The Residential Collateral Channel

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Abstract

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

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1 Introduction

The Great Recession has highlighted strong links between house prices, credit and the real economy. One of the theories to explain these links is the collateral channel: movements in real estate prices change the value of the collateral that determines economic agents' borrowing capacity. This affects the investment and spending decisions of firms as well as households. Figure 1 suggests that the mechanism is present in aggregate time series data.

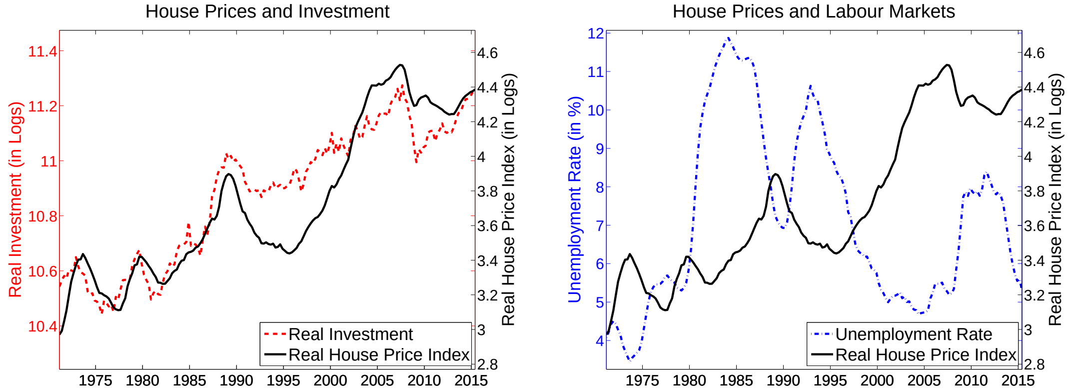
There are several possible channels through which real estate collateral may affect the economy, with a stylised representation presented in Figure 2. First, as shown in the bottom panel, an increase in the value of houses can enable the owners to extract equity to fuel consumption (e.g. Mian and Sufi (2011)). Second, as shown in light blue at the top of the figure, an increase in the value of commercial properties can enable increased corporate borrowing to fund investment (e.g. Chaney, Sraer, and Thesmar (2012)) and wages. We refer to this as the *corporate* collateral channel. However, one cannot divide the mechanisms by which residential and corporate real estate affect firm activity so starkly. The owners of companies are households. And residential collateral may be used to support ongoing firm activity by unlocking the wealth held in director's homes. This hitherto unexplored channel, which we refer to as the *residential* collateral channel, is highlighted in light red in Figure 2.

We have two main sets of empirical findings based on a sample of UK firms covering the 2002-2012 period. The first set of results is on the corporate collateral channel: a £1 increase in corporate collateral values leads firms to increase investment by around £0.09 and total wage costs by around £0.04. These findings are of comparable magnitude to the US evidence based on public firms (Chaney, Sraer, and Thesmar, 2012). The second set of results is on the residential collateral channel: a £1 increase in the total value of the homes of company directors causes the average firm in our sample to increase investment and total wages by around £0.02. To the best of our knowledge, our evidence related to the residential collateral channel is entirely novel.

This unexplored channel may have important aggregate effects. The median firm in the UK has corporate collateral worth 6% of turnover. By contrast, the directors of the median firm have residential property which between them is worth around 20% of annual turnover. In our sample the median firm has around 50 employees. In the UK, such small firms along with start-ups were responsible for 66% of jobs created from 1998 to 2010 (Michael Anyadike-Danes and Hart (2011)). Firms with less than 50 employees have been the most important determinant of aggregate employment growth over 2008-2015, and were responsible for 50% of the fall in aggregate UK investment across 2009 and 2010.[1] Moreover, we estimate that the value of residential real estate held by company directors (£1,100 Billion) is around 4 times larger than the value of commercial property held by owner-occupying firms (£280 Billion), suggesting that

[1]These estimates are produced using microdata from the Office of National Statistics, specifically, the Business Structure Database and the Annual Business Survey.

Figure 1: Real House Prices and the UK Business Cycle



Notes: House price index is from Nationwide, investment (total GFCF) and unemployment data are from the ONS.

the residential collateral channel may have an important macroeconomic impact.[2]

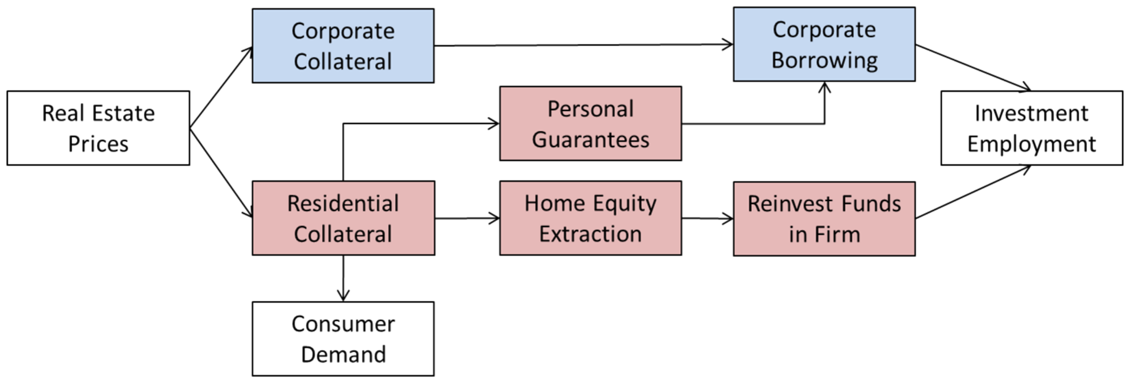
Yet the existing literature provides little empirical evidence on the relative strength of the residential and corporate collateral channels affecting firm behaviour. Our paper is able to fill this gap by using a unique combination of UK datasets including firm-level accounting data matched with loan-level residential mortgage data and transaction-level house price data. This allows us to identify whether real estate price shocks propagate into corporate activity via corporate collateral (highlighted in blue in Figure 2) or via household collateral (highlighted in red in Figure 2). One of our contributions is to use archival firm-level data which provides unrivaled data coverage compared to the existing literature and is a necessity for measuring residential collateral.

To arrive at the first set of estimates, on the corporate collateral channel, we use variations in regional land prices, across 172 local authorities in England and Wales, as shocks to the collateral value of land-holding firms. Using firm-level accounting data, we measure how a firm's investment and employment decisions react to an increase in the value of real estate owned. Building on the recent corporate finance literature, we use two sources of variation. Within regions, we rely on differences in the initial levels of corporate collateral across firms and between regions we exploit differences in the evolution of real estate prices. Our dataset provides the full postcode of all trading addresses for each firm, allowing us to focus on firms trading exclusively within one of our 172 regions, enabling precise estimation of the corporate collateral channel.

In this type of regression design, endogeneity problems may arise because unobserved factors such as regional demand shocks may cause firms' financing decisions to be correlated with (i) regional real estate prices and with (ii) firms' decision to own real estate. To address the former problem, we use region-time fixed effects to control for time-varying, region-specific unobserved factors. To address the latter problem, we control for a set of observables that may capture the

[2]The methodology to estimate the value of director's residential collateral is explained in Section 6, whilst the estimated value of commercial property comes from IPF (2014).

Figure 2: Real Estate Collateral Channels



determinants of firms' land-holding decisions. A further potential endogeneity problem is that some firms may be sufficiently large to affect local real estate prices when they invest, giving rise to reverse causality. Whilst this may be less of a concern in our case, with our focus on firms which trade exclusively within one of the 172 regions, we nevertheless also present our results following the IV strategy adopted by Mian and Sufi (2011) amongst others. More specifically, we instrument local authority level house prices by interacting geographical constraints on housing supply from Hilber and Vermeulen (2016) with shifts in the nationwide average mortgage interest rate. Changes in aggregate interest rates will have a greater effect on real estate prices in areas with more inelastic housing supply, providing a shock to local corporate collateral values unrelated to local firm activity.

To arrive at the second set of estimates, on the residential collateral channel, we merge our firm-level dataset with transaction-level residential property sales data in order to measure the value of collateral available to company directors in the form of their homes. This merger is possible because company directors by UK law have to report their usual residential addresses. By matching this address with our transactions database we can determine the price at which the director bought their property before using regional house price indices to iterate the property valuation to the time when the company's accounts were filed. Given this measure, we can then trace the impact of changes in residential property values on corporate activity through the residential collateral channel. We can also observe how changes in the value of directors' residential collateral influence the financing of their company. This can be through insider financing via director loans and equity issuance paid for by the directors extracting equity from their homes. Alternatively, the directors can use their homes to personally guarantee bank debt allowing the firm to seek more external financing.

The use of residential collateral is not confined to small firms. Banks like to have commercial loans secured at least in part by the director's residential collateral as it provides a more liquid source of collateral than commercial real estate, and aligns incentives through piercing the corporate veil. For this latter reason, the two types of collateral may complement each other. A recent unpublished Bank of England survey of major lenders highlights the importance of both sources of collateral for firm activity, finding that 68% of lending to SMEs and mid-size corporations[3] (by volume) is secured on property with 34%[4] of lending secured with a personal guarantee, typically with an explicit or implicit claim against their residential property.[5] Whilst personal guarantees are more prevalent for smaller firms, 26% of larger firms also use personal guarantees when borrowing. This suggests that residential collateral may still be relevant for larger companies.

A back-of-the-envelope calculation based on our microeconometric results suggests that a 1% rise in real estate prices leads to a 0.13% rise in investment and 0.03% rise in total wage costs through the residential collateral channel, and a respective 0.12% and 0.01% rise for the corporate collateral channel. Of course, such estimates omit general equilibrium feedback effects, thus to explore the macroeconomic implications of our channels we build a general equilibrium model featuring credit constrained entrepreneurs that extends Liu, Wang, and Zha (2013). We find that in response to a 1% land price shock, on impact, the combined effect of both channels leads to a rise of up to 1% on investment and 0.3% on total wages.

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

On the other hand, a number of theoretical papers such as Iacoviello (2005), Philippon and Midrigan (2011), Calza, Monacelli, and Stracca (2013), Cloyne, Ferreira, and Surico (2015) and Justiniano, Primiceri, and Tambalotti (2015) emphasise the role of collateral constraints on households as an important mechanism for amplifying and propagating shocks. The microeconometric evidence provided by Mian and Sufi (2011), Mian, Rao, and Sufi (2013) and Mian and Sufi (2014) shows that the deterioration in household balance sheets in response to falling

[3]Defined as firms with annual revenue of less than £500million.

[4]Note that loans can be secured by more than one type of collateral, so the shares across collateral types can sum to more than 100%.

[5]Whilst a personal guarantee may be secured by other assets such as cash, in the event the guarantee is not met, the bank has the option of obtaining a court order to seize the guarantor's house.

house prices played a significant role in explaining the depth of the Great Recession. Whilst these papers focus on consumption and related aggregate demand effects, other papers such as Schmalz, Sraer, and Thesmar (2013), Robb and Robinson (2014), Adelino, Schoar, and Severino (2015) and Corradin and Popov (2015) have explored the links between the household collateral channel and the creation of new companies. In contrast to this set of recent papers, we examine the role of household collateral in the financing of *existing* firms.

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

Structure of the Paper The remainder of the paper is structured as follows: Section 2 presents the construction of the data and summary statistics. Section 3 describes the empirical methodology and results for the corporate collateral channel, whilst Section 4 presents the results when the residential collateral channel is also included. In Section 5 the robustness of these results to alternative specifications is considered, whilst Section 6 presents a theoretical model which embeds both the corporate and residential collateral channels. Section 7 concludes.

2 Data

We use accounting data on firms from England and Wales covering the period 2002-2012, merged with transaction-level house price data and loan-level mortgage origination data.

2.1 Accounting Data

We start with a large micro dataset of firms' financial accounts and ownership structure provided by Bureau van Dijk (BVD). The dataset also contains detailed information on the company directors including their date of birth and usual residential address, allowing matching with the residential transaction and mortgage data. This is a commercial dataset based on company filings at Companies House, which is a UK government agency acting as the registrar of companies in accordance with the Companies Acts of 1985 and 2006. The dataset contains information on approximately ten million private and public companies, thereby covering virtually the corporate universe of the UK. The data is updated continuously as new company accounts are filed.

