estate is still highly significant, and the point estimate is larger.

C.4 Using Transactions to Value a Director's Home Address

C.4.1 Determining the Dates a Director Lives at a Property

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 to determine which 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 7 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.

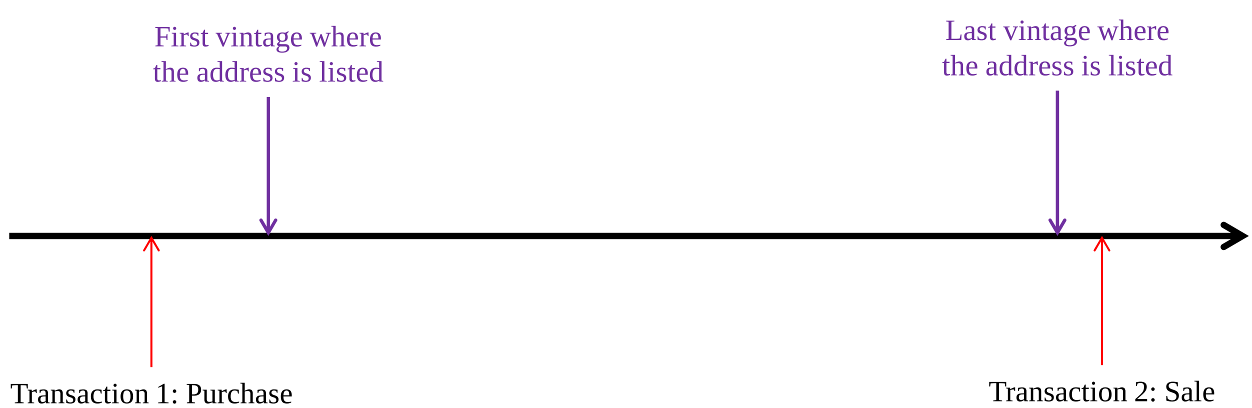
Table 24: Firm Investment and the Real Estate Channels: Excluding Observations After 2008

	Investment	
	Baseline	
	2002-2014	2002-2008
	(1)	(2)
Residential RE	0.0298***	0.0422***
	(0.011)	(0.014)
Corporate RE	0.0511***	0.0262
	(0.017)	(0.027)
Cash	0.0777***	0.0961***
	(0.012)	(0.019)
Profits	0.1092***	0.0889***
	(0.016)	(0.024)
Observations	32244	18958
Adjusted R^2	0.25	0.27
Add. Firm, Dir. Controls	Yes	Yes
Region-time FE	Yes	Yes
Industry-time FE	Yes	Yes
Firm FE	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 real estate, corporate real estate, and firm investment. The sample covers reporting UK firms over the period 2002-2014. The dependent variable, Investment, is defined as the change in "Fixed Assets" less "Depreciation". Residential RE is the total value of residential property held by directors of the firm, holding the composition of directors and their properties fixed in 2002, updating the value through time with changes in their respective regional house price indices, as defined in Equation 3.2. Corporate RE is the 2002 book value of firm Land and Buildings iterated forward using the regional house price index, as defined in Equation 3.1. Cash and Profits enter with a lag. All of these variables are scaled by the lag of firm turnover. Add. Firm. Dir. Controls comprises of quintiles for firm and director characteristics in 2002 interacted with the house price index in the firm region; the firm's regional house price index; and the inverse of lagged "Turnover" (see Section 4). All ratios are winsorized at the median ± 5 times the interquartile range. Standard errors, clustered by firm region, in parentheses. Column (1) is the baseline regression including all controls and fixed effects. Column (2) runs the baseline regression from 2002-2008.

Figure 7: Time line for dating director property transactions: simple case



There may be a "Transaction 0" in the registry, which corresponds to the person who the director bought the property from in 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.

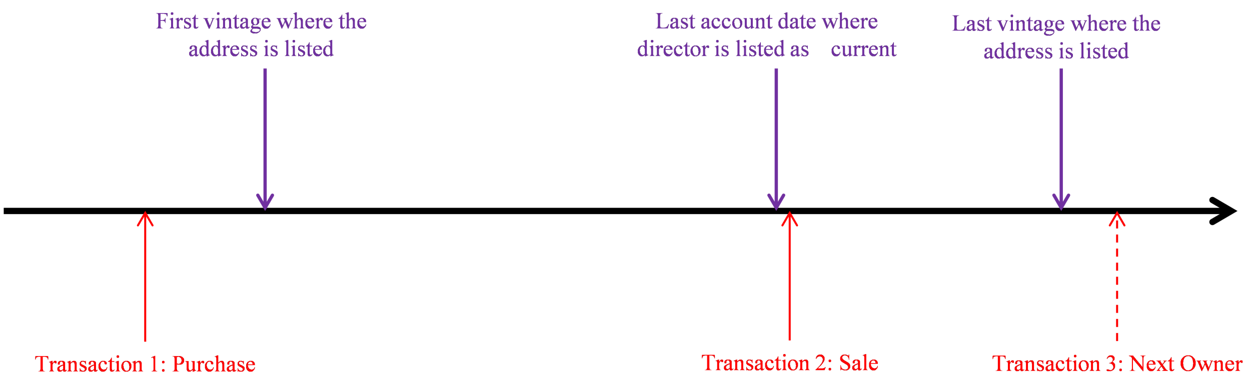
The other 19.7% of cases where there is an intermediate transaction can largely be explained by lags in reporting. BvD retains directors in the database after they have resigned (whether the director is currently at the company or has resigned is a field within our data) but firms have no obligation to keep the address information up to date for directors who are no longer present. This means that the last vintage of BvD where the director's address is listed is not an accurate depiction of when the director left the property.