BVD is a live database. This leads to several limitations. First, the company ownership structure is only accurate at the time of access and not for historical observations. Second, companies that die exit the database after four years. Third, the historical information based on past filed accounts has significantly more missing data than the most recent filings. Fourth, and most importantly, the director information is updated in the database over time and is only accurate for the current directors of the firm. It is thus inaccurate for historical observations if the company directors have changed over time, or indeed if they have moved house. To circumvent these issues, we use archived data sampled at a six monthly frequency to capture information when it was first published. This substantially improves data coverage, allows us to observe the birth and death of companies, provides accurate information on the ownership structure of companies at the time the accounts were filed, and makes estimation of the residential collateral channel possible by providing historical information on who the company directors were and where they lived. We now discuss some of the key variables in detail.

Land Holdings To measure corporate land holdings, we use the balance sheet item "Land and Buildings" from BVD. One challenge is to impute market values from the book values that firms report to the company registrar. To address this, we adopt 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:

$$
\begin{aligned}
L^Y_{i,j,t} &= \begin{cases} L^Y_{i,j,t-1}\frac{L^P_{j,t}}{L^P_{j,t-1}} + dB_{i,j,t} & if\ dB_{i,j,t} \geq 0 \\ L^Y_{i,j,t-1}\frac{L^P_{j,t}}{L^P_{j,t-1}} + dB_{i,j,t}\frac{L^P_{j,t}}{L^B_{i,j,t-1}} & if\ dB_{i,j,t} < 0 \end{cases} \\
L^B_{i,j,t} &= \begin{cases} L^P_{j,t} & if\ dB_{i,j,t} \geq 0 \\ L^B_{i,j,t-1} & if\ dB_{i,j,t} < 0, \end{cases}
\end{aligned} \tag{2.1}
$$

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

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

For the purposes of empirical analysis, a further difficulty is that the firm's choice of $dB_{i,j,t}$ will be both serially correlated and endogenous to the environment that the firm is operating in, including information about the firm's future prospects that may not be directly observable in the data. Hence, the level of collateral at the start of the firm's accounting period ($L^Y_{i,j,t-1}$) may be endogenous to the firm's behaviour within the accounting period. This could either be because the firm has invested in Land and Buildings in anticipation of future growth or because investment decisions are serially correlated (for example, a firm that buys a new building one year, may be much less likely to buy a new building in the following year).

To solve this potential endogeneity issue, we follow the literature (Benmelech and Bergman

(2009), Chaney, Sraer, and Thesmar (2012), Chaney, Huang, Sraer, and Thesmar (2015)) and rely on fluctuations in the price of collateral rather than the quantity of collateral the firm employs (the intensive margin of collateral in the terminology of Benmelech and Bergman (2009)) to identify the corporate collateral channel. Specifically, we estimate the value of firm collateral by fixing the value of $L^Y_{i,j,t}$ at its 2002 level and iterating forward using the regional price index, specifically:

$$collateral_{i,j,t} = L^Y_{i,j,2002} \frac{L^P_{j,t}}{L^P_{j,2002}}. \tag{2.2}$$

We select 2002 as it is the earliest year where we can conduct this exercise and preserve a sufficient number of observations. Our key identifying assumptions are then that $L^Y_{i,j,2002}$ is uncorrelated with other factors that affect the sensitivity of firm behaviour to local real estate prices beyond the collateral channel and that regional property prices are not caused by the individual firm's behaviour. We discuss both assumptions in detail below.

Corporate Activity and Financing To measure corporate activity, we construct ratios by using past year's turnover as the scaling variable. Alternatively, we could have followed Chaney, Sraer, and Thesmar (2012) in using property plant and equipment as the scaling variable. However, unlike their dataset, ours is not limited to listed and relatively large companies, but includes a large number of small companies with potentially small amounts of fixed assets. The choice of turnover as a scaling variable is therefore better suited to our sample, and avoids placing too much weight on smaller companies with small holdings of fixed assets.

To compute investment rates, we calculate the yearly change in the item "Fixed Assets" (ΔFA) less depreciation as a proxy for yearly capital expenditures. Total labour cost is computed as the ratio of the item "Remuneration" to lagged turnover. Similarly, employment is defined as the ratio of the item "Number of Employees" to lagged *real* turnover. 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.

Firms' location is a key variable in identifying changing collateral values in response to regional land price shocks. Our dataset provides the full postcode of all the trading addresses of each firm, which allows us to focus on companies that trade exclusively within one of our house price regions, allowing more precise estimation of the corporate collateral channel.[6] In contrast, a limitation of previous papers such as Chaney, Sraer, and Thesmar (2012) is that they focused on large firms which may own commercial real estate across several different regions. As they proxy

[6]The matching between postcodes and regions is performed using the Office for National Statistics *Postcode Lookup* dataset. This dataset contains all the UK postcodes as well as codes for matching them to a variety of different types of geographical regions.

changes in the value of the firms' real estate with changes in the house price index in the city where they are head-quartered, their proxy may have substantial measurement error, resulting in attenuation bias.

We consider a number of balance sheet variables from BVD including the items "Bank Deposits", "Bank Overdrafts", "Long-Term Debt", "Short Term Loans and Overdrafts", "Short Term Director Loans", "Long-Term Director Loans" and "Issued Equity". All these variables are defined as ratios using turnover as a scaling variable. In addition, we construct the cash rates, leverage ratios and profit margins as follows:

$$\begin{aligned} Cash\ Ratio &= \frac{Bank\ Deposits - Bank\ Overdrafts}{Turnover} \\ Leverage\ Ratio &= \frac{Long\ Term\ Debt}{Total\ Assets} \\ Profit\ Margin &= \frac{Operating\ Profit}{Turnover}. \end{aligned}$$

These variables will be used to control for potential firm heterogeneity. To prevent outliers distorting the results, all the ratios are winsorised at the 1st and 99th percentile.

2.2 Real Estate Data

Our regional house price data is taken from the Land Registry Price Paid dataset, which covers the nearly 20 million residential property transactions in England and Wales since 1995. Using this data the Land Registry produce monthly repeat sales house price indices across 172 different regions which we use as a proxy for the market value of commercial real estate.[7][8] Real house prices are calculated by deflating the nominal repeat sales house price index from each local authority with the national consumer price index. The advantage of using the Land Registry dataset, compared to other popular UK house price indices such as Halifax and Nationwide, is that it (i) includes cash purchases, (ii) is not limited to applications for mortgages through a given financial institution, (iii) is not based on approved mortgage applications but on the price at completion of the transaction, and (iv) is available at far more disaggregated geographical regions.

The Land Registry Price Paid dataset also forms our source for computing the value of company director's homes. The challenge is to match individual company directors to this dataset. By law, every company director (who is a natural person) must disclose their "usual residential address" to Companies House. These addresses are recorded as an unstructured string of text in

[7] Details on the index can be found here: https://www.gov.uk/government/publications/about-the-house-price-index/about-the-house-price-index

[8] Of course, one limitation of using this as a proxy for changes in the market value of corporate real estate holdings in (2.2) is that it is based on residential rather than commercial real estate prices. Therefore, as an alternative measure, in our empirical analysis we use the commercial real estate price index provided by the Investment Property Databank, which is based on commercial property valuations for a range of major cities.

the BVD database, with the notable exception of the director's postcode which is also recorded in a separate field. We construct a textual analysis algorithm that searches the unstructured address strings for regular expressions that can be used to determine the director's house number/house name and (if applicable) flat number/flat name. These two bits of information coupled with the postcode are sufficient to uniquely identify a property in the UK.

Director Collateral Given this information, we can match the director's address to our transaction-level dataset. For every matched address, the Land Registry dataset gives us the date of and price paid at every transaction involving that property since 1995. To determine the value of a director's home at the time when the director's company files its accounts we start by selecting a reference transaction. We select the reference transaction by first looking backwards in time to find the most recent transaction prior to when the company's accounts were filed. This will be the price the director paid for the property. If no transaction exists prior to the accounts being filed, presumably because the last transaction on the property was prior to 1995,[9] we then search forward in time to find the most recent transaction after the filing date. This will be the price the director sold their property for. We then use the ratio between the regional property price index at the account filing date and the regional property price index at the date of the reference transaction to convert the price at the time of the transaction into a valuation of the director's home when the accounts are filed. Our match rate is around 50%. We discuss the match rate in detail in the online Appendix.

Our explanatory variable of interest is the market value of directors residential collateral. This enters our regressions as the average value of the houses of matched directors within a firm at the time of the accounts being filed. The approach of using the average circumvents the need to match every director within a company in order to include it in the analysis. To prevent any direct causal links between firm performance and the value of directors' houses, we omit from our average directors who have purchased their property during the accounting period. In a subsequent robustness test we extend this exclusion further back in time.

2.3 Mortgage Data

Data on mortgage originations are taken from the Product Sales Database (PSD) provided by the UK Financial Conduct Authority.[10] The dataset provides a wealth of loan-level information on the universe of regulated residential mortgage originations in the UK since 2005, including

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

[10] 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.

the mortgage amount, property value, income of the borrower, interest rate charged and the purpose of the mortgage, whether for house purchase, or a remortgage, and indeed the reason for the remortgage. Most importantly, we can observe the date of birth (including year) and full postcode of the home address of the mortgagor. This enables us to identify whether the given mortgagor is a director of a company whose balance sheet information we observe in the BVD dataset.[11]

In future work we shall use the PSD to estimate the equity a director has in their house over time, which may allow more precise estimation of the residential collateral channel and allow us to determine the importance of director leverage. This will follow a similar methodological procedure as with the matching of director residential house prices. The date of birth and full postcode of the director's address can be used to identify any mortgage transaction the director has carried out at that address in the past. Regardless of whether this was a house purchase or remortgage, it will provide information on the house value and mortgage amount at that point in time, allowing calculation of housing equity. This value can be updated to the period of interest using information on the mortgage amortisation period and changes in the local house prices index over time. Information can also be gleaned from transactions that occur after the period of interest. First, any future remortgaging of the current property will be identifiable in the PSD and can be used to provide a subsequent value of housing equity. By focusing on the remortgages that do not include equity extraction, we can obtain an estimate of the housing equity prior to the remortgage, and then use the local house price index to obtain an estimate in the current period. Second, by utilising information on the director's future residential address, we will be able to identify any future house purchase they make in the PSD and obtain an estimate of the housing equity at that point in time.[12] On the assumption that the housing equity from one property is transferred to the next, we will be able to obtain an estimate of the director's housing equity prior to moving, and then using the local house price index, an estimate of their equity in the current period. This methodology will allow ten years of data with which to try and identify the housing equity of company directors.

2.4 Sample Selection and Summary Statistics

Our selection of firms is similar to Michaely and Roberts (2012), Chaney, Sraer, and Thesmar (2012) and Kleiner (2013). We focus on private limited and public quoted firms and follow the literature in excluding firms that operate in certain industries.[13] We also exclude companies that

[11] The typical UK postcode contains around 15-20 residential addresses, thus it is highly unlikely that there are two distinct individuals with the same date (and year) of birth living in the same postcode.

[12] If no mortgage transaction shows up in the PSD for that director around the transaction date at the new property we infer that they have 100% equity in the new house.

[13] Specifically we exclude companies of the following types: "Economic European Interest Grouping", "Guarantee", "Industrial/Provident", "Limited Liability Partnership", "Not companies Act", "Other", "Royal Charter",

have a parent with an ownership stake greater than 50%. This is to ensure that the accounts used have the highest degree of consolidation possible, to prevent the double counting of subsidiaries and to ensure that the financial position of the company regarding the collateral it has available is correctly accounted for. For the purpose of empirical analysis, we drop observations which are missing data on the key variables. Specifically, we exclude firms that do not report our scaling variable, "Turnover"; our variables of interest, "Fixed Assets", "Remuneration" and "Number of Employees"; the three control variables defined above and, last, our measure of corporate collateral. This leaves us with, in our most extensive sample, approximately 41,886 firm year observations covering 12,578 firms. The exact sample size for each specification is reported in the regression tables.

Table 1 presents summary statistics on variables of interest for our sample of firms. The median values of turnover and number of employees in the whole sample are about £9.3m and 76, respectively, which is much smaller than the corresponding mean values (£165m and 908). This skew in the distribution suggests that our sample is dominated by small and medium-sized enterprises (in the United Kingdom a large firm is defined as one with more than 250 employees). Figures 6 and 7 of the Appendix presents histograms to show the shape of the distribution for all the variables in Table 1.