Figure 8 provides a second time line detailing how this issue can emerge and how we address it. In this case, 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 has a current role at the company.[58] This accounts for an additional 11.6% of addresses. As a final step, we also extend the window to include transactions that occur a year prior to the final account date where the director has a current role to allow for lags in the director 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 a firm where the director's

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

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



role is current, i.e. the addresses predate the dataset. So it is not surprising that the transaction information does not align.

C.4.2 Calculating the Value of Real Estate Held by a Director

We next value the real estate held by a director. Where a director's address has been matched to one of the Land Registries, we have an estimated purchase and/or sale date, with corresponding purchase/sale prices. In addition, the director-address pair may be matched to the PSD mortgage database, as described in Online Appendix D. This mortgage activity could correspond to the director buying the house, or a subsequent remortgaging.

We use the house price index in the director's region to value the house outside of transaction/mortgaging dates. We pick a reference house value and date, and simply use the house price index to value the property at other dates. In the first instance our preference is to use transaction data for the reference value, as this records the actual transacted price for the house, in contrast to the PSD, where the value of the house associated with a remortgage will be an estimated value. Where we observe both a purchase and sale price for a director's house, we use the purchase price as this will be independent of the director's subsequent behaviour.

This method uniquely values all the matched director properties at all dates in our dataset. To avoid simultaneously counting the value of all properties a director has lived in at different times, we set the value of each director-address pair to 0 outside of the estimated dates they lived at the property. This allows us to accurately measure the value of real-estate owned by a director through

Table 25: Characteristics of Matched and Unmatched Directors

	Mean		Median		25%tile		75%tile	
Variable	Matched (M)	Unmatched (U)	M	U	M	U	M	U
Director Age (Years)	47.37	52.13	46.32	52.75	39.73	44.40	54.33	60.13
Male Directors	0.695	0.641	1	1	0	0	1	1
Non-UK Directors	0.0594	0.129	0	0	0	0	0	0
Experience (Years)	7.063	6.844	5.583	5.333	2.833	2.750	9.917	9.667
No. Industries Worked In	1.500	1.376	1	1	1	1	2	2
Firms with at Birth	0.878	0.651	1	1	0	0	1	1
Firms that have Failed	0.378	0.263	0	0	0	0	1	0

Notes: The statistics are calculated for the directors of all live companies in England, Wales, and Scotland over the period 2002-2014. *Matched* refers to directors whose address we are able to value through matching to either the Land Registries or the Product Sales Database. *Unmatched* refers to directors whose address we are not able to value. Director variables are defined in Online Appendix B. All variables except Male Directors and Non-UK Directors are truncated at the 5/95% levels.

time, including capturing house moves. For each director we then sum across the value of all matched addresses at each date to calculate the total value of real estate held through time.

C.5 Characteristics of Matched and Unmatched Directors

We next turn to the question of whether there is a significant difference between the characteristics of the directors whose houses we are able to value from those we are not. Table 25 presents summary statistics for a number of director characteristics broken down into directors whose address we can value by matching to either the Land Registries or the Product Sales Database and those we cannot. In general, the characteristics of the two groups are similar, with a few differences. First, directors with unmatched houses tend to be older, with both the mean and median unmatched director being around five years older. This is likely because older directors are less likely to have moved house within the period of our transactions databases, and so we are unable to pick up a housing transaction for their address. Second, non-UK nationals are less likely to be matched. This is unsurprising as they are more likely to live abroad, and we are only able to match UK addresses. Finally, directors with matched addresses tend to be slightly more experienced. This is likely because more experienced directors will list their address across a greater number of our vintages and across a greater number of companies, reducing the impact of typos in listing their address, and improving our chances of a match.

D Computing Housing Equity

This section explains how we estimate the housing equity held by directors, using transaction data and mortgage data.

D.1 Matching Company Directors with Mortgage Contracts

The first step in calculating director home equity is to merge the directors in the BvD database with a loan level database, known as the Product Sales Database (PSD), which covers the universe of regulated mortgage originations in the UK since April 2005. 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 company directors from BvD with the mortgage contracts they signed. We then look at the details of each mortgage contract and, from it, we compute the dynamics of mortgage principal of each company director who has ever had a mortgage in our sample.

D.1.1 The Product Sales Database

The PSD contains information on the characteristics of mortgage contracts at origination, covering more than 10,000,000 contracts. The database contains information on the loan size, date of origination, the valuation of the property, the type (fixed or 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, and the type of borrower (remortgagor with or without equity extraction, mover or first-time buyer).

Missing Interest Rate Values Around 32% of mortgage contracts do no report interest rates in the PSD database. Given that we have virtually full coverage on other contract characteristics, we estimate an interest rate model in the spirit of Best et al. (2015) and use the estimated parameters for out-of-sample prediction to fill in the missing interest rate values. The interest rate is modelled as follows:

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

where r_i is the mortgage rate for individual i. LTV_i is a vector of dummies, each corresponding to 0.25%-point LTV bins, 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 D.1, we use the estimates to fill in the missing interest rate values via out-of-sample forecasting. We winsorize the fitted values at 0%-points and 15%-points. For the remaining missing interest rate values (because of missing values for some of the RHS variables in D.1) we use the 2-year 75% LTV mortgage rate at the time of origination.[59]

D.1.2 Mortgage Principal Calculation

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 fixed monthly repayment M can be written as, at month k since origination:

$$
P_k = (1+i)^k L - \left[1 + (1+i) + (1+i)^2 + \cdots + (1+i)^{k-1}\right] M, \tag{D.2}
$$

where the polynomial can be simplified as $1 + (1+i) + (1+i)^2 + \cdots + (1+i)^{k-1} = \frac{(1+i)^k - 1}{i}$. The monthly repayment M is calculated by setting the principal in the final period (N) to zero:

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

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

Substituting D.3 into D.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 principal k periods after origination can be written as[60]:

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

D.2 Calculating Residential Equity

For the England & Wales Land Registry we have a variable that indicates, for the period 2002-2014, whether a property was bought with a mortgage or not. We combine this information with mortgage information from the PSD and information on the house value to estimate the equity a director has in their house. In calculating this, we take the first available observation on home equity for a director, and calculate the evolution of home equity assuming no future remortgaging activity. This is to avoid potential endogeneity issues that may arise from subsequent mortgage decisions being correlated with firm performance.

Where the Land Registry dataset indicates that the director's property was bought without a mortgage, and any matched mortgage contract for the director-address pair in the PSD occurs after the month of purchase, the director's principal is calculated as 0 for all dates. In this case the property is bought without a mortgage, and we abstract from the subsequent mortgage activity, which could be endogenous to firm behaviour, e.g. if the director remortgages their property to inject equity into their firm. In all other cases we apply Equation D.4 to the first observable mortgage contract of the

[60]In practice, formula D.4 together with the interest rate i are applied to compute monthly payments for mortgages whose terms are typically much longer than the initial period to which the fixed interest rate applies. In the UK, 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.

In light of this, we also experimented with an alternative method of calculating principal, whereby we used all subsequent information (following the first observable mortgage decision) available to us. This includes all additional remortgaging decisions in the *flow* of mortgages (PSD 001), and we also used data on the *stock* of mortgages (PSD 007), which covers the outstanding stock of regulated residential mortgages at a point in time (we used H2 2015 as it is the first available vintage of this dataset). In effect, we aimed at computing principal and equity dynamics that have the highest possible degree of accuracy, often making use of information contained in the stock of mortgages as of 2015. When using this alternative method, we did not find any material difference in the investment sensitivity of firms to residential home equity values. These results are available upon request.

director in the PSD, ignoring information contained in subsequent remortgaging decisions.

Our measure of residential equity for firm i at time t is then computed as

$$Residential\ Equity_{i,t} = \frac{N_i}{(\widehat{N_i})} \sum_{d=1}^{\widehat{N_i}} \left(L^d_{i.t} - P^d_{i,t} \right), \tag{D.5}$$

where $L^d_{i.t}$ is the home value of director d at firm i at time t, calculated as described in Online Appendix C.4.2; $P^d_{i,t}$ is the mortgage principal for director d at firm i at time t, as described above; N_i is the number of directors in firm i, and $\widehat{N_i}$ is the number of directors in firm i whose home equity we can calculate.

E Model

E.1 The Full Model

The model builds on previous models with corporate collateral constraints as in Kiyotaki and Moore (1997), Liu et al. (2013), Pinter (2015) and Liu et al. (2016), and models with household collateral constraints 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 et al. (2013), Pinter (2015) and Liu et al. (2016).

E.1.1 Household

The representative household maximises the utility function:

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

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:

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

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:

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

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:

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

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:

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

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.

E.1.2 Entrepreneur

The entrepreneur's utility function is written as:

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

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):

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

where $\alpha \in (0, 1)$ and $\kappa \in (0, 1)$ 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:

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

and the transitory component follows the stochastic process:

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

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:

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

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:

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

where B_{t-1} is the amount of matured entrepreneurial debt and B_t/R_t is the value of new debt. Following Greenwood et al. (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:

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

and the transitory component follows the stochastic process:

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

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:

$$B_t \leq \theta_t \mathbb{E}_t \left[q_{l,t+1} \left(\omega_1 L_{c,t} + \omega_2 L_{r,t} \right) + \omega_3 q_{k,t+1} K_t \right], \tag{E.14}$$

where $q_{k,t+1}$ is the shadow value of capital in consumption units, also referred to as Tobin's q, and ω parameters capture the pledgeability of the assets. The credit constraint E.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 a shock to the collateral constraint (Jermann and Quadrini (2012)) which is written as:

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

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.

E.1.3 Market Clearing

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

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

The land market clearing condition implies:

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

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

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

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.

E.2 Stationary Equilibrium

We transform the trending variables into their stationary counterparts (denoted by $\tilde{}$).[61]

E.2.1 Household

$$\begin{aligned}
\tilde{\lambda}_{h,t} &= \frac{1}{\tilde{C}_{h,t} - h_h \tilde{C}_{h,t-1}\Gamma_{t-1}/\Gamma_t} - \mathbb{E}_t \frac{\beta h_h}{\tilde{C}_{h,t+1}\Gamma_{t+1}/\Gamma_t - h_h \tilde{C}_{h,t}} \left(1 + \lambda_{a,t+1}\right) \\
\frac{1}{R_t} &= \beta \mathbb{E}_t \frac{\tilde{\lambda}_{h,t+1}}{\tilde{\lambda}_{h,t}} \frac{\Gamma_t}{\Gamma_{t+1}} \left(1 + \lambda_{a,t+1}\right) \\
\tilde{w}_t &= \frac{\psi_t}{\tilde{\lambda}_{h,t}} \\
\tilde{q}_{l,t} &= \beta \mathbb{E}_t \frac{\tilde{\lambda}_{h,t+1}}{\tilde{\lambda}_{h,t}} \left(1 + \lambda_{a,t+1}\right) \tilde{q}_{l,t+1} + \frac{\varphi_t}{\tilde{\lambda}_{h,t} L_{h,t}}.
\end{aligned} \tag{E.19}$$