Table 1: Summary Statistics

Variable	**Mean**	**Median**	**25%tile**	**75%tile**	**N**
Levels					
Turnover (£ 000s)	165110	9257	3097	25456	41886
No. Employees	908	76	25	196	41886
Ratios (to Turnover)					
Operating Profit	0.03	0.03	0.00	0.08	41310
Remuneration	0.30	0.25	0.13	0.39	41886
Investment	0.09	0.015	0.02	0.06	41886
Total Assets	1.5	0.59	0.38	1.10	41876
Firm Collateral	0.61	0.06	0	.22	41886
Avg Director Collateral	0.29	0.05	0.02	0.14	28882
Cash	0.03	0.01	-0.04	0.07	39768
Debt	1.20	0.14	0.06	0.38	37555
Directors Loans	0.03	0	0	0.00	36775

Note: The statistics are calculated using our sample of observations from the BVD used in the regressions in table 2. This excludes firms who have an ownership stake greater than 50%, operate in more than one region and do not report the value of employment, remuneration, investment and land and buildings.

The median value of our measure of firms' collateral is 6% of Turnover. The average company

"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 agriculture (UK Standard Industrial Classification [SIC] codes 0111-0322), utilities (UK SIC code 3500-3900), construction (UK SIC code 4100-4400), finance and insurance (UK SIC code 6400-6700), real estate (UK SIC code 6800-6840) and public administration (UK SIC code 8400-8440) sectors.

director's residential home is worth about 5% of the given firm's annual turnover (or around £450,000). Given that the average firm in our sample has around four directors, the value of potentially collateralisable residential property owned by company directors can amount to around 20% of the given firm's annual turnover.

Tables 6 and 7 of the Appendix present the statistics for firms with and without land holdings. We remark that the median investment rate of land-owning firms is larger than that of non-landholding firms.[14] Moreover, profit margins and total labour costs are broadly similar across firm types. As expected, firms that own real estate tend to be larger than firms without real estate. However, the median value of director collateral relative to turnover is much larger for firms without real estate compared to firms that own real estate. This suggests that directors' residential real estate as a source of collateral could potentially be more important for firms that are small.

3 The Corporate Collateral Channel

As a starting point, and to place our results within the existing literature, we first turn to the evidence on the corporate collateral channel in isolation, running from corporate holdings of real estate to firm activity. Building on Chaney, Sraer, and Thesmar (2012), the corporate collateral channel is identified by exploiting two sources of variation. Within regions, we rely up differences in the initial levels of corporate collateral across firms. Between our 172 regions we exploit differences in the evolution of real estate prices, using (in our baseline case) the regional house price index as a proxy for corporate real estate prices.

To explore how collateral values affect different aspects of firm activity, including investment and employment expenditure, we estimate different specifications of a regression model. Specifically, for firm i, at date t, operating in region j, firm activity is estimated as:

$$ACT_{i,j,t} = \alpha_i + \delta_{j,t} + \beta \times collateral_{i,j,t} + \gamma \times controls_{i,j,t} + \varepsilon_{i,j,t}, \tag{3.1}$$

where $ACT_{i,j,t}$ is firm activity measured by three different variables: investment, total labour cost and employment. The term α_i is a firm fixed effect, $\delta_{j,t}$ is a region-time fixed effect which aims to capture aggregate as well as region-specific business cycle fluctuations. The term $collateral_{i,j,t}$ is the ratio of collateral to lagged turnover, whereby collateral is computed by the recursion algorithm using equations 2.1 and 2.2. The set of control variables $controls_{i,j,t}$ include profit margins, leverage ratio, and cash-ratio as defined above.

A potential endogeneity problem related to regression model 3.1 is that real estate prices and therefore collateral values could be correlated with investment opportunities, e.g. because an

[14]Note that non-land holding firms can still record a positive value for firm collateral if they they have a positive value for Land and Buildings in 2002 but divest of all their holdings during the sample period.

Table 2: Firm Activity and the Corporate Collateral Channel

	Investment	Total Labour Cost	Employment
Firm Collateral	0.1111***	0.0493***	0.0031***
	(0.012)	(0.004)	(0.000)
Cash Ratio	0.1572***	0.0305***	0.0016**
	(0.041)	(0.011)	(0.001)
Leverage Ratio	-0.0400	0.0194	0.0027***
	(0.032)	(0.012)	(0.001)
Profit Margin	0.1271**	-0.1950***	-0.0091***
	(0.052)	(0.017)	(0.001)
N	37990	37990	37990
Adjusted R^2	0.24	0.79	0.84
Region-time FE	Yes	Yes	Yes
Industry-time FE	No	No	No
Firm FE	Yes	Yes	Yes

Firm region clustered standard errors in parentheses

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

Notes: The table reports the empirical link between corporate collateral, and firm activity. The dependent variables are Investment (change in fixed assets less depreciation), Total Labour Costs (remuneration) and Employment. Firm Collateral is the 2002 market value of firm Land and Buildings (calculated using the LIFO recursion) iterated forward using the regional house price index: $collateral_{i,j,} = L^{Y}_{i,j,2002} L^{p}_{j,t} / L^{p}_{j,2002}$. Cash Ratio, Profit Margins and Leverage Ratio enter with a lag. All variables are scaled by the lag of firm turnover and winsorised at the 1% and 99% levels. Standard errors, clustered by firm region, in parentheses. The sample covers reporting UK firms over the period 2002-2012. All models control for firm fixed effects and region-time fixed effects. The number of observations is lower than in Table 1 due to the dropping of singleton observations.

increase in local real estate prices fuels local consumption (Mian and Sufi (2011)). The inclusion of region-time fixed effects, $\delta_{j,t}$ will deal with this problem, so long as firms within a given region respond similarly to changes in local demand.[15]

Table 2 reports the estimates of various specifications of equations 3.1, which explores the corporate collateral channel. The estimates suggest that a £1 rise in the value of a firm's real estate holdings increases investment by approximately 11p. The estimated size of this channel is around twice as strong as found by Chaney, Sraer, and Thesmar (2012), likely reflecting the inclusion of smaller, non publically-listed firms in our sample, for whom the effect is likely to be stronger, and our focus on firms who trade exclusively within one region, reducing attenuation bias. We also find a significant impact on labour market variables, with the total labour costs of the firm rising by around 5p. Further, the employment estimate (0.0031) can be interpreted as an increase of £320,000 (in 2005 prices) in corporate collateral values resulting in the hiring of approximately one additional worker.

[15] In a further robustness check we also include industry-time fixed effects.

Table 3: Firm Behaviour: Remortgaging versus Non-Remortgaging Directors

Number of Directors Remortgaging	0		1		2 or more	
Variable	**Mean**	**N**	**Mean**	**N**	**Mean**	**N**
Change in Total Assets	15.591	796541	16.243	29597	19.132	1237
Investment	7.804	697185	8.077	25842	11.127	1036
Change in Issued Equity Rate	0.009	999935	0.012	36769	0.028	1534
Change in Director Loans	1.095	149123	1.464	7317	2.286	480
Change in ST External Financing	2.396	279647	2.918	12282	5.181	675
Change in LT External Financing	7.522	199210	10.976	9080	4.793	554

Notes: These statistics are calculated using all firm observations from BVD and all mortgagor observations from the FCA's Product Sales Database, where we could match company directors with mortgage contracts using information on the director's date of birth and home postcode. We have excluded firms that have more than 10 directors. The data cover the period 2005-2012. The data presented is as a percentage of the firm's previous period turnover. Investment is defined as change in fixed assets less depreciation. ST External Financing is short-term debt and overdrafts plus trade credit less short-term director loans. Long-Term External Financing is long-term debt less long-term director loans. Observations are winsorized at the 1% and 99% levels.

4 The Residential Collateral Channel

We now turn to the main contribution of the paper, which is to explore the residential collateral channel, whereby the residential property of company directors can be used as a source of funds for their business.

4.1 Suggestive Evidence on the Residential Collateral Channel

As highlighted in Figure 2, director residential collateral can affect firm activity either through using a charge on the director's house to guarantee a loan to the company,[16] or by via the director extracting equity from their house to inject of the funds directly into the firm in the form of insider debt financing (director loans) or equity. In this subsection, we explore whether directors remortgaging their property is associated with differences in firm behaviour.

Table 3 provides some descriptive statistics on the connection between the residential remortgaging decision of the director(s) of a given company and the contemporaneous change in the given company's balance sheet. All measures are as a percentage of the previous period's turnover.

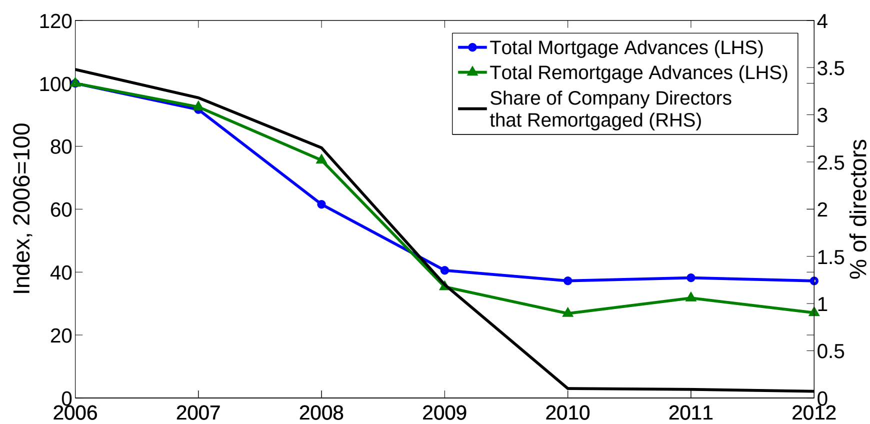
We distinguish between companies according to the number of directors that remortgaged in the given accounting year. Our results show that a company in which *one* director remortgaged in a given year had a higher rate of asset growth (16.2 vs 15.6) and invested more (8.1 vs 7.8) than a company where none of the directors remortgaged. These rates increase further for companies where *two* or more directors remortgaged in a given year (19.1 and 11.1 respectively). The expansion of the asset side of the balance sheet when a director remortgages is mirrored on the liabilities side; we see more insider finance in the form of equity injections and director loans

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

in companies where more directors remortgage. Short term external finance (potentially backed by a guarantee that is reflected in remortgaging data) also expands more quickly. In fact, with the notable exception of long-term external financing, all the balance sheet measures in Table 3 increase monotonically in the number of remortgaging directors. The magnitudes are much smaller for the change in issued equity, which may reflect the tax preferences for using director loans or corporate debt as a source of funding, and the fact that we are focusing on the funding of *existing* companies – the findings may well be different for the creation of new companies. These results provide strong suggestive evidence that households, who act as company directors, indeed reinvest into their businesses some of the funds obtained from remortgaging, thereby increasing corporate credit supply. To the best of our knowledge, our paper is the first to document this phenomenon.

To explore the macroeconomic behavior of director remortgaging, Figure 3 plots the evolution of the aggregate share of company directors that remortgage (right axis) alongside the evolution of total mortgage and total remortgage advances (left axis). The overall aggregate dynamics of director remortgaging track the behavior of mortgage markets. However, during the Great Recession, the collapse of director remortgaging was much larger, and it was virtually zero in 2010-2012.

Figure 3: Aggregate Series of Director Remortgaging: The Collapse During the Great Recession



Source: BVD, FCA's Product Sales Data, and author calculations

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We now turn to the formal estimation of the residential collateral channel.

4.2 The Residential Collateral Channel: Main Results

To estimate the residential collateral channel we combine the firm level data with the transaction-level house price data from the Land Registry Price Paid dataset, which allows us to compute the market value of company directors' homes as described in Section 2.2. We then estimate how a change in the market value of a company director's residential real estate affects the activity of their firm.

To estimate the effects of real estate shocks on firm activity via the changing collateral values of company directors' residential homes, we estimate the following regression model:

$$ACT_{i,j,t} = \alpha_i + \delta_{j,t} + \eta \times directorcollateral_{i,j,t} + \beta \times collateral_{i,j,t} + \gamma \times controls_{i,j,t} + \varepsilon_{i,j,t}, \quad (4.1)$$

where $ACT_{i,j,t}$ is firm activity measured by three different variables: investment, total labour cost and employment. The term α_i is a firm fixed effect, $\delta_{j,t}$ is a region-time fixed effect, $collateral_{i,j,t}$ is corporate collateral and $controls_{i,j,t}$ refers to the same control variables as in 3.1. A key feature of specification 4.1 is the inclusion of the term $directorcollateral_{i,j,t}$, which is the market value of the residential collateral owned by the average company director in each firm, scaled by firm turnover.

Table 4 reports the estimates of various specifications of equations 4.1. The estimates suggest that a £1 rise in the *average* value of the residential real estate holdings of the average company director increases investment by around 11p and the total wage bill by around 9p. The employment estimate (0.0082) can be interpreted as an increase of £120,000 (in 2005 prices) in the residential collateral values of the average company director resulting in the hiring of approximately one additional worker.

Once the residential collateral of company directors is accounted for, the impact of the corporate collateral channel is diminished, with the estimated impact on total labour costs falling from 5p to 4p, and the estimated impact on investment falling from 11p to around 9p. One possible explanation for the diminished estimated role of the corporate collateral channel on employment variables would be collinearity between the two collateral measures for a firm. However, the average within-firm correlation between the two series is just 0.29, in part because many firms do not own corporate real estate and because directors often do not live in the same region as their firm.[17]

Director collateral enters the regression as an average across matched directors. This approach circumvents missing values for directors who are not matched to the Land Registry. However, it means that the coefficient estimates on director collateral are not comparable to firm collateral, as the latter is the total value of the firm's land and buildings. The average number of directors for the firms in the regression is 4.3 directors. Rescaling the director collateral estimates by this number suggests that a £1 increase in the *total* value raises firm investment by 2.5p and the total wage bill by 2.1p. These estimates are of the same order of magnitude as the estimates for the corporate collateral channel, if a little bit lower. However, as discussed in the introduction, the

[17]Out of the directors in our sample, more than 60% of them live in a region different from where their firms are located.

Table 4: Firm Activity and the Collateral Channels

	Investment	Total Labour Cost	Employment
Director Collateral	0.1057***	0.0921***	0.0080***
	(0.037)	(0.008)	(0.001)
Firm Collateral	0.0949***	0.0377***	0.0019***
	(0.014)	(0.006)	(0.000)
Cash Ratio	0.1472***	0.0138	0.0008
	(0.054)	(0.018)	(0.001)
Leverage Ratio	-0.0793*	0.0002	0.0008
	(0.045)	(0.014)	(0.001)
Profit Margin	0.1828**	-0.1591***	-0.0054***
	(0.087)	(0.021)	(0.001)
N	25437	25437	25437
Adjusted R^2	0.25	0.81	0.86
Region-time FE	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes

Firm region clustered standard errors in parentheses

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

Notes: The table reports the empirical link between residential collateral, corporate collateral, and firm activity. The dependent variables are Investment (change in fixed assets less depreciation), Total Labour Costs (remuneration) and Employment. Director Collateral is the average value of the firm's directors' homes at the time the firm's accounts were filed, omitting directors who purchased their home in the firm's accounting period. Firm Collateral is the 2002 market value of firm Land and Buildings (calculated using the LIFO recursion) iterated forward using the regional house price index:$collateral_{i,j,} = L^{Y}_{i,j,2002} L^{p}_{j,t} / L^{p}_{j,2002}$. Cash Ratio, Profit Margins and Leverage Ratio enter with a lag. All variables are scaled by the lag of firm turnover and winsorised at the 1% and 99% levels. Standard errors, clustered by firm region, in parentheses. The sample covers reporting UK firms over the period 2002-2012. All models control for firm fixed effects and region-time fixed effects.

total value of director collateral in the economy as whole is 4 times larger than that of real estate collateral held by owner-occupying corporates, suggesting the investment effects from the two channels are of similar magnitude, whilst the effect on total wages is greater for the residential collateral channel.

Interestingly the two channels have different labour market implications. Combining the estimated strength of the channels on total labour costs and employment allows us to estimate the wage paid to the marginal worker hired when collateral values increase. For instance, £125,000 of residential collateral for the average company director will imply that the firm hires one more worker and pays around an additional £12,000 (using the coefficient estimate of 0.0921). For corporate collateral, the analogous calculation estimates that the marginal worker is paid around £20,000, which is close to the median wage per employee rate paid by the firms in our sample. There are several interpretations for this difference. First, workers hired using the funds from increased director collateral may be of lower quality/wage, or hired on a part-time basis. Alternatively, there may be a greater lag between changes in director collateral values and the hiring of a worker, which would result in the wage appearing to be lower as the worker will only be paid for part of the firm's accounting year.

4.3 Firm Financing

To explore the channels through which capital gains on real estate are converted into firm funding we estimate the effects of the residential and corporate collateral channels on changes in specific parts of the liabilities side of firms' balance sheets. The results are presented in Table 5. As for the corporate collateral channel, the impact of increased firm collateral has the largest and most significant effect on the change of external long-term debt : a £1 increase in corporate collateral increases long-term debt by about 5p. Short-term external debt increases by an additional 2.5p. As would be expected, firm collateral has no impact on our measures of insider finance; neither director loans nor issued equity respond.

Table 5: Firm Financing and Collateral

	Issued Equity	Director Loans	ST External Financing	LT External Financing
Director Collateral	0.0019**	-0.0010	0.0413***	0.0327
	(0.001)	(0.003)	(0.014)	(0.031)
Firm Collateral	0.0002	0.0008	0.0242***	0.0452***
	(0.000)	(0.001)	(0.007)	(0.011)
N	24121	21683	22979	22451
Adjusted R^2	0.30	-0.03	-0.04	0.10
Region-time FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes

Firm region clustered standard errors in parentheses

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

Notes: The table reports the empirical link between residential collateral, corporate collateral, and firm financing. ST External Financing is short-term debt and overdrafts plus trade credit less short-term director loans. LT External Financing is long-term debt less long-term director loans. Director Collateral is the average value of the firm's directors' homes at the time the firm's accounts were filed, omitting directors who purchased their home in the firm's accounting period. Firm Collateral is the 2002 market value of firm Land and Buildings (calculated using the LIFO recursion) iterated forward using the regional house price index: $collateral_{i,j,t} = L^{Y}_{i,j,2002} L^{p}_{j,t} / L^{p}_{j,2002}$. All variables are scaled by the lag of firm turnover and winsorised at the 1% and 99% levels. Standard errors, clustered by firm region, in parentheses. The sample covers reporting UK firms over the period 2002-2012. All models control for firm fixed effects and region-time fixed effects.

As for the residential collateral channel, an increase in the residential collateral of the average company director has a significant effect on both equity issuance and short-term debt, with a more material impact on the latter: a £1 increase in the market value of the directors' homes increases net equity and short-term corporate debt issuance by about 0.2p and 4.1p, respectively. The point estimate on long-term external borrowing suggests a 3p 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 director collateral, on the asset side of the balance sheet, suggests that this mechanism is present.

The estimate related to increased equity issuance is consistent with the residential collateral channel operating through the reinvestment of funds of company directors by extracting equity from their residential property. This channel is indicated by the bottom arrows connecting the red boxes in Figure 2. This result is also consistent with the suggestive evidence of Table 5 above (as is the result for short-term external finance). However, the small size of the coefficient estimate suggests that equity issuance is not the important marginal source of finance unlocked via director collateral. Instead, the estimate related to increased short-term debt is consistent with the residential collateral channel operating through increasingly valuable personal guarantees of company directors - the channel shown in the upper red box of Figure 2 – which expands the corporate borrowing capacity of the firm. The magnitude of the results suggests that the residential collateral channel primarily operates through the personal guarantees of company directors. There are several reasons why this method of funding may be more prevalent than the injection of funds following the remortgaging of a residential property. First, a personal guarantee extends the company's tax shield to the director. Second, banks like the use of personal guarantees as they pierce the corporate veil and align the incentives of the company director with those of the bank.

5 Identification and Robustness

Table 8 of the Appendix shows that the benchmark results for investment in Table 4 are robust to altering the specification along the dimensions of the included control variables and fixed effects.

For the residential collateral channel, one potential endogeneity concern is reverse causality: when the firm is doing well, the firm director may be more likely to purchase additional residential real estate. To address this concern, we run a series of regressions that exclude company directors that purchased a house in recent years. Table 9 of the Appendix shows that the estimated impact of director collateral on firm investment is similar when we exclude directors who have purchased a house up to 5 years previously, suggesting reverse causality is not driving our results. Even if we exclude all directors who have purchased homes in the last 10 years, we still find a statistically significant effect, although this effect is now much attenuated (as the match rate of director collateral becomes much lower), and the point estimate should not be interpreted too closely as a result.

One possible criticism of our estimated results for the corporate collateral channel is the use of residential house prices to proxy changes in the market value of firm collateral. We therefore re-estimate the baseline regression 4.1 after using commercial real estate prices in the land recursion algorithm 2.1 to compute firm collateral. The data on CRE prices comes from the Investment Property Databank, however, as this is only available for a range of major UK cities (as opposed to local authority level), we lose around 50% of the observations compared to the baseline estimates in Table 4. The results, presented in Table 10 of the Appendix, show similar estimates of both the corporate and residential collateral channels, suggesting that the use of residential real estate prices is not a bad proxy.

A further possible source of endogeneity, related to the corporate collateral channel, is that a firm's decision over whether or not to own real estate could be correlated with other determinants of the firm's response to real estate price changes. Firm characteristics such as age, size or profitability may affect firms' decision to own real estate as well as influence their sensitivity to shocks to collateral values. We therefore follow Chaney, Sraer, and Thesmar (2012) in constructing five quintiles of age, size and profitability that can proxy ownership decisions. Table 11 of the Appendix presents results from a linear probability model confirming that larger firms were are more likely to own real estate, however there appears to be little relationship with profitability, and a non-monotonic relationship with age. Nevertheless, for robustness we construct dummy variables indicating the age, size and profitability quintiles in which the firm is located at each point in time. We then include in our baseline regression 4.1 the interaction of these quintile dummies with firm collateral values. Moreover, we also include industry-time fixed effects at the 2-digit SIC-code level to control for firm characteristics specific to certain industries which can have systematic effects on collateral values and firm activities. We thus estimate the following regression:

$$\begin{aligned} ACT_{i,j,t} =& \alpha_i + \delta_{j,t} + \eta \times directorcollateral_{i,j,t} + \beta \times collateral_{i,j,t} + \gamma \times controls_{i,j,t} \\ &+ \mu_{l,t} + \sum_k \kappa_k X_{i,j,t} \times collateral_{i,j,t} + \varepsilon_{i,j,t}, \end{aligned} \tag{5.1}$$

where $\mu_{l,t}$ is a time fixed effect specific to industry l, and $\sum_k \kappa_k X_{i,j,t}$ are the quintile dummies. The estimates are presented in Table 12 of the Appendix, which confirms that the results relative to the baseline do not materially change.

A further potential concern with our identification strategy for the corporate collateral channel is that large firms could affect local real estate prices through their investments. As many of the firms in our dataset are not large, this may be less of a concern. Nevertheless, to address this concern we present our results following the IV strategy adopted by Mian and Sufi (2011) and Chaney, Sraer, and Thesmar (2012) among others. More specifically, we instrument local authority level house prices by interacting geographical constraints on housing supply with aggregate shifts in the interest rate on 2-year 75%-LTV mortgages.[18] When mortgage rates fall, the demand for real estate rises. If local housing supply is very elastic, the increased demand will translate mostly into more construction rather than higher prices. If local housing supply is very inelastic on the other hand, the increased demand will translate mostly into higher prices rather than more construction. Our measure of local housing supply constraints is the share of all developable land that was developed in 1990. The data are from Hilber and Vermeulen (2016) who originally derived the measure from the Land Cover Map of Great Britain using satellite images, allocating land to 25 cover types on a 25 meter grid.[19] We thus estimate, for region j,

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

[19]The data covers England (excluding 22 local authorities in Wales), so we include only 150 local authorities

at date t, the following first-stage regression to predict house prices:

$$L_{j,t}^{P} = b_{0j} + b_{1t} + b_2 \times elasticity_j \times i_t + u_{jt}, \tag{5.2}$$

where $elasticity_j$ measures constraints on land supply at the local authority level. The term i_t is the nationwide mortgage rate at monthly frequency, b_{0j} is a region fixed effect, and b_{1t} captures macroeconomic fluctuations in real estate prices, from which we aim to abstract. Figure 8 of the Appendix plots the predicted house prices against the realised values. The scatter and the large marginal F-statistics confirm the strength of the instrument. Given our predicted house price series, we repeat the recursion 2.1 to compute firm collateral values. The results from re-estimating the regression 4.1 using the IV-ed house prices series 5.2 are very similar to our baseline results. These estimates are presented in Table 13 of the Appendix.