E.2.2 Entrepreneur

$$\begin{aligned}
\tilde{\lambda}_{e,t} &= \frac{1}{\tilde{C}_{e,t} - h_e \tilde{C}_{e,t-1}\Gamma_{t-1}/\Gamma_t} - \mathbb{E}_t \frac{\beta h_e}{\tilde{C}_{e,t+1}\Gamma_{t+1}/\Gamma_t - h_e \tilde{C}_{e,t}} \\
\tilde{w}_t &= \left(1 - \alpha\right) \frac{\tilde{Y}_t}{N_t} \\
\frac{1}{R_t} &= \beta \mathbb{E}_t \frac{\tilde{\lambda}_{e,t+1}}{\tilde{\lambda}_{e,t}} \frac{\Gamma_t}{\Gamma_{t+1}} + \frac{\tilde{\mu}_{e,t}}{\tilde{\lambda}_{e,t}} \\
1 &= \tilde{q}_{k,t} \left[1 - \frac{\Omega}{2} \left(\frac{\tilde{I}_t}{\tilde{I}_{t-1}} \frac{Q_t \Gamma_t}{Q_{t-1}\Gamma_{t-1}} - \bar{\lambda}_I\right)^2 - \Omega \left(\frac{\tilde{I}_t}{\tilde{I}_{t-1}} \frac{Q_t \Gamma_t}{Q_{t-1}\Gamma_{t-1}} - \bar{\lambda}_I\right) \frac{\tilde{I}_t}{\tilde{I}_{t-1}} \frac{Q_t \Gamma_t}{Q_{t-1}\Gamma_{t-1}}\right] \\
&\quad + \Omega \beta \mathbb{E}_t \frac{\tilde{\lambda}_{e,t+1}}{\tilde{\lambda}_{e,t}} \frac{Q_t \Gamma_t}{Q_{t+1}\Gamma_{t+1}} \tilde{q}_{k,t+1} \left(\frac{\tilde{I}_{t+1}}{\tilde{I}_t} \frac{Q_{t+1}\Gamma_{t+1}}{Q_t \Gamma_t} - \bar{\lambda}_I\right) \left(\frac{\tilde{I}_{t+1}}{\tilde{I}_t} \frac{Q_{t+1}\Gamma_{t+1}}{Q_t \Gamma_t}\right)^2 \\
\tilde{K}_t &= \left(1 - \delta\right) \tilde{K}_{t-1} \frac{Q_t \Gamma_t}{Q_{t-1}\Gamma_{t-1}} + \left[1 - \frac{\Omega}{2} \left(\frac{\tilde{I}_t}{\tilde{I}_{t-1}} \frac{Q_t \Gamma_t}{Q_{t-1}\Gamma_{t-1}} - \bar{\lambda}_I\right)^2\right] \tilde{I}_t
\end{aligned} \tag{E.20}$$

$$\begin{aligned}
\tilde{q}_{k,t} &= \beta \mathbb{E}_t \frac{\tilde{\lambda}_{e,t+1}}{\tilde{\lambda}_{e,t}} \left[\alpha \left(1 - \kappa\right) \frac{\tilde{Y}_{t+1}}{\tilde{K}_t} + \tilde{q}_{k,t} \frac{Q_t \Gamma_t}{Q_{t+1}\Gamma_{t+1}} \left(1 - \delta\right)\right] + \frac{\tilde{\mu}_{e,t}}{\tilde{\lambda}_{e,t}} \mathbb{E}_t \theta_t \tilde{q}_{k,t+1} \omega_3 \frac{Q_t}{Q_{t+1}} \\
\tilde{q}_{l,t} &= \beta \mathbb{E}_t \frac{\tilde{\lambda}_{e,t+1}}{\tilde{\lambda}_{e,t}} \left[\alpha \kappa \frac{\tilde{Y}_{t+1}}{L_{c,t}} + \tilde{q}_{l,t+1}\right] + \frac{\tilde{\mu}_{e,t}}{\tilde{\lambda}_{e,t}} \mathbb{E}_t \theta_t \tilde{q}_{l,t+1} \omega_1 \frac{\Gamma_{t+1}}{\Gamma_t} \\
\tilde{q}_{l,t} &= \beta \mathbb{E}_t \frac{\tilde{\lambda}_{e,t+1}}{\tilde{\lambda}_{e,t}} \tilde{q}_{l,t+1} + \frac{\upsilon}{\tilde{\lambda}_{e,t} L_{r,t}} + \frac{\tilde{\mu}_{e,t}}{\tilde{\lambda}_{e,t}} \mathbb{E}_t \theta_t \tilde{q}_{l,t+1} \omega_2 \frac{\Gamma_{t+1}}{\Gamma_t}.
\end{aligned} \tag{E.21}$$

[61] See Liu et al. (2013) for further details.