Some firms that own property may do so for speculative purposes and therefore may be more likely to invest more in property when prices rise. While speculative behaviour would not explain the sensitivity between the firm's labour inputs and corporate collateral, it may explain the sensitivity between investment and corporate collateral. To address this, in Table 14, we rerun our investment equation for investment rates excluding land and buildings. As can be seen, firm collateral (and director collateral) both still influence investment in other forms of fixed assets.

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

$$collateral_{i,j,t} = L_{i,j,t-1}^{Y} \frac{L_{j,t}^{P}}{L_{j,t-1}^{P}},$$

where $L_{i,j,t-1}^{Y}$ is computed using the recursion in equation 2.1. This means that investment decisions in previous quarters now affect our collateral measure (although, for obvious reasons, we do not include investment in the current period). Table **15** presents the regression estimates when corporate collateral is redefined in this fashion. The coefficients on both the labour variables and investment are diminished, particularly for investment. One explanation for the particularly diminished results for investment is that investment in Land and Buildings has a negative serial correlation: if a firm bought a building in the previous period it is unlikely to invest in the current period, which would bias down the coefficient estimate. To illustrate this, we also include the estimates for investment excluding Land and Buildings. The coefficient on corporate collateral is of a similar magnitude to the benchmark case shown in Table **14** (0.048 vs 0.032). The low total investment coefficient therefore appears to be driven by a fall in investment in Land and Buildings as $L_{i,j,t-1}^{Y}$ increases. This finding also illustrates our reasoning behind the use of our baseline collateral measure. Importantly for the robustness of our main result: the coefficient on

in our IV regressions.

director collateral is insensitive to changes in the definition of corporate collateral.

Having established the significance of the collateral channels, we ask whether they are stronger when house prices increase compared to when they decrease. To explore this type of asymmetry, we include in the baseline regression the interaction of firm collateral and a dummy that takes value 1 when local house price growth is positive and 0 when it is negative. Table 16 of the Appendix shows that labour market outcomes behave symmetrically across booms and busts for both channels. However, there is an interesting asymmetry between the impact of the residential and corporate collateral channels on investment: whilst the corporate collateral channel has a stronger impact on investment in booms, the residential collateral channel has a greater impact on investment in housing busts.

We also consider how the strength of both channels varies with firm size, interacting both director and residential collateral with a dummy variable that takes value 1 if the firm employs less than 10 workers and takes 0 otherwise. The results are presented in Table 17 of the Appendix. As may be expected, the corporate collateral channel has a smaller impact on investment and labour decisions of small firms, with these firms less likely to own real estate. The residential collateral channel affects both large and small firms alike: both large and small firms can use the residential properties of their directors as a source of funds. Intriguingly, the residential collateral channel appears to have a bigger impact on relatively larger firms.

There are several explanations for this counter-intuitive finding. It may be simply that larger firms are more sensitive to the value of their director's residential collateral. This seems unlikely but as described in the Introduction, personal guarantees are still commonplace for larger firms. However, there are other explanations. Recall that residential collateral enters the regression as an average across matched directors. One explanation for the diminished estimates for small firms is that they have fewer directors on average (3 vs 4.6), so a £1 increase in the average value of director collateral translates to a smaller increase in the total value of residential collateral available to the firm. Rescaling the coefficient estimates to reflect the differences in the average number of directors explains around half the ratio between small and large firms.[20]

Another explanation is that the ratio of residential collateral to turnover is much greater for small firms. The mean small firm has a ratio of around 1.5 compared to 0.1 for large firms (using the definition in Table 17). Small firms invest relatively more than large firms and have similar remuneration to turnover ratios (respectively 0.15 versus 0.08 and 0.29 versus 0.31). By multiplying the coefficient estimates in Table 17 by the ratio between collateral to turnover and investment to turnover (or remuneration to turnover) one can rephrase the estimated unit elasticities as percentage elasticities. This reveals that, after adjusting for the differences in the

[20]To see this, consider the investment column in Table 17: large firms have a coefficient of 0.202 on the director collateral versus 0.079 for small firms. Dividing these coefficients by the average number of directors for each type of firm to a comparison of 0.044 versus 0.026. In other words, adjusting for the number of directors reduces the ratio between large and small firms response to director collateral from 2.56 to 1.69.

number of directors, the response of small firms in percentage terms is over 2.5 times stronger for investment and over 5 times stronger for total remuneration.

As a final test, we examine whether director collateral affects firms behaviour for firms for which total director collateral is very small compared to the size of the balance sheet. Specifically, in Table 18, we limit our sample to firms for which the total value of director collateral is less than 1% of total assets.[21] As one would expect, for such firms, director collateral does not have a statistically significant impact on firm behaviour.

6 Insights from a Theoretical Model

Our empirical findings suggest that shocks to house prices can propagate to expand production via increased corporate collateral values (the corporate collateral channel) and via increased residential collateral values of company directors (the residential collateral channel). To measure the relative strength of these mechanisms and to explore potential feedback effects that the partial equilibrium regression design of the previous sections could not account for, this section extends the general equilibrium model of Liu, Wang, and Zha (2013) by incorporating both collateral channels.

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

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

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

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

[21] We approximate the total value of collateral using the average value of matched directors houses multiplied by the number of directors in the firm.

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

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

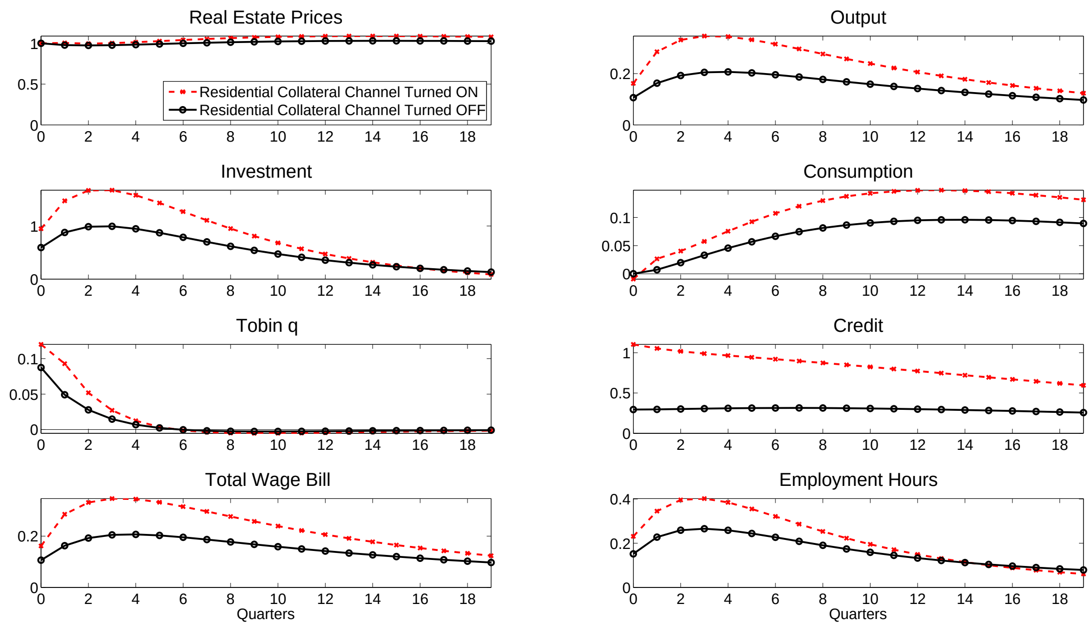
We build on this mechanism by introducing entrepreneurial residential land. To quantify the relative importance of the residential collateral channel, we solve and simulate the model under different values of ω in the credit constraint 6.1. Our main goal is to see whether increasing the value of ω (and thereby increasing the collateralisability of residential real estate owned by the entrepreneur) would change the dynamic propagation of housing shocks to the macroeconomy. This exercise can be interpreted as a way of assessing the importance of the residential collateral channel. It is important to note that, while changing ω, we keep the steady-state level of corporate debt fixed.[22]

For this exercise, we use a combination of calibrated and estimated parameters to fit the model to UK data. An important aspect of our calibration is the assumption that 20% of total residential land is owned by the entrepreneur in steady state. This introduces a non-trivial source of residential collateral for the production sector. We argue that this is a conservative estimate of the total residential collateral held by company directors. We estimate that the value of the homes of company directors in 2013 was about £1,100 Billion. Together with the 2013 estimate for the total value of UK residential properties being £4,600 Billion (IPF, 2014), this suggests

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

that around 25% of the residential housing stock by value is owned by company directors.[23]

Figure 4: The Impact of a Housing Demand Shock in the DSGE Model: The Role of the Residential Collateral Channel



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

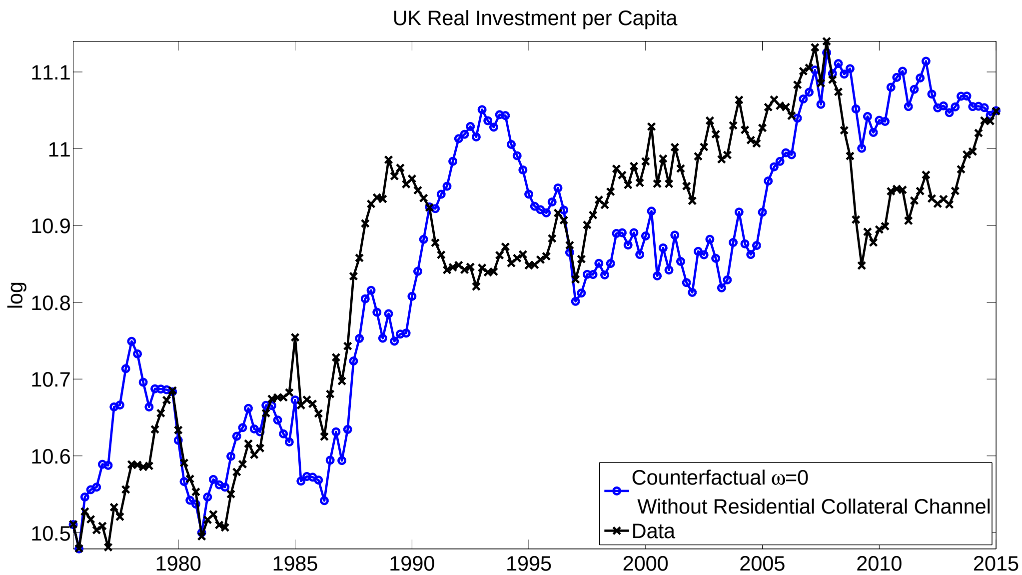
To explore how important the residential collateral channel may be in affecting macroeconomic fluctuations, we first analyse the effects of the housing demand shock *with* and *without* the residential collateral channel. To perform this exercise, Figure 4 shows the impulse response functions for the baseline ($\omega = 1$) and for the model without the residential collateral channel ($\omega = 0$). In the baseline, depicted by the red crossed lines, a shock which increases house prices by 1% on impact has a 0.3-0.4% peak effect on output, the total wage bill and employment, and it has a 1% and 1.5% peak impact on corporate credit and investment, respectively. In the counterfactual economy, the impact of the housing shock drops substantially. In fact, the black circled lines in Figure 4 show that a housing shock of the same magnitude has about a *40%* smaller effect on all macroeconomic variables relative to the baseline.

A key conclusion from this simple exercise is to illustrate that the partial equilibrium effect related to the residential collateral channel studied in Section 4 may play an important role in

[23]To show this, we use the following formula $V = n_{D,2012} \times p_{H,2012} \times \frac{\bar{p}_D}{\bar{p}_{ALL}}$, where V is the total value of residential director collateral in 2012, $n_{D,2012} \approx 4,692,000$ is the number of unique company directors (that are not companies) in 2012, $p_{H,2012} \approx$ £160,000 is the average house price in England and Wales in 2012, $\bar{p}_D \approx$ £244,000 is the average transaction price of houses bought by directors in our sample, and $\bar{p}_{ALL} \approx$ £162,000 is the average price of all transactions throughout the whole sample. This gives an estimate of $V \approx £1.13 trillion$. This is a main conceptual departure from the model of Liu, Wang, and Zha (2013), where residential land is owned entirely by the household.

understanding macroeconomic fluctuations as well. The model of Liu, Wang, and Zha (2013) focuses on the role of productive (commercial) land as collateral and ignores the role of residential land as a source of collateral for producers. Though unproductive, residential land may be a quantitatively important source of collateral for producers: the market value of residential real estate held by company directors (£1,100 Billion) is around 75% greater than the value of commercial real estate (£650 Billion) in the UK. Ignoring the residential collateral channel may therefore underestimate the macroeconomic relationships between real estate prices, credit and business cycle fluctuations.

Figure 5: The Importance of the Residential Collateral Channel over the UK Business Cycle



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

The UK Business Cycle and the Residential Collateral Channel As part of our motivation, Figure 1 illustrated the strong comovement between house prices and investment in the UK. To shed light on the historical importance of the residential collateral channel over the last four decades of UK business cycles, we use our estimated model to compute the counterfactual path of investment that would have realised if the residential collateral channel had been absent. To perform this counterfactual exercise we proceed in three steps. First, we estimate the model and store the estimated series of structural shocks. Second, we change ω from the baseline 1 to 0, thereby shutting down the residential collateral channel, and compute policy functions for this new model. Third, we combine the estimated structural shocks from step 1 with the new policy functions in step 2 to compute the counterfactual path of the variables of interest. By doing so, we ask: how would the propagation of all structural shocks (including that of the housing shock) to investment have changed if the collateral value of residential land held by entrepreneurs had been zero? Figure 5 shows the counterfactual (circled blue line) path of investment along with the actual (black line) path in the data. The result suggests that the residential collateral channel played a major role in the fall of investment in the early 1990s as well as during the Great Recession. Conversely, the channel had a sizeable positive contribution to the economic expansion during the housing boom of the late 1980s and early 2000s.

7 Conclusion

The global housing boom of the 2000s and the Great Recession that followed demonstrated striking correlations between real estate prices and economic activity. This paper articulates two channels via which this may emerge: the use of corporate real estate as collateral to fund business activity and a second, previously unexplored residential collateral channel, via the residential wealth of company directors. We show that a £1 increase in the value of a firm's corporate real estate leads to around a £0.09 increase in investment and a £0.04 increase in total wage costs. Similarly, a £1 increase in the total value of director's residential real estate within a company leads to around a £0.02 increase in investment and total money spent on wages.

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

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

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A Additional Tables and Figures

A.1 Descriptive Statistics

Table 6: Descriptive Statistics: Non-Property Holding Firms

Variable	**Mean**	**Median**	**25%tile**	**75%tile**	**N**
Levels					
Turnover (£'000s)	27262	2973	547	8736	10357
No. Employees	95	22	7	65	10357
Ratios (to Turnover)					
Operating Profit	.0088	.03	-.0031	.086	10196
Remuneration	.33	.27	.13	.45	10357
Investment	.047	.0071	0	.03	10357
Total Assets	1.3	.45	.31	.74	10355
Firm Collateral	.19	0	0	0	10357
Avg Director Collateral	.64	.14	.049	.56	7011
Cash	.053	.017	-.034	.097	9550
Debt	1.3	.12	.04	.32	8492
Director Loans	.041	0	0	.011	8328

Note: The statistics are calculated using our sample of observations from the BVD used in the regressions in table 2. This excludes firms who have a corporate owner with stake greater than 50%, operate in more than one region and do not report the value of employment, remuneration, investment and Firm Collateral.

Table 7: Descriptive Statistics: Property Holding Firms

Variable	**Mean**	**Median**	**25%tile**	**75%tile**	**N**
Levels					
Turnover (£'000s)	214100	12387	5145	33215	30264
No. Employees	1198	102	43	250	30264
Ratios (to Turnover)					
Operating Profit	.034	.03	.0058	.074	29877
Remuneration	.29	.24	.13	.38	30264
Investment	.099	.018	.0028	.067	30264
Total Assets	1.6	.64	.42	1.2	30256
Firm Collateral	.74	.1	.027	.32	30264
Avg Director Collateral	.17	.034	.013	.086	20957
Cash	.021	.0044	-.044	.065	29034
Debt	1.1	.15	.061	.39	27937
Director Loans	.021	0	0	.0016	27346

Note: The statistics are calculated using our sample of observations from the BVD and used in the regressions in table 2. This excludes firms who have a corporate owner with stake greater than 50%, operate in more than one region and do not report the value of employment, remuneration, investment and Firm Collateral.

Figure 6: Distribution of Some of the Key Variables

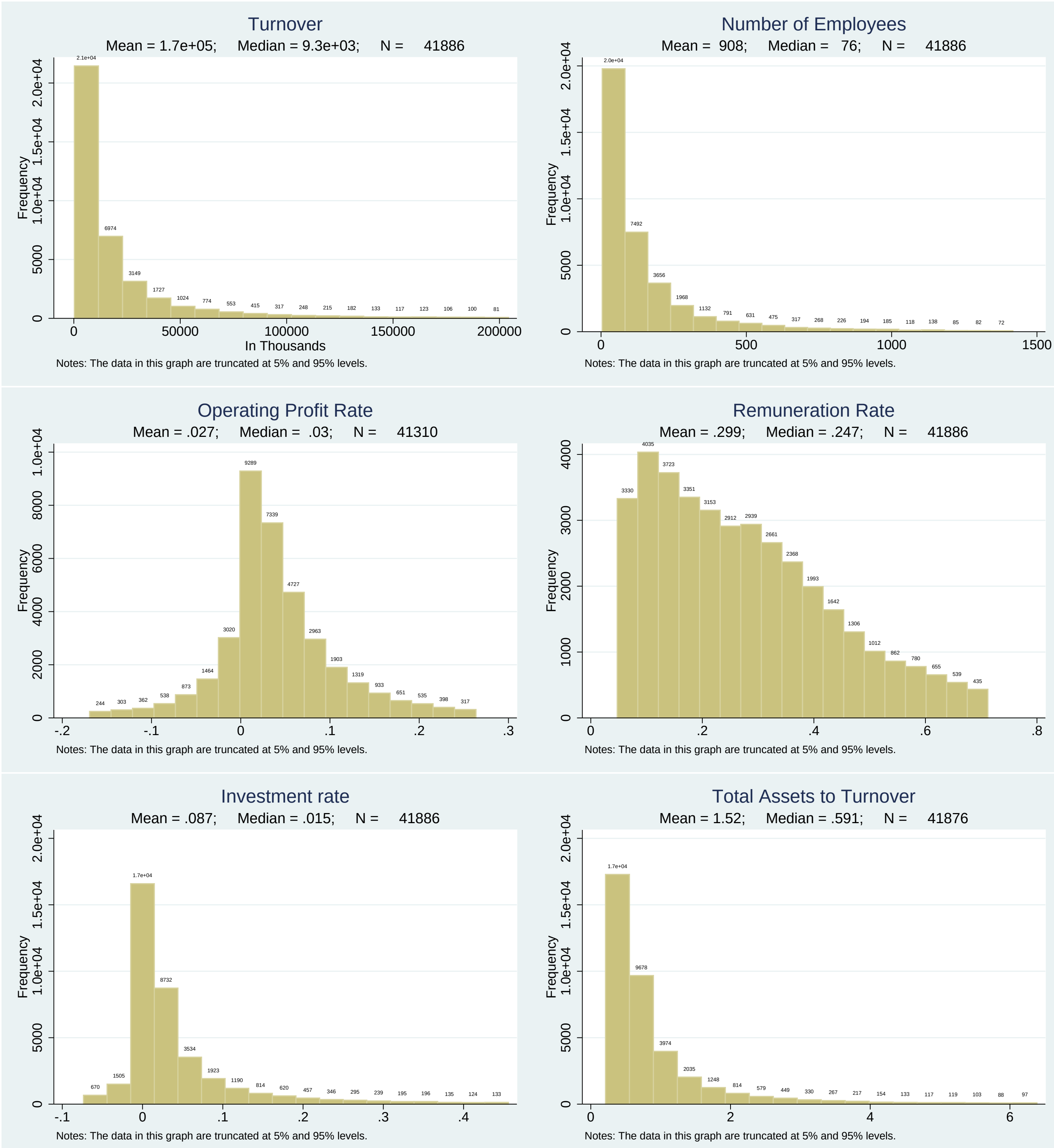
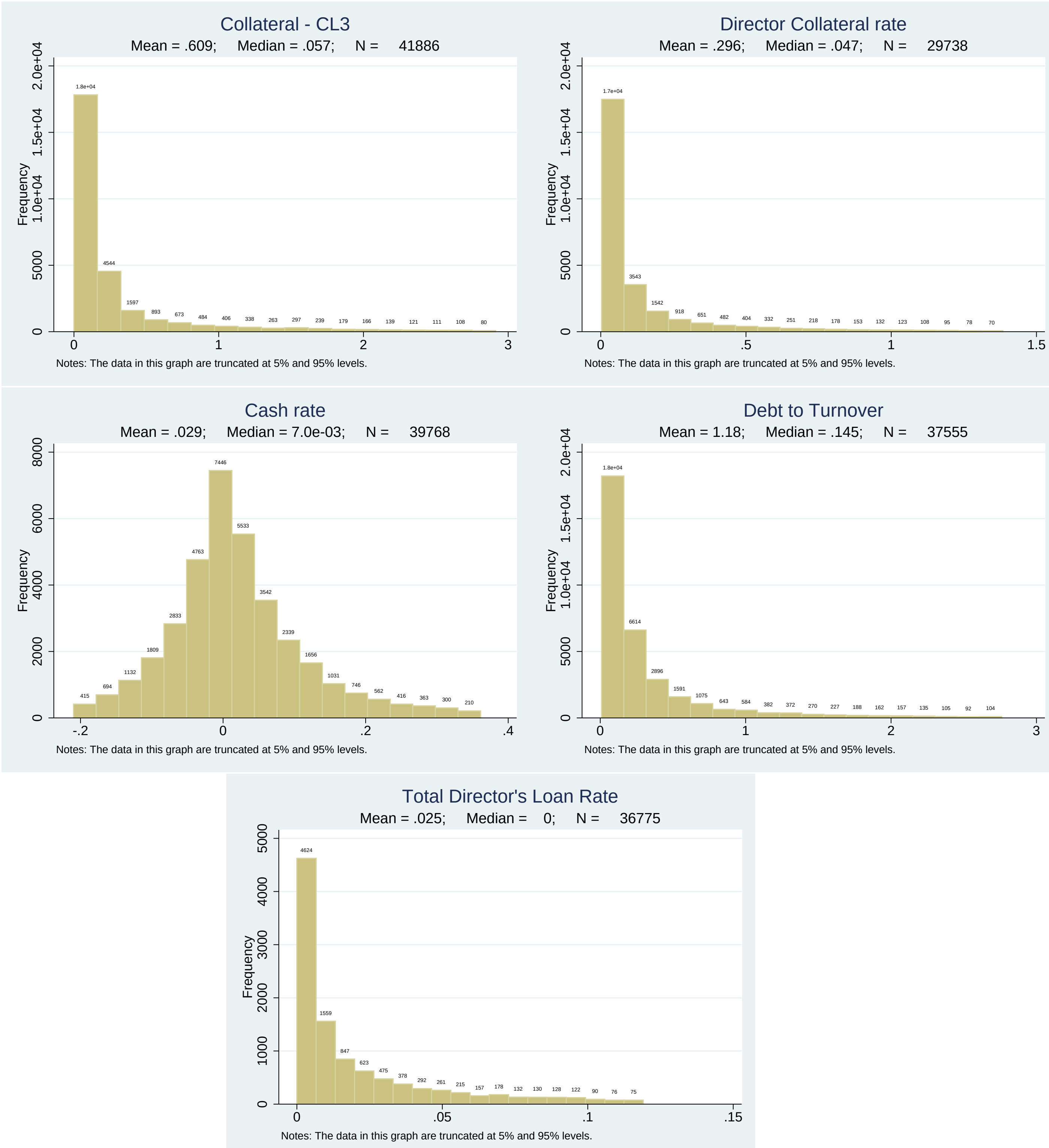