E.2.3 The Rest of the Model

$$
\begin{aligned}
\tilde{Y}_t &= \left(\frac{Z_t Q_t}{Z_{t-1} Q_{t-1}}\right)^{-\frac{(1-\kappa)\alpha}{1-(1-\kappa)\alpha}} \left[\tilde{K}_{t-1}^{1-\kappa} L_{c,t-1}^{\kappa}\right]^{\alpha} N_t^{1-\alpha} \\
\tilde{Y}_t &= \tilde{C}_{h,t} + \tilde{C}_{e,t} + \tilde{I}_t \\
\bar{L} &= L_{h,t} + L_{c,t} + L_{r,t} \\
\tilde{B}_t &= \theta_t \mathbb{E}_t \left[\tilde{q}_{l,t+1} \left(\omega_1 L_{c,t} + \omega_2 L_{r,t}\right) \frac{\Gamma_{t+1}}{\Gamma_t} + \tilde{q}_{k,t+1} \omega_3 K_t \frac{Q_t}{Q_{t+1}}\right].
\end{aligned} \tag{E.22}
$$

E.3 Steady-state

Here we derive the model's steady-states. The interest rate and shadow prices are:

$$
\begin{aligned}
\frac{1}{R} &= \frac{\beta\left(1+\bar{\lambda}_a\right)}{g_\gamma} \\
\frac{\tilde{\mu}_e}{\tilde{\lambda}_e} &= \frac{\beta \bar{\lambda}_a}{g_\gamma}.
\end{aligned} \tag{E.23}
$$

The marginal utility of consumption of the two agents:

$$
\begin{aligned}
\tilde{\lambda}_h &= \frac{1}{\tilde{C}_h}\left[\frac{g_\gamma - \beta\left(1+\bar{\lambda}_a\right) h_h}{g_\gamma - h_h}\right] \\
\tilde{\lambda}_e &= \frac{1}{\tilde{C}_e}\left[\frac{g_\gamma - \beta h_e}{g_\gamma - h_e}\right].
\end{aligned} \tag{E.24}
$$

To get the ratio of commercial land to output, use the entrepreneur's commercial land Euler-equation and the definition E.23:

$$
\frac{\tilde{q}_l L_e}{\tilde{Y}} = \frac{\alpha\kappa\beta}{1-\beta-\beta\bar{\lambda}_a\omega_1\theta}. \tag{E.25}
$$

So the parameter κ is given by:

$$
\kappa = \frac{\frac{\tilde{q}_l L_e}{\tilde{Y}}\left(1-\beta-\beta\bar{\lambda}_a\omega_1\theta\right)}{\alpha\beta}, \tag{E.26}
$$

whereas the scale parameter α is given by capital demand:

$$\alpha = \frac{\frac{1-\frac{\tilde{\mu}_e}{\bar{\lambda}_e}\theta}{\beta/g_\gamma} - (1-\delta)}{g_\gamma(1-\phi)} \frac{\tilde{K}}{\tilde{Y}}. \tag{E.27}$$

Given the target values for the steady-state $\frac{\tilde{K}}{\tilde{Y}}$, $\frac{\tilde{q}_l L_c}{\tilde{Y}}$ and $\frac{\tilde{q}_l L_e}{\tilde{Y}}$, equations E.26–E.27 pin down κ and α. The steady-state investment-output ratio can be matched by choosing the appropriate value for δ:

$$\frac{\tilde{I}}{\tilde{K}} = 1 - \frac{1-\delta}{\lambda_k}. \tag{E.28}$$

Using the definition of the return on capital, the steady-state capital-output ratio is:

$$\frac{\tilde{K}}{\tilde{Y}} = \frac{\beta\left[\alpha(1-\kappa)\right]}{1 - \frac{\beta}{\lambda_k}\left[\bar{\lambda}_a\theta\omega_3 + (1-\delta)\right]}.$$

The investment-output ratio is:

$$\frac{\tilde{I}}{\tilde{Y}} = \frac{\tilde{I}}{\tilde{K}}\frac{\tilde{K}}{\tilde{Y}} = \frac{\beta\alpha(1-\phi)\left[1 - \frac{1-\delta}{\lambda_k}\right]}{1 - \frac{\beta}{\lambda_k}\left(\bar{\lambda}_a\theta\omega_3 + 1 - \delta\right)}. \tag{E.29}$$

The corporate debt to output ratio is:

$$\frac{B}{Y} = \theta g_\gamma \tilde{q}_l\left(\omega_1\frac{L_e}{\tilde{Y}} + \omega_2\frac{L_r}{\tilde{Y}}\right) + \omega_3\frac{\theta}{\bar{\lambda}_q}\frac{\tilde{K}}{\tilde{Y}}.$$

The entrepreneurial consumption to output ratio is:

$$\frac{\tilde{C}_e}{\tilde{Y}} = \alpha - \frac{\tilde{I}}{\tilde{Y}} - \frac{1-\beta\left(1+\bar{\lambda}_a\right)}{g_\gamma}\frac{\tilde{B}_e}{\tilde{Y}}. \tag{E.30}$$

The household consumption to output ratio is:

$$\frac{\tilde{C}_h}{\tilde{Y}} = 1 - \frac{\tilde{C}_e}{\tilde{Y}} - \frac{\tilde{I}}{\tilde{Y}}.$$

The preference parameter ν is given by:

$$\frac{\tilde{q}_l L_r}{\tilde{C}_e} = \frac{\nu(g_\gamma - h_e)}{g_\gamma(1-\beta h_e/g_\gamma)\left(1-\beta-\beta\bar{\lambda}_a\theta\omega_2\right)}. \tag{E.31}$$

The preference parameter φ_h is given by:

$$\frac{q_l L_h}{\tilde{C}_h} = \frac{\varphi_h (g_\gamma - h_h)}{g_\gamma (1 - g_\gamma/R)(1 - h_\gamma/R)}.$$

The relative land shares $\frac{L_h}{L_e}$ and $\frac{L_r}{L_e}$ are written as:

$$\begin{aligned}
\frac{L_h}{L_e} =& \frac{\varphi_h (g_\gamma - h_h)\left(1 - \beta - \beta\bar{\lambda}_a \theta\omega_1\right)}{g_\gamma \alpha\kappa\beta (1 - g_\gamma/R)(1 - h_\gamma/R)} \frac{\tilde{C}_h}{\tilde{Y}} \\
\frac{L_r}{L_e} =& \frac{\nu (g_\gamma - h_e)\left(1 - \beta - \beta\bar{\lambda}_a \theta\omega_1\right)}{g_\gamma \alpha\kappa\beta (1 - \beta h_e/g_\gamma)\left(1 - \beta - \beta\bar{\lambda}_a \theta\omega_2\right)} \frac{\tilde{C}_e}{\tilde{Y}}.
\end{aligned}$$

E.4 The Log-linearised System

Given the steady-states and the defined constants $\Omega_h \equiv \left(g_\gamma - \beta\left(1 + \bar{\lambda}_a\right) h_h\right)(g_\gamma - h_h)$ and $\Omega_e \equiv (g_\gamma - \beta h_e)(g_\gamma - h_e)$, the log-linearised first-order conditions are:

$$\begin{aligned}
\hat{\Omega}_h \hat{\lambda}_h =& - \left[g_\gamma^2 + h_h^2 \beta\left(1 + \bar{\lambda}_a\right)\right] \hat{C}_{h,t} + g_\gamma h_h \left(\hat{C}_{h,t-1} - \hat{g}_{\gamma,t}\right) \\
& - \beta\bar{\lambda}_a h_h (g_\gamma - h_h) \mathbb{E}_t \hat{\lambda}_{a,t+1} + \beta\left(1 + \bar{\lambda}_a\right) g_\gamma h_h \mathbb{E}_t \left(\hat{C}_{h,t+1} + \hat{g}_{\gamma,t+1}\right) \\
\hat{\Omega}_e \hat{\lambda}_e =& - \left[g_\gamma^2 + h_e^2 \beta\right] \hat{C}_{e,t} + g_\gamma h_e \left(\hat{C}_{e,t-1} - \hat{g}_{\gamma,t}\right) + \beta g_\gamma h_e \mathbb{E}_t \left(\hat{C}_{e,t+1} + \hat{g}_{\gamma,t+1}\right) \\
\hat{\lambda}_{e,t} - \hat{R}_t =& \frac{1}{1 + \bar{\lambda}_a}\left[\mathbb{E}_t\left(\hat{\lambda}_{e,t+1} - \hat{g}_{\gamma,t+1}\right) + \bar{\lambda}_a \hat{\mu}_{e,t}\right] \\
\hat{\lambda}_{h,t} - \hat{R}_t =& \mathbb{E}_t\left[\hat{\lambda}_{h,t+1} + \frac{\bar{\lambda}_a}{1 + \bar{\lambda}_a} \hat{\lambda}_{a,t+1} - \hat{g}_{\gamma,t+1}\right] \\
\hat{q}_{k,t} =& \Omega\lambda_k^2 \left[(1 + \beta)\hat{I}_t - \hat{I}_{t-1}\right] + \Omega\lambda_k^2 (\hat{g}_{q,t} + \hat{g}_{\gamma,t}) - \beta\Omega\lambda_k^2 \mathbb{E}_t\left[\hat{I}_{t+1} + \hat{g}_{q,t+1} + \hat{g}_{\gamma,t+1}\right] \\
\hat{q}_{l,t} + \hat{\lambda}_{h,t} =& \beta\left(1 + \bar{\lambda}_a\right) \mathbb{E}_t\left(\hat{\lambda}_{h,t+1} + \hat{q}_{l,t+1}\right) + \left[1 - \beta\left(1 + \bar{\lambda}_a\right)\right]\left(\hat{\varphi}_t - \hat{L}_{h,t}\right) + \beta\bar{\lambda}_a \mathbb{E}_t \hat{\lambda}_{a,t+1} \\
\hat{w}_t + \hat{\lambda}_{h,t} =& \hat{\psi}_t \\
\hat{w}_t + \hat{N}_t =& \hat{Y}_t
\end{aligned} \tag{E.32}$$