Figure 7: Distribution of Some of the Key Variables



A.2 Additional Regressions

Table 8: Investment and the Collateral Channels: Alternative Specifications

	1	2	3	4	5
Director Collateral	0.0819**	0.0801**	0.0788**	0.1088***	0.1070***
	(0.034)	(0.033)	(0.034)	(0.036)	(0.036)
Firm Collateral	0.0905***	0.0905***	0.0947***	0.0911***	0.0910***
	(0.015)	(0.014)	(0.014)	(0.014)	(0.014)
Cash Ratio				0.1449***	0.1462***
				(0.054)	(0.054)
Leverage Ratio				-0.0620	-0.0720*
				(0.042)	(0.042)
Profit Margin				0.1885**	0.1852**
				(0.086)	(0.085)
N	25563	25563	25437	25563	25563
Adjusted R^2	0.24	0.25	0.25	0.25	0.26
Time FE	No	Yes	No	No	Yes
Region-time FE	No	No	Yes	No	No
Firm FE	Yes	Yes	Yes	Yes	Yes

Notes: ${}^{\star}p < 0.10, {}^{\star\star}p < 0.05, {}^{\star\star\star}p < 0.01$. The table reports the empirical link between residential collateral, corporate collateral, and investment across alternative specifications. The dependent variables is Investment (change in fixed assets less depreciation). Director Collateral is the average value of the firm's directors' homes at the time the firm's accounts were filed, omitting directors who purchased their home in the firm's accounting period. Firm Collateral is the 2002 market value of firm Land and Buildings (calculated using the LIFO recursion) iterated forward using the regional house price index: $collateral_{i,j,t} = L^{Y}_{i,j,2002} L^{p}_{j,t} / L^{p}_{j,2002}$. Cash Ratio, Profit Margins and Leverage Ratio enter with a lag. All variables are scaled by the lag of firm turnover and winsorised at the 1% and 99% levels. Standard errors, clustered by firm region, in parentheses. The sample covers reporting UK firms over the period 2002-2012. Model 1 has controls only for the variables of interest. Model 2 adds time fixed effects. Model 3 adds region-time fixed effects. Model 4 adds additional controls but has no time fixed effects. Model 5 includes additional controls and time fixed effect. All models control for firm fixed effects.

Table 9: Firm Activity and the Collateral Channels: Excluding Recent Director House Purchases

	All Directors	1 Year	3 Years	5 Years	10 Years
Director Collateral	0.0994**	0.1070***	0.0871**	0.0615	0.0036***
	(0.039)	(0.036)	(0.039)	(0.042)	(0.001)
Firm Collateral	0.0903***	0.0910***	0.0946***	0.0975***	0.0858***
	(0.014)	(0.014)	(0.014)	(0.015)	(0.018)
Cash Ratio	0.1390***	0.1462***	0.1611***	0.1633***	0.2845***
	(0.051)	(0.054)	(0.056)	(0.062)	(0.089)
Leverage Ratio	-0.0635	-0.0720*	-0.0638	-0.0666	-0.0686
	(0.042)	(0.042)	(0.050)	(0.053)	(0.057)
Profit Margin	0.1924**	0.1852**	0.1989**	0.1893*	0.1308
	(0.084)	(0.085)	(0.099)	(0.113)	(0.145)
N	26450	25563	23029	20175	10712
Adjusted R^2	0.26	0.26	0.25	0.25	0.25
Region-time FE	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes

Notes: $^{\star}p < 0.10, ^{\star\star}p < 0.05, ^{\star\star\star}p < 0.01$. The table reports the empirical link between residential collateral, corporate collateral, and firm activity. The dependent variables is Investment (change in fixed assets less depreciation). Director Collateral is the average value of the firm's directors' homes at the time the firm's accounts were filed. Each column presents the results excluding directors who have purchased a house in the x previous accounting years. Firm Collateral is the 2002 market value of firm Land and Buildings (calculated using the LIFO recursion) iterated forward using the regional house price index: $collateral_{i,j,} = L^{Y}_{i,j,2002}L^{p}_{j,t}/L^{p}_{j,2002}$. Cash Ratio, Profit Margins and Leverage Ratio enter with a lag. All variables are scaled by the lag of firm turnover and winsorised at the 1% and 99% levels. Standard errors, clustered by firm region, in parentheses. The sample covers reporting UK firms over the period 2002-2012. All models control for firm fixed effects and region-time fixed effects.

Table 10: Firm Activity and the Collateral Channels: Commercial Real Estate Price Index

	Investment	Total Labour Cost	Employment
Director Collateral	0.1163***	0.0886***	0.0073***
	(0.035)	(0.010)	(0.001)
Firm Collateral	0.1101***	0.0334***	0.0018***
	(0.013)	(0.007)	(0.001)
Cash Ratio	0.0976	0.0255	0.0013
	(0.065)	(0.025)	(0.001)
Leverage Ratio	-0.1117**	-0.0138	0.0004
	(0.056)	(0.019)	(0.001)
Profit Margin	0.1738	-0.1684***	-0.0056***
	(0.120)	(0.023)	(0.001)
N	12225	12225	12225
Adjusted R^2	0.29	0.81	0.85
Region-time FE	Yes	Yes	Yes
Industry-time FE	No	No	No
Firm FE	Yes	Yes	Yes

Notes: *Notes*: $^{\star}p < 0.10, ^{\star\star}p < 0.05, ^{\star\star\star}p < 0.01$. The dependent variables are Investment (change in fixed assets less depreciation), Total Labour Costs (remuneration) and Employment. Director Collateral is the average value of the firm's directors' homes at the time the firm's accounts were filed, omitting directors who purchased their home in the firm's accounting period. Firm Collateral is the 2002 market value of firm Land and Buildings (calculated using the LIFO recursion) iterated forward using the commercial property price index covering a range of UK major cities as sourced from the Investment Property Databank: $collateral_{i,j,t} = L^{Y}_{i,j,2002}L^{p}_{j,t}/L^{p}_{j,2002}$. Cash Ratio, Profit Margins and Leverage Ratio enter with a lag. All variables are scaled by the lag of firm turnover and winsorised at the 1% and 99% levels. Standard errors, clustered by firm region, in parentheses. The sample covers reporting UK firms over the period 2002-2012. All models control for firm fixed effects, region-time fixed effects and industry-time fixed effects.

Table 11: Linear Probability Model on Determinants of Commercial Property Ownership in 2002

		Collateral
Assets	2nd quintile	0.1856***
		(0.0236)
	3rd quintile	0.3701***
		(0.0245)
	4th quintile	0.5278***
		(0.0246)
	5th quintile	0.6774***
		(0.0250)
Margins	2nd quintile	0.0182
		(0.0229)
	3rd quintile	0.0041
		(0.0229)
	4th quintile	0.0272
		(0.0227)
	5th quintile	-0.0115
		(0.0229)
Age	2nd quintile	0.0164
		(0.0227)
	3rd quintile	0.0729***
		(0.0228)
	4th quintile	-0.0416*
		(0.0242)
	5th quintile	-0.2403***
		(0.0235)
N		3328
Adjusted R^2		0.35

Firm region clustered standard errors in parentheses
$^{\star}p < 0.10, ^{\star\star}p < 0.05, ^{\star\star\star}p < 0.01.$

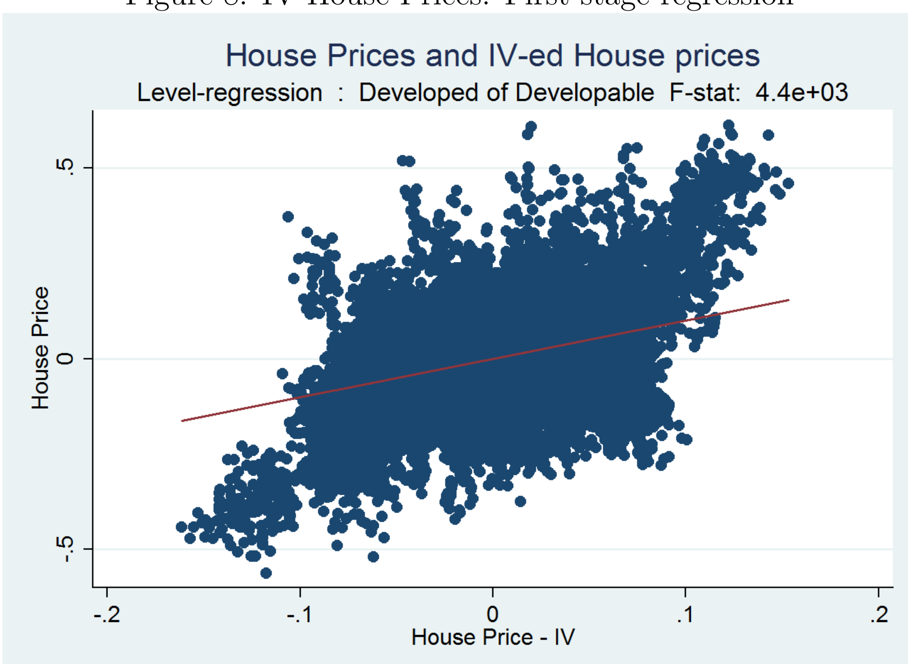
Notes: Regression coefficients of a linear probability model on firm property ownership, including dummy variable for whether the firm belongs to a certain quintile of the total assets, profit margins or age distribution. The regression includes region and industry fixed effects.

Table 12: Firm Activity and the Collateral Channels: Ownership Determinants and Industry Fixed Effect Included

	Investment	Total Labour Cost	Employment
Director Collateral	0.1028***	0.0936***	0.0078***
	(0.039)	(0.009)	(0.001)
Firm Collateral	0.0957***	0.0379***	0.0019***
	(0.014)	(0.007)	(0.000)
Cash Ratio	0.1632***	0.0125	0.0009
	(0.052)	(0.019)	(0.001)
Leverage Ratio	-0.0730	-0.0001	0.0009
	(0.047)	(0.015)	(0.001)
Profit Margin	0.1587*	-0.1594***	-0.0053***
	(0.084)	(0.023)	(0.001)
N	24142	24142	24142
Adjusted R^2	0.26	0.81	0.87
Region-time FE	Yes	Yes	Yes
Industry-time FE	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes

Notes: $^{*}p < 0.10, ^{**}p < 0.05, ^{***}p < 0.01$. The dependent variables are Investment (change in fixed assets less depreciation), Total Labour Costs (remuneration) and Employment. Director Collateral is the average value of the firm's directors' homes at the time the firm's accounts were filed, omitting directors who purchased their home in the firm's accounting period. Firm Collateral is the 2002 market value of firm Land and Buildings (calculated using the LIFO recursion) iterated forward using the regional house price index: $collateral_{i,j,t} = L^{Y}_{i,j,2002} L^{p}_{j,t} / L^{p}_{j,2002}$. Cash Ratio, Profit Margins and Leverage Ratio enter with a lag. All variables are scaled by the lag of firm turnover and winsorised at the 1% and 99% levels. Standard errors, clustered by firm region, in parentheses. The sample covers reporting UK firms over the period 2002-2012. All models control for firm fixed effects, region-time fixed effects and industry-time fixed effects.

Figure 8: IV House Prices: First-stage regression



Notes: The scatter plots the realised house prices (projected on the region and time fixed effects) against predicted houses using the instrument $elasticity_j \times i_t$ and region and time fixed effects. See equation 5.2.