$$
\begin{aligned}
\hat{q}_{l,t} + \hat{\lambda}_{e,t} &= \beta \mathbb{E}_t \left(\hat{\lambda}_{e,t+1} + \hat{q}_{l,t+1} \right) + \left[1 - \beta \left(1 + \bar{\lambda}_a \right) \right] \left(\hat{\varphi}_t - \hat{L}_{r,t} \right) \\
\hat{q}_{l,t} + \hat{\lambda}_{e,t} &= \beta \mathbb{E}_t \left(\hat{q}_{l,t+1} + \hat{\lambda}_{e,t+1} \right) + \frac{\tilde{\mu}_e}{\tilde{\lambda}_e} \theta \omega_2 g_\gamma \left(\hat{\mu}_{e,t} + \hat{\theta}_t + \hat{q}_{l,t+1} + \hat{g}_{\gamma,t+1} \right) \\
&\quad + \left(1 - \beta - \beta \bar{\lambda}_a \theta \omega_2 \right) \mathbb{E}_t \left[-\hat{L}_{r,t} \right] \\
\hat{q}_{l,t} + \hat{\lambda}_{e,t} &= \frac{\tilde{\mu}_e}{\tilde{\lambda}_e} \theta \omega_1 g_\gamma \mathbb{E}_t \left(\hat{\mu}_{e,t} + \hat{\theta}_t + \hat{q}_{l,t+1} + \hat{g}_{\gamma,t+1} \right) + \left(1 - \frac{\tilde{\mu}_e}{\tilde{\lambda}_e} g_\gamma \theta \omega_1 \right) \mathbb{E}_t \hat{\lambda}_{e,t+1} \\
&\quad + \beta \mathbb{E}_t \hat{q}_{l,t+1} + \left(1 - \beta - \beta \bar{\lambda}_a \theta \omega_1 \right) \mathbb{E}_t \left[\hat{Y}_{t+1} - \hat{L}_{e,t} \right] \\
\hat{q}_{k,t} + \hat{\lambda}_{e,t} &= \frac{\tilde{\mu}_e}{\tilde{\lambda}_e} \frac{\theta}{\bar{\lambda}_q} \omega_3 \mathbb{E}_t \left(\hat{\mu}_{e,t} + \hat{\theta}_t + \hat{q}_{k,t+1} - \hat{g}_{\gamma,t+1} \right) + \frac{\beta (1-\delta)}{\lambda_k} \mathbb{E}_t \left(\hat{q}_{k,t+1} - \hat{g}_{q,t+1} - \hat{g}_{\gamma,t+1} \right) \\
&\quad + \left(1 - \frac{\tilde{\mu}_e}{\tilde{\lambda}_e} \frac{\theta}{\bar{\lambda}_q} \omega_3 \right) \mathbb{E}_t \hat{\lambda}_{e,t+1} + \beta \alpha (1-\kappa) \frac{\tilde{Y}}{\tilde{K}} \mathbb{E}_t \left(\hat{Y}_{t+1} - \hat{K}_t \right).
\end{aligned} \tag{E.33}
$$

The log-linearised equations for the rest of the model:

$$
\begin{aligned}
\hat{Y}_t &= \alpha \kappa \hat{L}_{e,t-1} + \alpha (1-\kappa) \hat{K}_{t-1} + (1-\alpha) \hat{N}_t - \frac{(1-\kappa)\alpha}{1-(1-\kappa)\alpha} \left[\hat{g}_{z,t} + \hat{g}_{q,t} \right] \\
\hat{K}_t &= \frac{1-\delta}{\lambda_k} \left[\hat{K}_{t-1} - \hat{g}_{\gamma,t} - \hat{g}_{q,t} \right] + \left(1 - \frac{1-\delta}{\lambda_k} \right) \hat{I}_t \\
\hat{Y}_t &= \frac{\tilde{C}_h}{\tilde{Y}} \hat{C}_{h,t} + \frac{\tilde{C}_e}{\tilde{Y}} \hat{C}_{e,t} + \frac{\tilde{I}}{\tilde{Y}} \hat{I}_t \\
0 &= \frac{L_h}{\bar{L}} \hat{L}_{h,t} + \frac{L_e}{\bar{L}} \hat{L}_{e,t} + \frac{L_r}{\bar{L}} \hat{L}_{r,t} \\
\alpha \hat{Y}_t &= \frac{\tilde{C}_e}{\tilde{Y}} \hat{C}_{e,t} + \frac{\tilde{I}}{\tilde{Y}} \hat{I}_t + \frac{\tilde{q}_l L_e}{\tilde{Y}} \left(\hat{L}_{e,t} - \tilde{L}_{e,t-1} \right) + \frac{\tilde{q}_l L_r}{\tilde{Y}} \left(\hat{L}_{r,t} - \tilde{L}_{r,t-1} \right) \\
&\quad + \frac{1}{g_\gamma} \frac{\tilde{B}}{\tilde{Y}} \left(\hat{B}_{t-1} - \hat{g}_{\gamma,t} \right) - \frac{1}{R} \frac{\tilde{B}}{\tilde{Y}} \left(\hat{B}_t - \hat{R}_t \right) \\
\hat{B}_t &= \hat{\theta}_t + \theta \frac{\tilde{q}_l L_c}{B} \omega_1 g_\gamma \left(\hat{q}_{l,t+1} + \hat{L}_{c,t} + \hat{g}_{\gamma,t} \right) \\
&\quad + \theta \frac{\tilde{q}_l L_r}{B} \omega_2 g_\gamma \left(\hat{q}_{l,t+1} + \hat{L}_{r,t} + \hat{g}_{\gamma,t} \right) \\
&\quad + \left(1 - \theta \frac{\tilde{q}_l g_\gamma}{B} \left(\omega_1 L_c + \omega_2 L_r \right) \right) \left(\hat{q}_{k,t+1} + \hat{K}_t + \hat{g}_{q,t} \right).
\end{aligned} \tag{E.34}
$$

The terms $\hat{g}_{z,t}$, $\hat{g}_{q,t}$ and $\hat{g}_{\gamma,t}$ are given by:

$$\hat{g}_{z,t} = \hat{\lambda}_{z,t} + \hat{\nu}_{z,t} - \hat{\nu}_{z,t-1}$$
$$\hat{g}_{q,t} = \hat{\lambda}_{q,t} + \hat{\nu}_{q,t} - \hat{\nu}_{q,t-1} \tag{E.35}$$
$$\hat{g}_{\gamma,t} = \frac{1}{1-(1-\kappa)\,\alpha}\hat{g}_{z,t} + \frac{(1-\kappa)\,\alpha}{1-(1-\kappa)\,\alpha}\hat{g}_{q,t}.$$

The technology shocks follow the processes:

$$\hat{\lambda}_{z,t} = \rho_z \hat{\lambda}_{z,t-1} + \hat{\varepsilon}_{z,t}$$
$$\hat{\lambda}_{q,t} = \rho_q \hat{\lambda}_{q,t-1} + \hat{\varepsilon}_{q,t} \tag{E.36}$$
$$\hat{\nu}_{z,t} = \rho_{\nu_z} \hat{\nu}_{z,t-1} + \hat{\varepsilon}_{\nu_z,t}$$
$$\hat{\nu}_{q,t} = \rho_{\nu_q} \hat{\nu}_{q,t-1} + \hat{\varepsilon}_{\nu_q,t}.$$

The other shocks follow the processes:

$$\hat{\varphi}_t = \rho_\varphi \hat{\varphi}_{t-1} + \hat{\varepsilon}_{\varphi,t}$$
$$\hat{\psi}_t = \rho_\psi \hat{\psi}_{t-1} + \hat{\varepsilon}_{\psi,t} \tag{E.37}$$
$$\hat{\theta}_t = \rho_\theta \hat{\theta}_{t-1} + \hat{\varepsilon}_{\theta,t}$$
$$\hat{\lambda}_{a,t} = \rho_a \hat{\lambda}_{a,t-1} + \hat{\varepsilon}_{a,t}.$$

E.5 Model Estimation

E.5.1 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.

E.5.2 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 $(K/Y) = 3.91$. 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. Government purchases are excluded from the ratio. The entrepreneur's subjective discount rate β is set to deliver this ratio.

Investment to capital ratio $(I/K) = 0.045$**.** Capital is defined as above. Investment is defined as total economy gross fixed capital formation. Government purchases are excluded from the ratio. The depreciation rate δ is set to deliver this ratio.

Entrepreneurial land to output ratio $q_l L_c/Y = 2.31$. Corporate land is defined as the total economy dwellings plus total economy buildings other than dwellings less dwellings owned by the household and government sectors. Output is defined as above. The production scale parameter κ is set to deliver this ratio.

Residential land to output ratio $q_l(L_h + L_r)/Y = 10.68$. Residential land is defined as the total value of dwellings owned by the household sector. Output is defined as above. The utility scale parameter $\bar{\varphi}$ is set to deliver this ratio.

Entrepreneurial share of residential land $L_r/(L_h + L_r) = 0.25$ which is set following the discussion in Section 6. The utility scale parameter ν is set to deliver this ratio.

Loan to value ratio $\theta = 0.78$**.** We define the total value of corporate debt as the loan and debt security liabilities of the non-financial corporate sector. As the denominator, we use total fixed assets of the non-financial corporate sector.

E.5.3 Estimated Model Parameters

Table 26 summarises the results from the Bayesian estimation of the model. A system of measurement equations links the observables, defined in Subsection E.5.1 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 100,000 random draws to approximate the shape of the posterior distributions.

Table 26: MCMC Results: Prior and Posterior Distributions of Structural Parameters

Parameter	Prior			Posterior		
	Distribution	$\underline{a}$	$\underline{b}$	Median	Low	High
h_h	Beta(a,b)	1.00	2.00	0.0394	0.0000	0.0762
h_e	Beta(a,b)	1.00	2.00	0.5228	0.1428	0.7715
Ω	Gamma(a,b)	1.00	0.50	0.2561	0.2103	0.2991
$100\,(g_\gamma - 1)$	Gamma(a,b)	1.86	3.01	0.1874	0.0212	0.3795
$100\left(\bar{\lambda}_q - 1\right)$	Gamma(a,b)	1.86	3.01	0.1652	0.0494	0.3043
ρ_z	Beta(a,b)	1.00	2.00	0.5589	0.3821	0.7160
ρ_{ν_z}	Beta(a,b)	1.00	2.00	0.1849	0.0000	0.4093
ρ_q	Beta(a,b)	1.00	2.00	0.3730	0.0000	0.6535
ρ_{ν_q}	Beta(a,b)	1.00	2.00	0.0355	0.0000	0.1118
ρ_φ	Beta(a,b)	1.00	2.00	0.9998	0.9998	0.9998
ρ_a	Beta(a,b)	1.00	2.00	0.8611	0.8323	0.8884
ρ_θ	Beta(a,b)	1.00	2.00	0.9811	0.9763	0.9859
ρ_ψ	Beta(a,b)	1.00	2.00	0.9842	0.9787	0.9902
ω_3	Gamma(a,b)	1.00	1.00	0.6683	0.5750	0.7559
σ_z	Inv-Gam(a,b)	0.3261	1.45e-04	0.0069	0.0052	0.0087
σ_{ν_z}	Inv-Gam(a,b)	0.3261	1.45e-04	0.0062	0.0048	0.0076
σ_q	Inv-Gam(a,b)	0.3261	1.45e-04	0.0077	0.0045	0.0125
σ_{ν_q}	Inv-Gam(a,b)	0.3261	1.45e-04	0.0099	0.0073	0.0120
σ_φ	Inv-Gam(a,b)	0.3261	1.45e-04	0.0517	0.0457	0.0585
σ_a	Inv-Gam(a,b)	0.3261	1.45e-04	0.1287	0.0906	0.1675
σ_θ	Inv-Gam(a,b)	0.3261	1.45e-04	0.0149	0.0130	0.0164
σ_ψ	Inv-Gam(a,b)	0.3261	1.45e-04	0.0076	0.0068	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 100,000 MCMC chains from the posterior simulation.