Table 13: Firm Activity and the Collateral Channels: IV House Price Series

	Investment	Total Labour Cost	Employment
Director Collateral	0.1003***	0.0915***	0.0080***
	(0.037)	(0.008)	(0.001)
Firm Collateral	0.0932***	0.0346***	0.0017***
	(0.012)	(0.006)	(0.000)
Cash Ratio	0.1484***	0.0136	0.0007
	(0.056)	(0.019)	(0.001)
Leverage Ratio	-0.0748	-0.0003	0.0008
	(0.045)	(0.014)	(0.001)
Profit Margin	0.1774**	-0.1623***	-0.0055***
	(0.089)	(0.022)	(0.001)
N	24711	24711	24711
Adjusted R^2	0.26	0.81	0.86
Region-time FE	Yes	Yes	Yes
Industry-time FE	No	No	No
Firm FE	Yes	Yes	Yes

Notes: $^{\star}p < 0.10, ^{\star\star}p < 0.05, ^{\star\star\star}p < 0.01$. The table reports the empirical link between residential collateral, corporate collateral, and firm activity. The dependent variables are Investment (change in fixed assets less depreciation), Total Labour Costs (remuneration) and Employment. Director Collateral is the average value of the firm's directors' homes at the time the firm's accounts were filed, omitting directors who purchased their home in the firm's accounting period. Firm Collateral is the 2002 market value of firm Land and Buildings (calculated using the LIFO recursion) iterated forward using the IV-ed regional house price index: $collateral_{i,j,t} = L^{Y}_{i,j,2002} L^{p}_{j,t} / L^{p}_{j,2002}$ (see section 5). Cash Ratio, Profit Margins and Leverage Ratio enter with a lag. All variables are scaled by the lag of firm turnover and winsorised at the 1% and 99% levels. Standard errors, clustered by firm region, in parentheses. The sample covers reporting UK firms over the period 2002-2012. All models control for firm fixed effects and region-time fixed effects.

Table 14: Firm Investment and the Collateral Channels: Excluding Real Estate Investments

	Investment Ex. Land & Buildings
Director Collateral	0.0517***
	(0.013)
Firm Collateral	0.0315***
	(0.007)
Cash Ratio	0.0568**
	(0.027)
Leverage Ratio	0.0003
	(0.026)
Profit Margin	0.0690
	(0.048)
N	24028
Adjusted R^2	0.18
Region-time FE	Yes
Firm FE	Yes

Notes: $^{*}p < 0.10, ^{**}p < 0.05, ^{***}p < 0.01$. The table reports the empirical link between residential collateral, corporate collateral, and firm investment. The dependent variable is Investment (change in fixed assets less depreciation) excluding investment in Land and Buildings. Director Collateral is the average value of the firm's directors' homes at the time the firm's accounts were filed, omitting directors who purchased their home in the firm's accounting period. Firm Collateral is the 2002 market value of firm Land and Buildings (calculated using the LIFO recursion) iterated forward using the regional house price index: $collateral_{i,j,t} = L^{Y}_{i,j,2002} L^{p}_{j,t} / L^{p}_{j,2002}$. Cash Ratio, Profit Margins and Leverage Ratio enter with a lag. All variables are scaled by the lag of firm turnover and winsorised at the 1% and 99% levels. Standard errors, clustered by firm region, in parentheses. The sample covers reporting UK firms over the period 2002-2012. All models control for firm fixed effects and region-time fixed effects.

Table 15: Firm Activity and the Collateral Channels: Alternative Corporate Collateral Measure

	Investment	Investment ex. Land & Buildings	Total Labour Cost	Employment
Director Collateral	0.0922***	0.0517***	0.0882***	0.0081***
	(0.030)	(0.016)	(0.009)	(0.001)
Firm Collateral	0.0119	0.0478***	0.0133***	0.0003
	(0.032)	(0.013)	(0.005)	(0.000)
Cash Ratio	0.1460*	0.0836*	0.0600**	0.0031**
	(0.079)	(0.050)	(0.024)	(0.001)
Leverage Ratio	-0.0023	0.0297	0.0004	0.0007
	(0.053)	(0.036)	(0.018)	(0.001)
Profit Margin	0.1026	0.0751	-0.2314***	-0.0077***
	(0.079)	(0.054)	(0.026)	(0.001)
N	10534	10336	10534	10534
Adjusted R^2	0.18	0.20	0.80	0.86
Region-time FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes

Notes: $^{*}p < 0.10, ^{**}p < 0.05, ^{***}p < 0.01$. The table reports the empirical link between residential collateral, corporate collateral, and firm activity. The dependent variables are Investment (change in fixed assets less depreciation), Total Labour Costs (remuneration) and Employment. Director Collateral is the average value of the firm's directors' homes at the time the firm's accounts were filed, omitting directors who purchased their home in the firm's accounting period. Firm Collateral is the market value of firm Land and Buildings (calculated using the LIFO recursion) lagged one period and multiplied by the change in the regional house price index. Cash Ratio, Profit Margins and Leverage Ratio enter with a lag. All variables are scaled by the lag of firm turnover and winsorised at the 1% and 99% levels. Standard errors, clustered by firm region, in parentheses. The sample covers reporting UK firms over the period 2002-2012. All models control for firm fixed effects and region-time fixed effects.

Table 16: Firm Activity and the Collateral Channels: Asymmetry

	Investment	Total Labour Cost	Employment
Director Collateral	0.1395***	0.0934***	0.0082***
	(0.041)	(0.011)	(0.001)
Director Collateral× positive price chg dum	-0.0377*	-0.0015	-0.0002
	(0.019)	(0.009)	(0.001)
Firm Collateral	0.0435***	0.0392***	0.0021***
	(0.015)	(0.007)	(0.000)
Firm Collateral×positive price chg dum	0.0569***	-0.0016	-0.0002
	(0.011)	(0.002)	(0.000)
Cash Ratio	0.1558***	0.0136	0.0008
	(0.054)	(0.018)	(0.001)
Leverage Ratio	-0.0802*	0.0002	0.0008
	(0.045)	(0.014)	(0.001)
Profit Margin	0.1527*	-0.1580***	-0.0053***
	(0.082)	(0.022)	(0.001)
N	25437	25437	25437
Adjusted R^2	0.27	0.81	0.86
Region-time FE	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes

Notes: ${}^{*}p < 0.10, {}^{**}p < 0.05, {}^{***}p < 0.01$. The table reports the empirical link between residential collateral, corporate collateral, and firm activity. The dependent variables are Investment (change in fixed assets less depreciation), Total Labour Costs (remuneration) and Employment. Director Collateral is the average value of the firm's directors' homes at the time the firm's accounts were filed, omitting directors who purchased their home in the firm's accounting period. Firm Collateral is the 2002 market value of firm Land and Buildings (calculated using the LIFO recursion) iterated forward using the regional house price index: $collateral_{i,j,t} = L^{Y}_{i,j,2002} L^{p}_{j,t} / L^{p}_{j,2002}$. The regression additionally includes the interaction of collateral measures and a dummy variable which takes value 1 when regional house price growth is positive and 0 otherwise. Cash Ratio, Profit Margins and Leverage Ratio enter with a lag. All variables are scaled by the lag of firm turnover and winsorised at the 1% and 99% levels. Standard errors, clustered by firm region, in parentheses. The sample covers reporting UK firms over the period 2002-2012. All models control for firm fixed effects and region-time fixed effects.

Table 17: Firm Activity and the Collateral Channels: Large vs Small Firms (Employment<10)

	Investment	Total Labour Cost	Employment
Director Collateral	0.2024***	0.1775***	0.0146***
	(0.041)	(0.019)	(0.001)
Director Collateral ×Small Firm	-0.1239***	-0.1098***	-0.0084***
	(0.046)	(0.020)	(0.002)
Firm Collateral	0.1065***	0.0470***	0.0026***
	(0.017)	(0.008)	(0.001)
Firm Collateral×Small Firm	-0.0299	-0.0244***	-0.0017***
	(0.024)	(0.006)	(0.000)
Cash Ratio	0.1424***	0.0097	0.0005
	(0.052)	(0.018)	(0.001)
Leverage Ratio	-0.0823*	-0.0024	0.0007
	(0.045)	(0.013)	(0.001)
Profit Margin	0.1827**	-0.1588***	-0.0054***
	(0.083)	(0.020)	(0.001)
N	25437	25437	25437
Adjusted R^2	0.26	0.82	0.87
Region-time FE	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes

Notes: $^{\star}p < 0.10, ^{\star\star}p < 0.05, ^{\star\star\star}p < 0.01$. The table reports the empirical link between residential collateral, corporate collateral, and firm activity. The dependent variables are Investment (change in fixed assets less depreciation), Total Labour Costs (remuneration) and Employment. Director Collateral is the average value of the firm's directors' homes at the time the firm's accounts were filed, omitting directors who purchased their home in the firm's accounting period. Firm Collateral is the 2002 market value of firm Land and Buildings (calculated using the LIFO recursion) iterated forward using the regional house price index: $collateral_{i,j,t} = L^{Y}_{i,j,2002} L^{p}_{j,t} / L^{p}_{j,2002}$. The regression additionally includes the interaction of collateral measures and a dummy variable which takes value 1 if the firm has less than 10 employees and 0 otherwise.Cash Ratio, Profit Margins and Leverage Ratio enter with a lag. All variables are scaled by the lag of firm turnover and winsorised at the 1% and 99% levels. Standard errors, clustered by firm region, in parentheses. The sample covers reporting UK firms over the period 2002-2012. All models control for firm fixed effects and region-time fixed effects.

Table 18: Firm Activity and the Collateral Channels: Largest Firms

	Investment	Total Labour Cost	Employment
Director Collateral	-1.4284	0.1628	-0.0116
	(1.304)	(0.287)	(0.025)
Firm Collateral	0.1157*	0.0556***	0.0032*
	(0.067)	(0.018)	(0.002)
Cash Ratio	-0.0150	0.0595***	0.0023
	(0.223)	(0.022)	(0.001)
Leverage Ratio	0.2734	0.0382	0.0036
	(0.519)	(0.062)	(0.003)
Profit Margin	1.1044***	0.0089	0.0013
	(0.218)	(0.037)	(0.002)
N	637	637	637
Adjusted R^2	0.38	0.74	0.62
Time FE	Yes	Yes	Yes
Industry-time FE	No	No	No
Firm FE	Yes	Yes	Yes

Notes: *Notes*: $^{\star}p < 0.10, ^{\star\star}p < 0.05, ^{\star\star\star}p < 0.01$. The table reports the empirical link between residential collateral, corporate collateral, and firm activity for firms where total director collateral is worth less than 1% of total assets. The dependent variables are Investment (change in fixed assets less depreciation), Total Labour Costs (remuneration) and Employment. Director Collateral is the average value of the firm's directors' homes at the time the firm's accounts were filed, omitting directors who purchased their home in the firm's accounting period. Firm Collateral is the 2002 market value of firm Land and Buildings (calculated using the LIFO recursion) iterated forward using the regional house price index: $collateral_{i,j,t} = L^{Y}_{i,j,2002}L^{p}_{j,t}/L^{p}_{j,2002}$. Cash Ratio, Profit Margins and Leverage Ratio enter with a lag. All variables are scaled by the lag of firm turnover and winsorised at the 1% and 99% levels. Standard errors, clustered by firm, in parentheses. The sample covers reporting UK firms over the period 2002-2012. All models control for firm fixed effects and time fixed effects.

B Theoretical Appendix

B.1 The Full Model

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

B.1.1 Household

The representative household maximises the utility function:

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

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:

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

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:

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

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:

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

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:

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

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.

B.1.2 Entrepreneur

The entrepreneur's utility function is written as:

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

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):

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

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

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

and the transitory component follows the stochastic process:

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

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:

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

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:

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

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

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

and the transitory component follows the stochastic process:

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

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

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

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

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

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.

B.1.3 Market Clearing

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

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

The land market clearing condition implies:

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

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

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

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.

B.2 Model Estimation

B.2.1 Data

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

$$\begin{aligned}
q_{l,t}^{data} &= \frac{Nationwide}{cdef} \\
q_t^{data} &= \frac{cdef}{idef} \\
I_t^{data} &= \frac{inv}{popindex} \\
C_t^{data} &= \frac{(pcons - imprent - actrent)\,/cdef}{popindex} \\
B_t^{data} &= \frac{Bcorp/cdef}{popindex} \\
N_t^{data} &= \frac{TotalHours}{popindex}
\end{aligned}$$

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.

B.2.2 Steady State Calibration

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

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

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

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

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

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

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

B.2.3 Estimated Model Parameters

Table 19 summarises the results from the Bayesian estimation of the model. A system of measurement equations links the observables, defined in subsection B.2.1 above, to the state variables. We use dynare 4.4.2 to perform the estimation. First we use the Kalman-filter to construct the likelihood function. After combining the likelihood with the priors we use numerical optimisers to maximise the posterior kernel. Using the modes of the maximised posterior kernel as starting points, we employ the Metropolis Hastings algorithm to simulate 200,000 random draws to approximate the shape of the posterior distributions.

Table 19: MCMC Results: Prior and Posterior Distributions of Structural Parameters

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

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